EXAMINATION REVIEW FOR ULTRASOUND

SECOND EDITION



Abdomen & Obstetrics and Gynecology

Wolters Kluwer

Steven M. Penny

Examination Review for Ultrasound

Abdomen & Obstetrics and Gynecology

Second Edition

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Dedication

To Him, my Teacher and Counselor—Thank you for allowing me the opportunity to serve others by granting me the wisdom and fortitude required to complete this undertaking. Thank you for everything that you have supplied, and will supply, for me and my family. I know that you are my shepherd and will never fail me. You will always be my pilot, my protector, and my provider.

To Lisa, my wife—Thank you for your abiding love and faith in my potential. I know that without you I would not be the man I am today. You have been my encourager and supporter. Thank you so much for all that you do for me and our children. Your daily sacrifices for me and my career do not go unrecognized. I neither say it, nor show it enough, but I love you, and I will always love you.

To Devin and Reagan—There are times that I wish I could temporarily place life's distractions on pause in order to enjoy the time that I spend with both of you more. You are a blessing to me and you are the motivation behind much of what I try to achieve in life. I pray that I am providing you with an adequate fatherly example, but more importantly, I pray that you both continually seek the will of our Heavenly Father in your lives.

Preface



The overwhelming success of the first edition of *Examination Review for Ultrasound: Abdomen & Obstetrics and Gynecology* confirmed the demand among aspiring sonographers for a narrative-style review for the national certification examinations offered by the American Registry for Diagnostic Medical Sonography (ARDMS) and American Registry of Radiologic Technologists (ARRT). We watched the book at it ascended the best-selling charts—where it still remains—to become one of the preeminent sourcebooks for registry review and clinical practice, quantifying its popularity, and solidifying the need for this much anticipated second edition.

Objective

Our profession demands the best of us because the best of us is what our patients both expect and deserve. Standardized tests, such as those offered by the ARDMS and ARRT, have remained, for many years, a hallmark of our profession. We can be assured that maintaining high-quality patient care rests at the heart of these certification examinations. It is through their successful completion that the sonographer earns recognition as a proficient medical professional. Consequently, the contents of this book are founded upon the components of these examinations.

Like the first edition, the primary objective of *Examination Review for Ultrasound: Abdomen & Obstetrics and Gynecology, Second Edition* is to provide the user with a comprehensive review in sonography of the abdomen, gynecology, and obstetrics in preparation for national certification. Secondarily, because of its straightforward narrative style, like the first edition, this book can further provide a quick reference guide in the clinical setting.

Organization

In general, the book is again divided into three sections: Section 1, Abdominal Sonography Review; Section 2, Gynecologic Sonography Review; and Section 3, Obstetric Sonography Review. Each chapter follows a similar path that was established in the first edition, with the addition of a few noteworthy improvements. Key terms—with plainly written, uncomplicated definitions—are provided in each chapter and highlighted in the chapters as well. The key terms allow for a rapid assessment of one's familiarity with the subject and also provide a quick reference for the reader. Each chapter begins with a review of basic anatomy, function, and sonographically relevant information. The narrative piece of this book is once more written in a clear-cut manner, offering the most essential facts about the topic, many times providing tables or boxes that include both clinical and sonographic findings. Throughout each chapter, a new feature referred to as "Sound Off" boxes can be found. "Sound Off" boxes are used to highlight imperative facts the reader must recognize about many of the topics. These boxes may also provide a specific way to recall this vital information. Tables and many new, high-quality sonographic images and anatomic drawings further enhance the straightforward narrative. Most chapters conclude with a review of the pertinent pathology for the subject matter. Also, at the end of each chapter, 40 review questions are provided for a basic appraisal of the reader's knowledge. With a total of 1,280 review questions in this edition, the assessment has undoubtedly been improved. The answers to these questions can be found in the back of the book.

Section 1—Abdominal Sonography Review—has many notable changes in this edition. In Chapter 1, a brief overview of infection control has been added, as well as several rules for surgical asepsis. Also, a table on Doppler artifacts can be found in Chapter 1. In Chapter 2, an enhanced section on liver Doppler, TIPS evaluation, and liver transplant assessment can be found. Chapter 5 includes a section on pancreatic transplant, whereas Chapter 7 includes more information about renal transplant assessment. In Chapter 12—Face and Neck—the reader will find information about the facial glands and associated pathology. Last, Chapter 14, which is the chapter on musculoskeletal and superficial structures, offers a brief review in breast imaging and developmental dysplasia of the infant hip.

In Section 2—Gynecologic Sonography Review—there are some vital additions as well. In Chapter 15, information on instrumentation, basic patient care, pediatric gynecologic sonography, and two-dimensional and Doppler artifacts in pelvic imaging is provided. In Chapter 19, the user will find a way to recall the relationship of the menstrual cycle phases of the ovary and endometrium. Also, distributed throughout the other gynecologic chapters, the user will find superior sonographic images, helpful drawings, and essential diagrams. In Section 3—Obstetric Sonography Review—

several revisions include an overview of gravidity and parity (Chapter 22), an improved review of the fetal heart (Chapter 27), and information concerning fetal alcohol syndrome (Chapter 32). Once more, these are only highlights, as there are countless improvements to this edition.

Additional Resources

As with the first edition, the review associated with this book does not need to end with its conclusion. There are several online resources for this book, including a mock registry examination that can be attempted by using the code at the beginning of this book and going to **thepoint.lww.com/penny_abobgyn2e**. This exam simulator will provide the user with more intense "registry-like" questions, with topics that can be selected and answers that provide rationale. Instructors can use the faculty resources as well, which include an image bank and PowerPoint presentations.

Final Note

The material contained in this book is deliberately not exhaustive. With candid prayer for discernment, much care has been taken to explore each topic, and I have tried to select the most vital information for you as you study for these complicated examinations. Thus, this book, if used for its primary purpose of registry review, should emerge to the user as focused and purposeful. The exclusion of numerical statistics and extraneous facts from the text—in most regards—is intentional. However, in the pursuit of exhaustive comprehension, where data or information is critical to more complete patient care, the list of bibliographical references at the end of each chapter should provide you with essential aid.

In the classroom setting, many instructors have discovered that the use of the first edition of this book can certainly be beneficial. This edition will also provide the instructor with a topic-based review that can identify subject matter weaknesses. And instructors that offer registry review courses will find that this book and its resources will offer them a focused tool for preparing their students for the national certification exams.

For those who have moved beyond national certification, the manner in which this book has been constructed—with clinical and sonographic findings highlighted—certainly allows for its application during sonographic practice. Nevertheless, it is my greater hope that you exploit all relevant resources in your mission and obligation to provide each patient with the most favorable care you can afford.

I anticipate that this book will serve you, your students, and your patients well. I may never meet you face-to-face, but I would like to express gratitude for the choice that you have made to select this book. I wish you well as you care for *our* patients, and my hope is that you have a long-lasting and prosperous career as a registered diagnostic medical sonographer.

Steven M. Penny

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To my coworkers and the leadership at Johnston Community College, thank you for your companionship and direction over the years. To my past, current, and future students, thank you for demanding that I continue to learn, and thank you for allowing me to be your instructor.

To all of my former teachers and professors, thank you for your unwavering patience.

Test-Taking Tips



"By failing to prepare, you are preparing to fail."

– Ben Franklin

The national certification examinations offered by the American Registry for Diagnostic Medical Sonography (ARDMS) and American Registry of Radiologic Technologist (ARRT) are not easy. These exams should be difficult because they have been created to test your knowledge of a vital imaging modality that can save people's lives. Consequently, preparing for and challenging these exams should not be approached dispassionately. There are many resources on test taking that you can access at your local library and online. Below are three basic steps, which include tips for getting organized, studying, and preparing for these significant certification exams.

Step 1—Get Organized and Schedule the Exam

Both the ARDMS (ardms.org) and ARRT (arrt.org) provide content outlines for each of their certification examination. In fact, the content of this book is based on these content outlines, and accordingly this book includes pertinent information on each topic. However, you can use these content outlines as a guide for focused study as well. Keep your study materials—which should include all of the resources you obtained throughout your sonography education—organized by these content outlines. School lecture notes, note cards, quizzes, and tests should be organized well before you begin to study.

Once you have organized your study materials, you should apply for the exam and then try to consider the best time to attempt it. When scheduling the examination, consider all of your other obligations (e.g., family responsibilities, vacations, job requirements) and allow for an ample amount of time to study so that you are thoroughly prepared on examination day. Do not postpone scheduling the exam. Scheduling the examination will provide you with a firm date, and it will hopefully help those of you who suffer from procrastination to focus on test preparation.

Step 2—Establish a Study Routine and Study Schedule

Next, since you have your deadline, find a quiet place to study and develop a study routine and schedule. Your study space should be quiet and free from distractions, like television and your cell phone (stay off of social media). The study schedule that you create for yourself should be realistic. That is to say, do not schedule two hours each night to study if you know that you will not be dedicated to that schedule. Instead, it may be best to schedule one solid hour each night. Also, studying in 45-minute increments with 15-minute breaks may work best for some. You can create your own deadlines on your schedule and strive to meet them. Be sure to study at least for a few minutes every day to maintain momentum going into the exam.

The amount of time one requires to study will vary per individual. Only *you* know how much time *you* need to study, so if you struggle with certain topics, then allow for extra time to focus more attention on those topics. It may be best to review those topics you are most familiar with first, and as the exam approaches, review the topics that you struggle with just before your attempt, with the hopes of making the challenging information more readily accessible.

Most people know what manner they prepare for an exam best. Some test takers find flashcard useful, some create their own notes from reading, whereas others may simply read and choose to gradually answer registry review questions. A study group may be helpful for some as well. Nonetheless, the main concern of your studies should be *learning* the material and not just *memorizing* it to pass the exam. By learning the information, you will most likely be successful on the exam, with the added benefit of being able to apply your knowledge in your daily clinical practice as a registered sonographer.

Step 3—Confidently Attempt the Exam

Test anxiety is a challenge for many people. Some tips for reducing anxiety include eating well, getting plenty of rest and exercise, keeping a positive attitude, and taking practice tests. The ARDMS offers some tips for exam-day success, which include getting a good night’s sleep before exam day, knowing how long it takes to get to the testing center (traffic included), being early to the testing center, and being familiar with all of the test center requirements, like testing day registrant identification specifications. Currently, the ARDMS Sonographic Principles & Instrumentation (SPI) exam consists of 110 questions, whereas the specialty exams consist of 170 questions. Nearly all of the questions are in multiple choice format. The SPI exam may also include advanced item type question in the form of a semi-

interactive console, which requires the test taker to make adjustments to a simulated ultrasound machine console. The specialty exams may also include an advanced item type question referred to as hotspot questions. These questions require that the test taker use the cursor to mark the correct answer directly on the image.

Multiple choice questions consist of the stem—which is the question—and four possible answers to choose from. The correct answer must be included along with three other options referred to as distractors. You should read the question cautiously first, and try to answer the question before looking at the provided choices. If your given answer is provided, it will most likely be the correct choice to make. If you do not know the answer immediately, then try to eliminate the choices you know are incorrect. For these exams, you are allowed to mark questions and return to answer them later. You can also make changes before final submission. But be careful, it may be best to not change any of your answers. You should only make changes to questions that you feel confident you have answered incorrectly because for many of us our first impulse or guess is correct.

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Section I: Abdominal Sonography Review

1

Abdominal Sonography Overview

Introduction

A synopsis of abdominal sonography practice is provided in this chapter. Accordingly, the subsequent abdominal chapters will build on the foundation established in this chapter. It is important for the sonographer to obtain and recognize vital clinical information from patients, including laboratory results and other data that are obtained through patient inquiry. This chapter offers relevant laboratory findings, imaging artifacts, a brief overview of physics and instrumentation, infection control, and serves as a general abdominal imaging guide. Lastly, cross-referencing of potential information that may be encountered on the abdominal certification examination offered by the American Registry for Diagnostic Medical Sonography (www.ardms.org) and the abdominal portion of the examination offered by the American Registry of Radiologic Technologists (www.arrt.org) has been performed to establish this chapter.

Key Terms

anemia—a condition in which the red blood cell count or the hemoglobin is decreased

anticoagulation therapy—drug therapy in which anticoagulant medications are given to a patient to slow the rate at which the patient's blood clots

ascites—a collection of abdominal fluid within the peritoneal cavity

chromaffin cells—the cells in the adrenal medulla that secrete epinephrine

and norepinephrine

clinical findings—the information gathered by obtaining a clinical history

clinical history—a patient's signs and symptoms, pertinent illnesses, past surgeries, laboratory findings, and the results of other diagnostic testing

coagulopathies—disorders that result from the body's inability to coagulate or form blood clots also referred to as bleeding disorders

computed tomography—an imaging modality that uses X-ray to obtain cross-sectional images of the body in multiple planes; also referred to as CT or CAT scan

elastography—a sonographic technique employed to evaluate a mass based on its stiffness, ultimately providing a prediction as to whether a mass is more likely malignant or benign

endoscopy—a means of looking inside of the human body using an endoscope

exudate ascites—a collection of abdominal fluid within the peritoneal cavity that may be associated with cancer

fluid-fluid level—a distinctive line seen within a cyst representing the layering of two different fluid densities

gastrin—hormone produced by the stomach lining that is used to regulate the release of digestive acid

hematocrit—a laboratory value that indicates the amount of red blood cells in the blood

homeostasis—the body's ability or tendency to maintain internal equilibrium by adjusting its physiologic processes

hyperthyroidism—a condition that results from the overproduction of thyroid hormones

hypothyroidism—a condition that results from the underproduction of thyroid hormones

intraluminal—something located within the lumen or opening of an organ or structure

intraperitoneal—located within the parietal peritoneum

Kaposi sarcoma—cancer that causes lesions to develop on the skin and other places; often associated with AIDS

leukocytosis—an elevated white blood cell count

lymphadenopathy—disease or enlargement of the lymph nodes

lymphedema—build-up of lymph that is most likely caused by the obstruction of lymph drainage

mass effect—the displacement or alteration of normal anatomy that is

located adjacent to a tumor

Morrison pouch—the space between the liver and the right kidney; also referred to as the posterior right subhepatic space

multiloculated—having many cavities

mural nodules—small solid internal projections of tissue originating from the wall of cyst

nosocomial infections—hospital-acquired infections

nuclear medicine—a diagnostic imaging modality that utilizes the administration of radionuclides into the human body for an analysis of the function of organs or for the treatment of various abnormalities

oncocytes—large cells of glandular origin

paracentesis—a procedure that uses a needle to drain fluid from the abdominal cavity for diagnostic and/or therapeutic reasons

parietal peritoneum—the portion of the peritoneum that lines the abdominal and pelvic cavities

pineal gland—endocrine gland located in the brain that secretes melatonin

radiography—a diagnostic imaging modality that uses ionizing radiation for imaging bones, joints, organs, and some other soft tissue structures

retroperitoneal—posterior to the peritoneum

serosal fluid—fluid that is secreted by the serous membranes to reduce friction in the peritoneal and other cavities of the body

signs—an objective evidence of a disease such as abnormal laboratory findings and fever

sonographic findings—information gathered by performing a sonographic examination

space of Retzius—the space between the urinary bladder and the pubic bone; also referred to as the retropubic space

standoff pad—a gel pad that is used to provide some distance between the transducer face and the skin surface, allowing superficial structures to be imaged more clearly

symptoms—any subjective evidence of a disease such as nausea, weakness, or numbness

thoracentesis—a procedure that uses a needle to drain fluid from the pleural cavity for either diagnostic or therapeutic reasons

thymus gland—gland of the immune and lymphatic system located in the chest

transudate ascites—a collection of abdominal fluid within the peritoneal cavity often associated with cirrhosis

tumor markers—substances produced by cancer cells or organs in response to cancer

unilocular—having a single cavity

visceral peritoneum—the portion of the peritoneum that is closely applied to each organ

voiding cystourethrogram—a radiographic examination used to evaluate the lower urinary tract, where a contrast agent is instilled into the urinary bladder by means of urethral catheterization

Wilson disease—a congenital disorder that causes a person to retain excess copper

SONOGRAPHIC TERMINOLOGY AND PRACTICE GUIDELINES

Before beginning your studies, you must have a fundamental appreciation of sonographic terminology and commonly used sonographic descriptive terms (Table 1-1). Abdominal sonograms may be requested for various reasons. The American Institute of Ultrasound in Medicine (AIUM) publishes the practice guidelines for an abdominal sonogram on their website at www.aium.org (Table 1-2).

SONOGRAPHIC DESCRIPTION OF ABNORMAL FINDINGS

The appreciation and recognition of sonographic pathology is vital for the sonographer. Not only should one be able to recognize the normal echogenicity of organs and structures, but one must also be capable of identifying abnormalities. The normal echogenicity of the abdominal organs from greatest (brightest) to least (darkest) is as follows: renal sinus → pancreas → spleen → liver → renal cortex → renal pyramids → gallbladder. Therefore, if the right kidney appears more echogenic than the liver, both the liver and the right kidney must be closely examined for a cause of this deviant sonographic finding.



SOUND OFF

The normal echogenicity of the abdominal organs from greatest (brightest) to least (darkest) is as follows: renal sinus → pancreas → spleen → liver → renal cortex → renal pyramids → gallbladder.

TABLE 1-1 Sonographic descriptive terms

Sonographic Descriptive Term	Definition	Examples
Anechoic	Without echoes	Gallbladder Simple renal cyst
Complex	Having both cystic and solid components	Hemorrhagic cyst Hepatic abscess
Echogenic	Structure that produces echoes	Fatty liver Chronic renal disease
Heterogeneous	Of differing composition	Graves disease Diffuse liver metastasis
Homogeneous	Of uniform composition	Normal liver Normal testicle
Hyperechoic	Having many echoes	Cavernous hemangioma Angiomyolipoma
Hypoechoic	Having few echoes	Hepatic adenoma Thyroid adenoma
Isoechoic	Having the same echogenicity	Focal nodular hyperplasia

TABLE 1-2 AIUM indications for abdomen and/or retroperitoneum sonogram

AIUM Indications for an Ultrasound Examination of the Abdomen and/or Retroperitoneum[a]

- Abdominal, flank, and/or back pain.
- Signs or symptoms that may be referred from the abdominal and/or retroperitoneal regions such as jaundice or hematuria.
- Palpable abnormalities such as an abdominal mass or organomegaly.
- Abnormal laboratory values or abnormal findings on other imaging examinations.
- Suggestive of abdominal and/or retroperitoneal pathology.
- Follow-up of known or suspected abnormalities in the abdomen and/or retroperitoneum.
- Search for metastatic disease or an occult primary neoplasm.
- Evaluation of suspected congenital abnormalities.
- Abdominal trauma.
- Pretransplantation and posttransplantation evaluation.
- Planning for and guiding an invasive procedure.

- Searching for the presence of free or loculated peritoneal and/or retroperitoneal fluid.
- Suspicion of hypertrophic pyloric stenosis or intussusceptions.
- Evaluation of a urinary tract infection.

An abdominal and/or retroperitoneal ultrasound examination should be performed when there is a valid medical reason. There are no absolute contraindications.

[a] This is a limited list of indications. Other indications exist.
AIUM, American Institute of Ultrasound in Medicine.

Pathology is often described sonographically, relative to surrounding or adjacent tissue. For example, a hepatic mass may be described as hyperechoic compared to the surrounding echotexture of the normal liver. Solid tumors may be hyperechoic (occasionally described as echogenic), hypoechoic, homogeneous, heterogeneous, complex, isoechoic, cystic, or a combination of terms. For example, a renal mass may be described as a hypoechoic mass with a central area of increased echogenicity.

Lastly, a cyst must fit certain criteria to be referred to as a simple cyst. Simple cysts have smooth walls or borders, demonstrate through transmission, are anechoic, and are round in shape (STAR criteria). Occasionally, with higher frequency transducers with superior resolution, a diminutive amount of internal debris may be noted within a simple cyst. However, cysts that have a large amount of internal debris, septations, mural nodules, have a fluid–fluid level, or other components may be described as complex cysts. Cysts may also be referred to as multiloculated or unilocular. Although simple cysts may not be worrisome, complex cysts may be followed closely or further analyzed with another imaging modality.



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A simple cyst should have *s*mooth walls, demonstrate *t*hrough transmission, be completely *a*nechoic, and be *r*ound in shape (STAR criteria).

PATIENT PREPARATION FOR AN ABDOMINAL SONOGRAM

Patients who are required to undergo an abdominal sonogram, and particularly patients who still have a gallbladder, need to fast for 8 hours, although some authors suggest that only a 6-hour fast may be warranted. However, diagnostic studies can be obtained in the nonfasting patient,

especially those requiring an emergency sonogram. The purpose of fasting is to ensure that the gallbladder is distended and to potentially reduce the amount of upper abdominal gas that may inhibit diagnostic accuracy. For renal sonograms, the patient is not typically required to fast, although some facilities may recommend that the patient be well hydrated. This is true especially if the urinary bladder needs to be assessed sonographically for intraluminal masses, irregularities, or urinary stones. Diabetic patients need to be scheduled early in the morning for studies that require them to fast to prevent hypoglycemic episodes. Abdominal sonography should also be performed prior to radiographic examinations that utilize barium contrast agents. For pediatric patients who must undergo renal sonography and urologic radiographic examinations, such as a voiding cystourethrogram, the renal sonogram is typically performed first. Small part sonography, such as scrotal and thyroid imaging, does not require patient preparation. The sonographic imaging process should be clearly explained to the patient, and a thorough clinical history obtained prior to performing each examination.

GATHERING A CLINICAL HISTORY AND LABORATORY FINDINGS

Although the patient–sonographer interaction is exceedingly important, a review of prior examinations and relevant documents should be performed by the sonographer before any contact with the patient. Gathering a thorough clinical history includes a review of reports from previous sonograms, computed tomography (CT) scans, magnetic resonance imaging studies, nuclear medicine examinations, radiography procedures, endoscopy examinations, and any additional related laboratory and diagnostic reports available. Moreover, sonographers must be capable of analyzing the clinical complaints of their patients. This practice will aid not only in clinical practice but also in answering complex certification examination questions. By correlating clinical findings with sonographic findings, the sonographer can directly impact the patient's outcome by providing the most targeted examination possible. Furthermore, when faced with a complicated, in-depth registry question, the test taker should be capable of eliminating information that is not applicable, to answer the question appropriately. Helpful information can be gathered from patient inquiry and from analyzing the registry review question at hand.

Although not all patients visit the sonography department with laboratory results (labs) in hand, sonographers must be capable of analyzing labs when they are available. For most inpatients and emergency room patients, labs from blood work and/or a urinalysis will be available. Although an increase

in most labs reveals evidence of an abnormality, some lab levels decrease with certain abnormalities. For example, leukocytosis, or an elevation in white blood cell (WBC) count, in general, indicates the presence of an inflammatory response due to infection. Patients who have some form of "itis" (such as cholecystitis or pancreatitis), or possibly even an abscess, will most likely have an abnormal WBC count with existing infection. Conversely, a decrease in hematocrit indicates bleeding. Patients who have suffered recent trauma or have an active hemorrhage will most likely have a decreased hematocrit level. Keep these two labs in mind as you study. Other labs and specific associated pathologies will be included in organ-specific chapters. A summary of labs can be found in Table 1-3 for quick broad reference (Table 1-3).



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Patients who have some form of "itis" (such as cholecystitis or pancreatitis), or possibly even an abscess, will most likely have an abnormal WBC count with existing infection.

BASIC PATIENT CARE AND EMERGENCY SITUATIONS IN ABDOMINAL IMAGING

Sonographers must be capable of providing basic patient care for every patient equitably and in a timely manner. Although we may spend a limited amount of time with each patient, we must also be prepared for emergency situations and know how to respond. Basic patient care includes the assessment of body temperature, pulse, respiration, and blood pressure if needed (Table 1-4). Sonographers should be competent at transferring patients safely from wheelchairs and stretchers to the examination stretcher, being mindful of intravenous therapy, postsurgical, and urinary catheter needs. For patients with intravenous therapy, the intravenous fluid bag should be continually elevated to prevent retrograde flow. For urinary catheter care, the urinary bag should be placed below the level of the urinary bladder to prevent retrograde urine flow that could result in a urinary tract infection. One of the most common causes of nosocomial infections, or hospital-acquired infections, is the urinary tract infection.

TABLE 1-3 Basic overview of commonly encountered and relevant laboratory findings for abdominal imaging

Lab	Results

Alanine aminotransferase	↑	Biliary tree disease
	↑	Pancreatic disease
	↑	Hepatic disease
Albumin	↓	Liver damage
Alkaline phosphatase	↑	Biliary obstruction
	↑	Liver cancer
	↑	Pancreatic disease
	↑	Gallstones
	↓	**Wilson disease**
Aspartate aminotransferase	↑	Liver damage
	↑	Pancreatic disease
Bilirubin	↑	Liver disease
	↑	Biliary obstruction
	↑	Other systemic disorders and syndromes
λ-glutamyl transferase	↑	Liver disease
	↑	Biliary obstruction
PTT	↑	Liver disease
	↑	Hereditary **coagulopathies**
	↓	Vitamin K (deficiency)
	↑	**Anticoagulation therapy**
PT	↑	Liver disease
	↑	Bleeding abnormalities
	↑	Anticoagulation therapy
Urobilirubin (urine test)	↑	Liver disease
	↑	Biliary obstruction
Calcitonin	↑	Thyroid cancer
	↑	Lung cancer
	↑	**Anemia**
Thyroid-stimulating hormone	↑	**Hypothyroidism**
	↓	**Hyperthyroidism**
Thyroxine (T_4) or free thyroxine	↑	Hyperthyroidism
	↓	Hypothyroidism
Triiodothyronine (T_3)	↑	Hyperthyroidism
	↓	Hypothyroidism
BUN	↑	Renal disease
	↑	Renal obstruction
	↑	Dehydration
	↑	Gastrointestinal bleeding
	↑	Congestive heart failure
Creatinine	↑	Renal damage
	↑	Renal infection
	↑	Renal obstruction
Amylase	↑	Pancreatic disorders
	↑	Gallbladder disease

Lipase	↑ Biliary or pancreatic obstruction ↑ Pancreatic disorders ↑ Gallbladder disease
Serum calcium	↑ Biliary or pancreatic obstruction ↑ Parathyroid abnormalities
Prostatic-specific antigen	↑ Prostate abnormalities
Hematocrit	↓ Hemorrhage
WBC	↑ Inflammatory disease/infection

BUN, blood urea nitrogen; PT, prothrombin time; PTT, partial thromboplastin time; WBC, white blood cell.

TABLE 1-4 Normal numbers or ranges for basic patient care assessment

Basic Patient Assessment	
Body temperature	98.6° (oral)
Adult pulse	60–100 beats/minute
Adult blood pressure	<120/80
Adult respiration	12–20 breaths/minute

INFECTION CONTROL AND TRANSDUCER CARE

The cycle of infection may be depicted as a succession of steps (Fig. 1-1). Sonographers should continually employ standard precautions and good hygiene to prevent the spread of infection. Standard precautions are put into place to reduce the risk of microorganism transmission in the clinical setting. Standard precautions, formerly referred to as universal precautions, include (1) hand hygiene, (2) the use of personal protective equipment, (3) safe injection practices, (4) safe handling of potentially contaminated equipment and surfaces, and (5) respiratory hygiene and coughing etiquette. These precautions apply to blood, nonintact skin, mucous membranes, contaminated equipment, and all other body fluids, except for sweat.

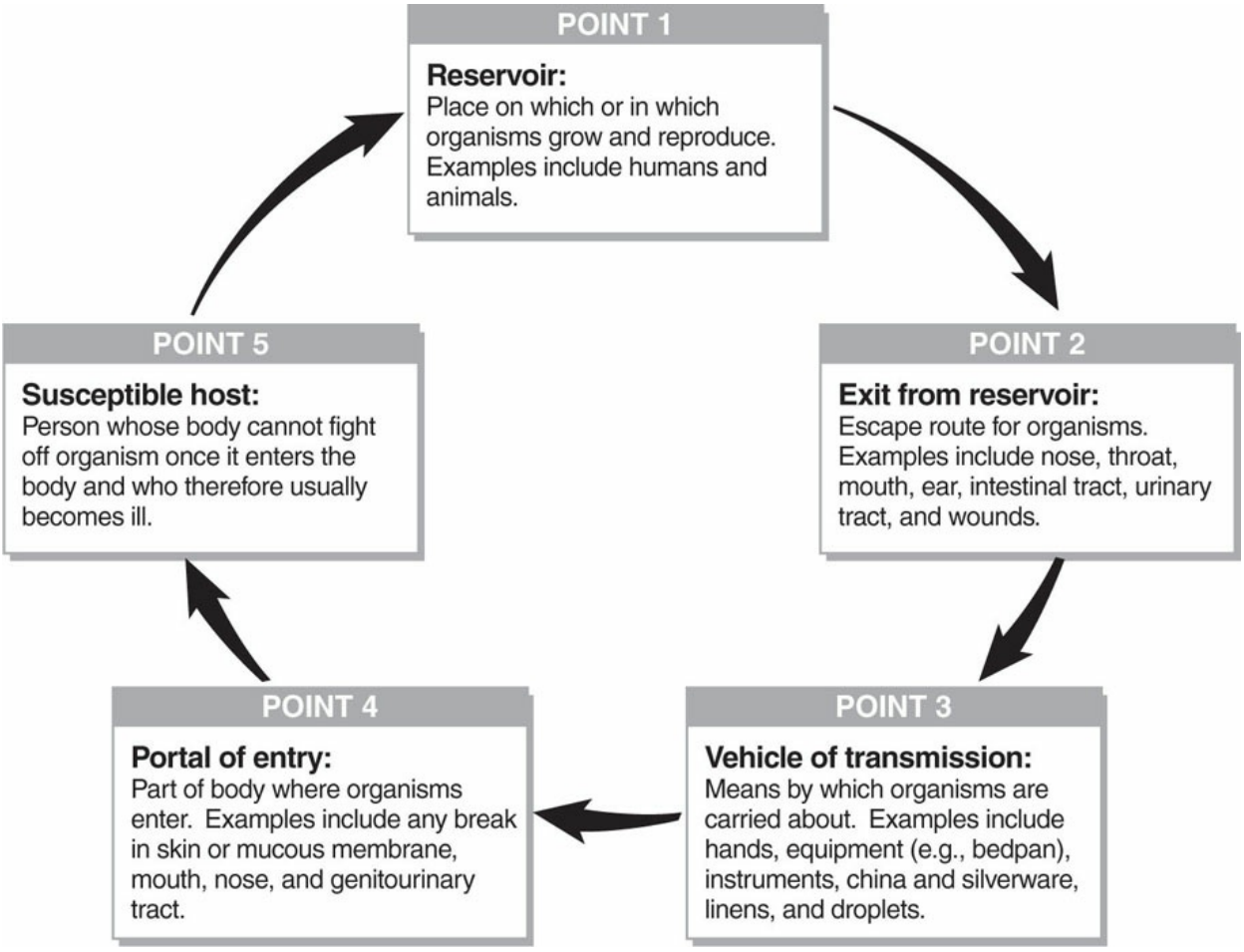


Figure 1-1 The cycle of infection.

The use of proper hand-washing and hand-cleaning techniques is one of the most effective means of preventing the spread of infection. The Center for Disease Control now recommends that health care workers employ an alcohol-based hand rub as the primary mode of hand hygiene in the clinical setting. Traditional hand-washing should be used as well when time permits, especially in situations when the hands are visibly soiled. Sonographers should also utilize personal protective equipment, such as gloves, gowns, face shields, and masks, when clinically applicable. Gloves, which are made of latex, nonlatex, or other synthetic material, should be worn during the sonographic examination and should be changed between patients. Be mindful of the potential for patient latex allergies and adapt accordingly by using another form of synthetic gloves.

Medical asepsis refers to the practices used to render an object or area free of pathogenic microorganisms. Although medical asepsis includes hand-washing, it also includes the use of disinfectants in the clinical setting, as well as the use of transducer or probe covers. Probe covers should be used for endocavity examinations, such as endovaginal and endorectal imaging. The use of sterile or nonsterile probe covers for these examinations is recommended by the institution. Transducers used during invasive

procedures should be covered with a sterile probe cover, and sterile ultrasound gel should be utilized.

Following each examination, the transducer, ultrasound machine, stretcher, and any other equipment used during the examination should be thoroughly disinfected. The transducer should be cleaned with a disinfectant spray or wipe as recommended by the institution and manufacturer. Endocavity transducers should be sterilized in some manner after each examination. Lastly, to prevent the spread of infection, sonographers should maintain good personal hygiene and health.

INVASIVE AND STERILE PROCEDURES

Patient preparation for invasive procedures varies among clinical facilities. However, informed consent from the patient and laboratory results are universally obtained. Laboratory findings, including an analysis of prothrombin time (PT), partial thromboplastin time (PTT), international normalizing ratio, fibrinogen, and platelets, are used to evaluate the patient for coagulopathies. Sterile field preparation is performed prior to the procedure as well, and sterile asepsis, also referred to as surgical asepsis, must be maintained (Table 1-5). Of course, sterile asepsis is always practiced in the surgical suite. Some invasive procedures that are commonly performed in the sonography department include thoracentesis, paracentesis, organ biopsies, mass biopsies, and abscess drainages. Biopsies can be performed using a freehand technique or under ultrasound guidance using a needle guide that attaches to the transducer. They may also be described as fine needle aspiration (FNA), which uses a thin needle and a syringe, or a core biopsy, which uses a much larger diameter needle to obtain a substantial tissue sample. An example of an FNA would be that of a thyroid biopsy, whereas an example of a core biopsy would be a liver biopsy.

TABLE 1-5 Ten vital rules of surgical asepsis to remember

1. Always know which area and items are sterile and which are not.
2. If the sterility of an object is questionable, it is considered nonsterile.
3. If you recognize that an item has become nonsterile, act immediately.
4. A sterile field must never be left unmonitored. If a sterile field is left unattended, it is considered nonsterile.
5. A sterile person does not lean across a sterile field.
6. A sterile field ends at the level of the tabletop.
7. Cuffs of a sterile gown are not considered sterile.
8. The edges of a sterile wrapper are not considered sterile.

9. If one sterile person must pass another, they must pass back-to-back.
10. Coughing, sneezing, or excessive talking over a sterile field leads to contamination.

INSTRUMENTATION

Although a thorough physics review is beyond the scope of this book, there are several topics that must be addressed in preparation for the abdominal examination. Sonographic images are typically recorded and stored in a picture-archiving and communication system (PACS). PACS allows for both easy storage and comparison between sonographic findings and straightforward correlation between other imaging modality findings.

General abdominal imaging requires the use of a transducer that balances penetration with high-quality resolution. In general, the higher the frequency employed, the poorer the penetration abilities, but the better the resolution. Conversely, the lower frequencies provide better penetration with a sacrifice in resolution. Transducers that may be used for abdominal and small part sonographic imaging include linear array, matrix array, curved or convex array, phased array, or vector or sector array. Higher frequency linear array transducers (7.5 to 18 MHz or higher when appropriate) should be used for superficial structures, such as thyroid, scrotum, breast, musculoskeletal (MSK) imaging, and some gastrointestinal examinations (e.g., appendix and pylorus). A standoff pad or a mound of gel may be used for imaging some superficial structures, such as splinters or foreign objects just below the skin surface. Lower frequency curved array transducers (2.0 to 5.0 MHz) are employed for general abdominal imaging for the assessment of deeper or larger structures such as the liver, abdominal aorta, or pancreas. When applicable, sonographers should utilize technology such as power Doppler, color Doppler, pulsed Doppler, harmonics imaging, compound imaging, extended-field of view, elastography, and three-dimensional (3D) sonography to promote diagnostic accuracy.



SOUND OFF

↑Frequency = ↑Resolution = ↓Penetration
↓Frequency = ↓Resolution = ↑Penetration

IMAGING AND DOPPLER ARTIFACTS

Gray-scale, or brightness mode (B-mode), provides a two-dimensional (2D)

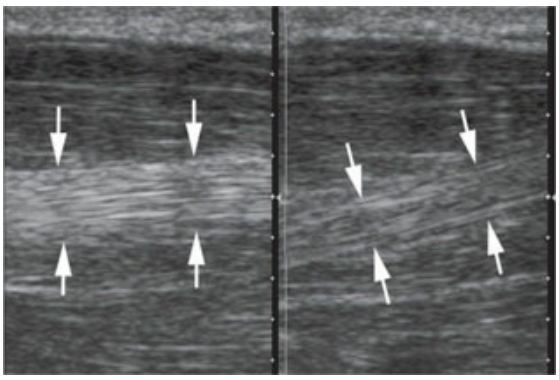
image of the human body in real time. Real-time imaging provides anatomy and motion, much like watching a live video of the internal structure being analyzed. Abdominal sonography involves careful analysis of vital structures. Often, artifacts will be observed during real-time imaging (Table 1-6). Also, there are several Doppler imaging artifacts (Table 1-7).

BODY SYSTEMS AND ABDOMINAL CAVITY

Overview of Body Systems

Throughout the following chapters, specific vital details will be provided for both normal and abnormal conditions that can be demonstrated with sonography. However, a fundamental understanding of several of the body systems is an important commission for the sonographer. The body consists of many mutually supporting body systems. These systems work together to preserve homeostasis, the body's tendency to maintain internal equilibrium by adjusting internal processes. These systems include the cardiovascular system, endocrine system, lymphatic system, MSK system, nervous system, and reproductive system. The excretory system includes the digestive system, urinary system, and respiratory system. Table 1-8 provides some insight into the basic functions of these systems and relevant topics to keep in mind as you study the various components that are applicable to abdominal imaging (Table 1-8).

TABLE 1-6 2D real-time imaging artifacts

Artifact	Explanation	Example
Anisotropy	Occurs when the sound beam strikes a structure in a nonperpendicular manner, resulting in a loss of the true echogenicity of the structure.	Seen when imaging tendons (Fig. 1-2).  **Figure 1-2** Anisotropy. Left image is obtained perpendicular to the tendon (arrows), while the right image is obliqued.
Comet tail	A type of	Seen with adenomyomatosis of the gallbladder

	reverberation artifact caused by several small, highly reflective interfaces.	(Fig. 1-3).

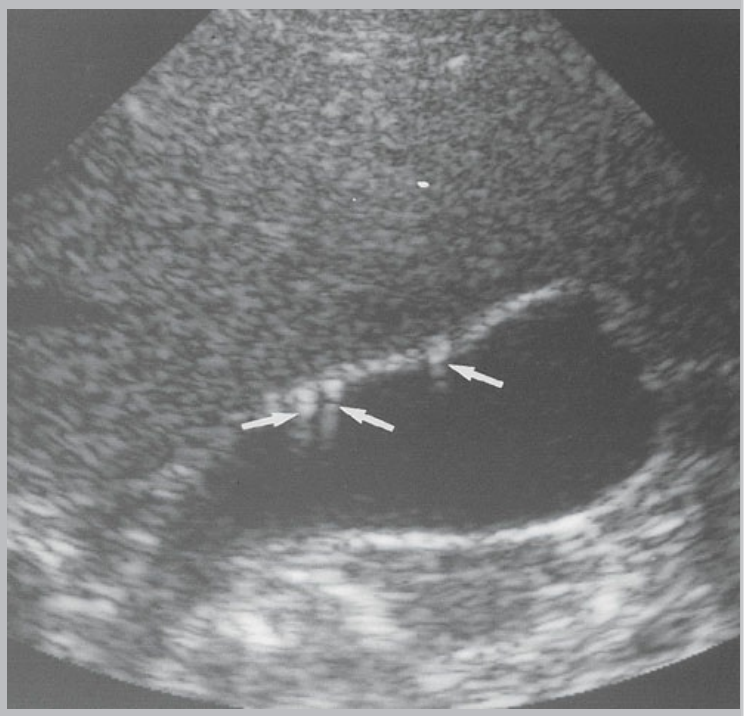


Figure 1-3 Comet tail artifact (arrows).

Dirty shadowing	Caused by air or bowel gas.	Most often seen emanating from bowel. May be seen posterior to gas within an abscess (Fig. 1-4).

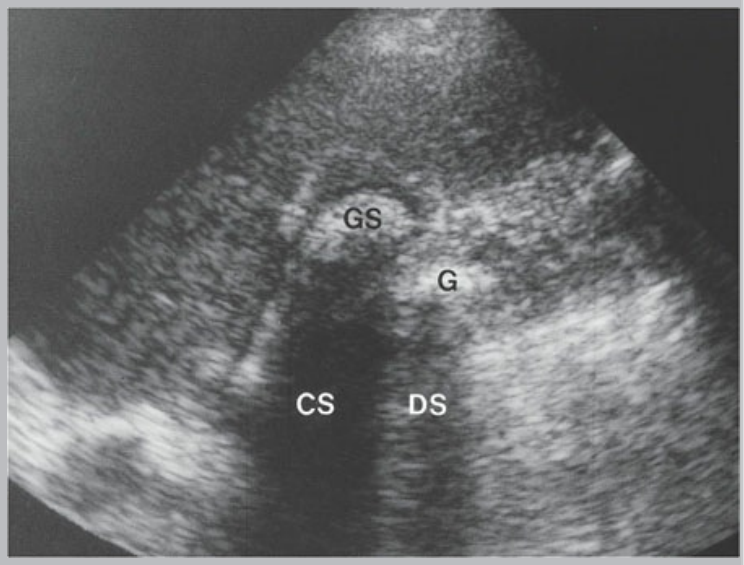


Figure 1-4 Dirty shadowing (DS) produced by gas (G). Clean shadow (CS) produced by gallstone (GS).

Edge shadowing	Reflective or refractive effect seen deep to the margins of a round structure that have a	Often seen arising from cystic structures and appears as narrow shadow lines originating at the edge of these structures (Fig. 1-5).

	significantly different speed of sound compared to surrounding tissue. May be termed refractive shadowing.	

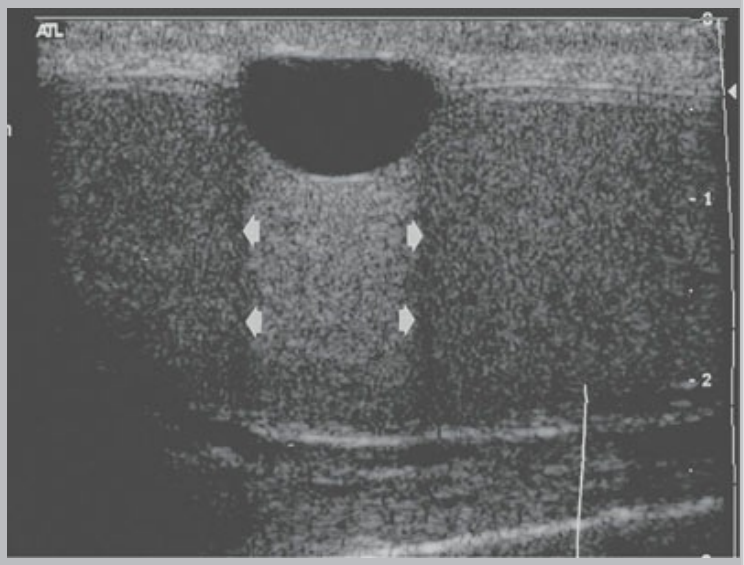


Figure 1-5 Edge artifact (arrowheads).

Mirror image	Produced by a strong specular reflector and results in a copy of the anatomy being placed deeper than the correct location.	Seen posterior to the liver and diaphragm (Fig. 1-6).

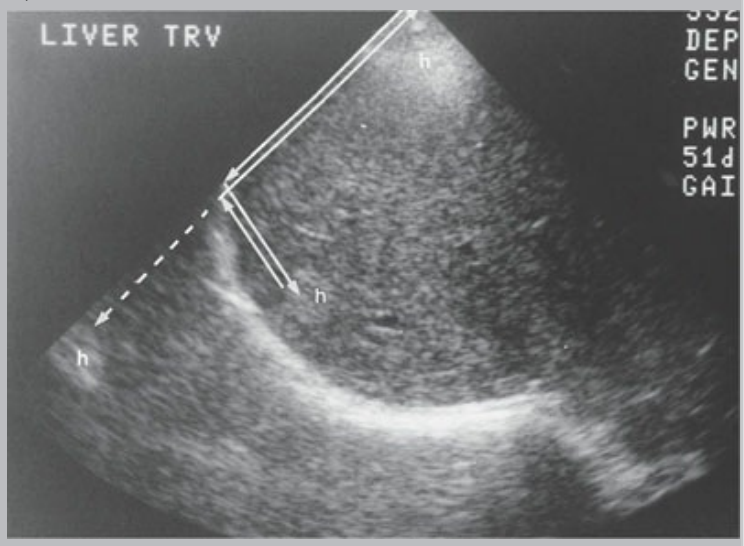


Figure 1-6 Mirror image artifact of a hemangioma (h) of the liver. The artifact is identified by the broken arrow outside of the liver.

Posterior (acoustic) enhancement or through transmission	Produced when the sound beam is barely attenuated through a fluid or a fluid-filled structure.	Seen posterior to fluid-filled structures such as the gallbladder and renal cysts, and with ascites (Fig. 1-7).

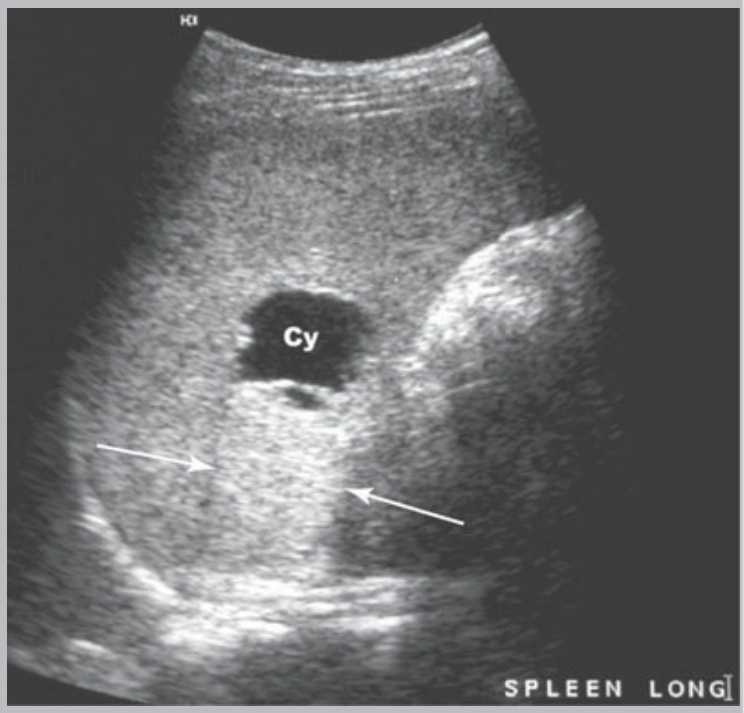


Figure 1-7 Through transmission (arrows) seen posterior to a liver cyst (Cy).

Refraction	Caused by the bending of the ultrasound beam when it passes through an interface between two tissues with vastly dissimilar speeds of sound and the angle of the approach is not perpendicular.	Seen when imaging through the rectus muscles of the abdominal wall (Fig. 1-8).

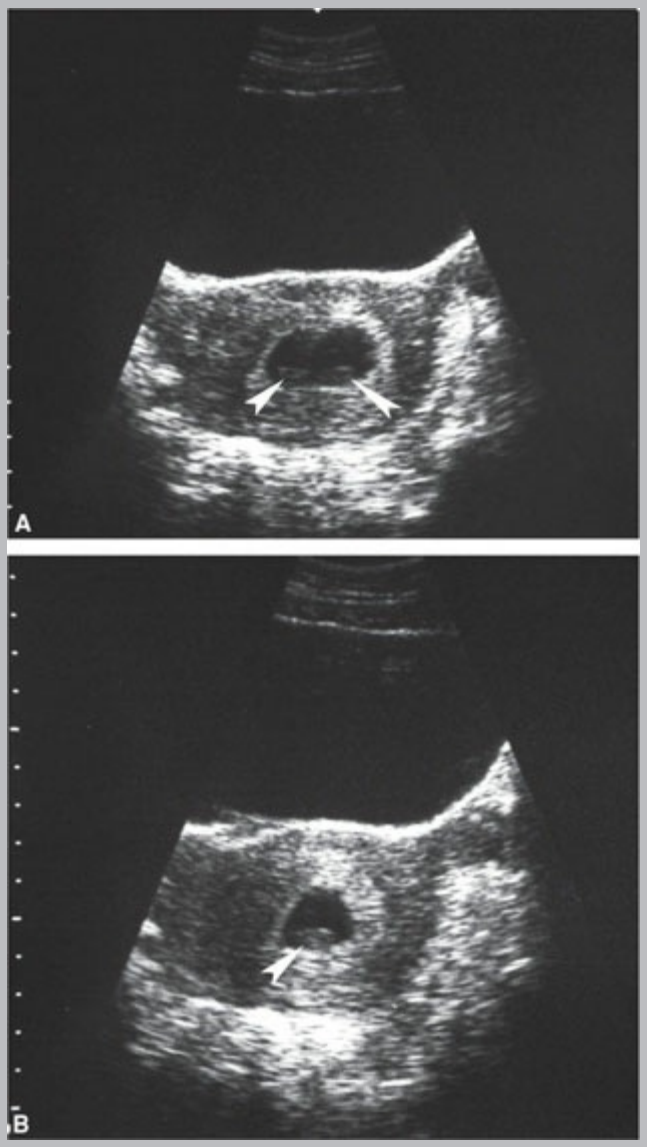


Figure 1-8 Refraction caused the appearance of two gestational sacs (image A arrowheads) when there was truly only one (image B arrowhead).

Reverberation artifact	Caused by a large acoustic interface and subsequent production of false echoes.	Seen as an echogenic region in the anterior aspect of the gallbladder or other fluid-filled structures (Fig. 1-9).

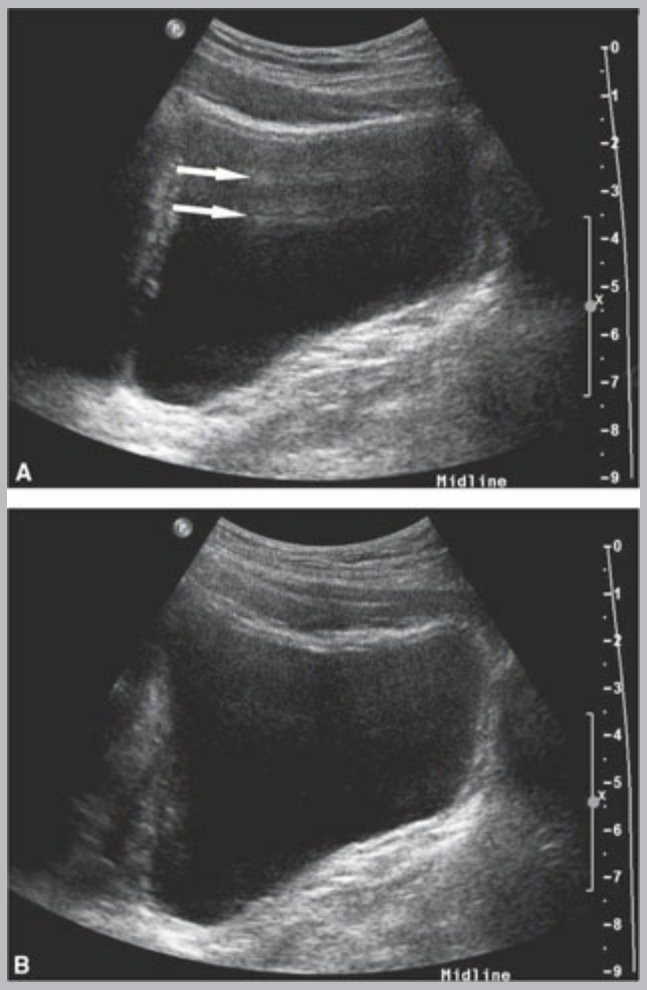


Figure 1-9 Reverberation. A. Reverberation in the anterior aspect of the urinary bladder (arrows). B. Changing the scanning angle minimizes the artifact.

Ring-down artifact	Artifact that appears as a solid streak or a chain of parallel bands radiating away from a structure.	Seen emanating from gas bubbles within the abdomen. Can help to identify the presence of air in a structure, such as in the case of pneumobilia (Fig. 1-10).

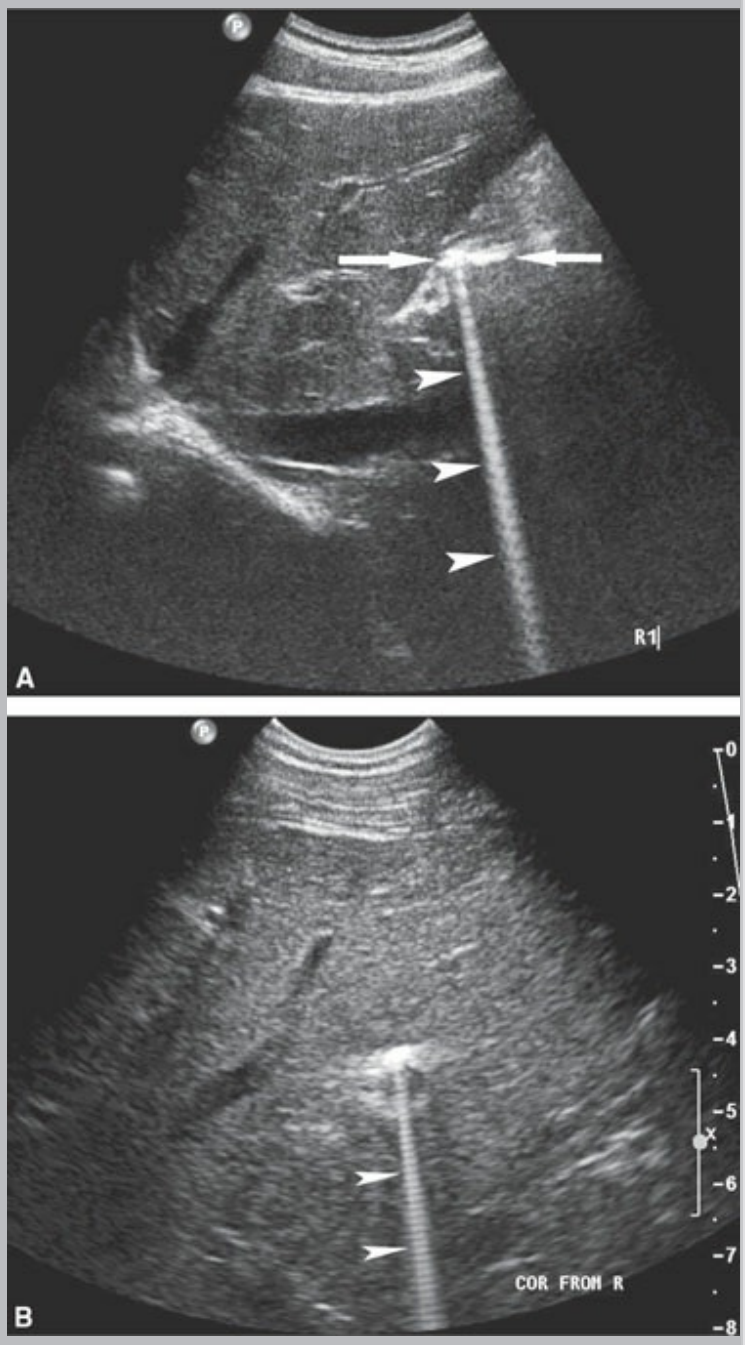


Figure 1-10 Ring down artifact. A and B. Air (between arrows in A) producing ring down artifact (arrowheads in A and B).

Shadowing	Caused by attenuation of the sound beam.	Seen posterior to bone, and calculi like gallstones and renal stones (see label CS in Fig. 1-4).
Side lobes	Caused by sound beams that are peripheral to the main sound beam.	Seen as low-level echoes within fluid, mimicking sludge, debris, or pus within a fluid-filled structure like the gallbladder (Fig. 1-11).

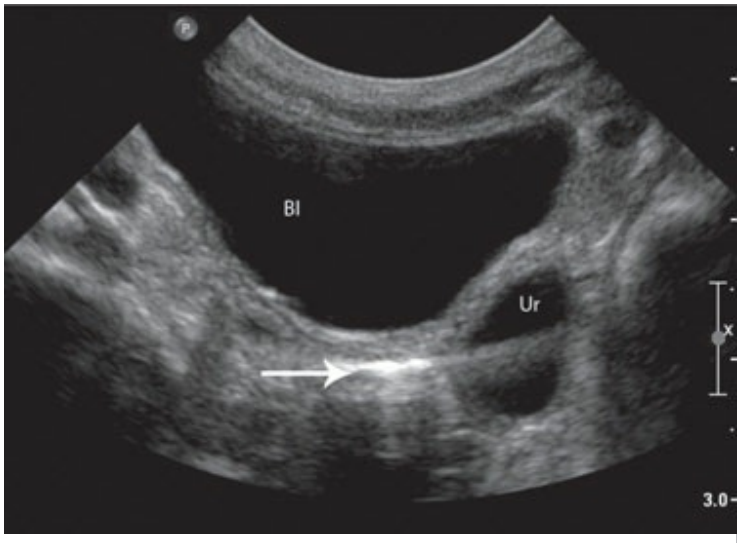


Figure 1-11 Side lobe artifact from air (arrow) within the rectum extending into the fluid-filled dilated ureter (Ur) that lies adjacent to the urinary bladder (Bl).

Slice thickness	Caused by compression from 3D to 2D images.	Simulates false echoes that could resemble sludge or debris in the urinary bladder or gallbladder (Fig. 1-12).

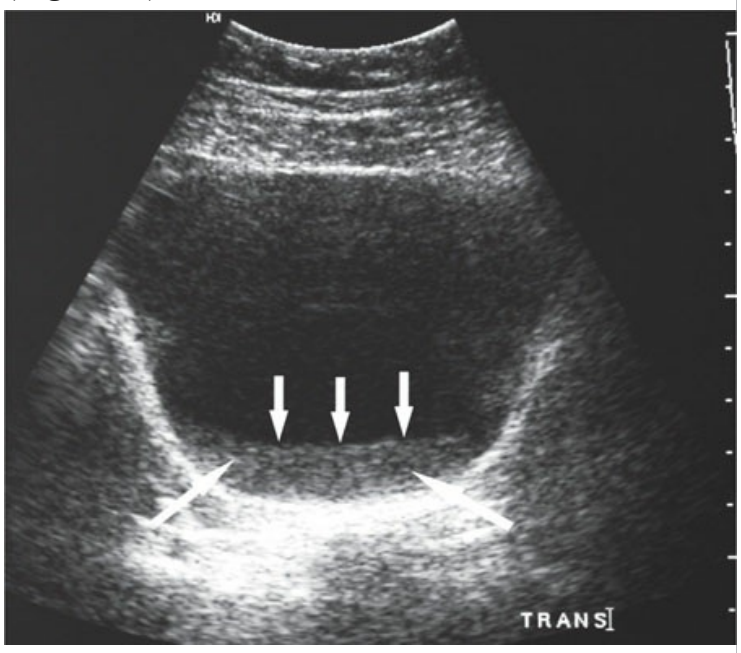


Figure 1-12 Slice thickness artifact produces false layering debris (arrows) within the urinary bladder.

Although a detailed comprehension of cardiac system function and circuitry may not be compulsory for the abdominal sonographer, you should have a fundamental understanding of blood circulation to enhance your grasp

of some abdominal anatomy and pathologic processes. The cardiovascular system has both a pulmonary and systemic function. The pulmonary circulation provides blood to the lungs and drains the lungs as well, while the systemic circulation provides this same function for the rest of the body's organs and structures.

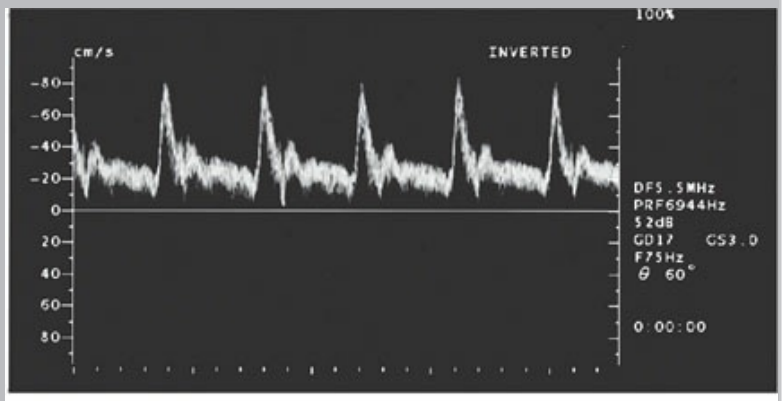
The heart consists of four chambers: two atria and two ventricles. Blood returning from the heart from the system circulation is via the superior vena cava and the inferior vena cava (IVC). The superior vena cava and the IVC empty into the right atrium of the heart. Thus, recognizing an enlargement of IVC during an abdominal sonogram can be indicative of right-sided heart failure. Although the heart is not specifically imaged by the abdominal sonographer, the fluid around the heart, or a pericardial effusion, may be noted during an abdominal sonogram. Also, fluid within the chest cavity, or a pleural effusion, may be noted. Vascularity of the abdomen can be evaluated with sonography with real-time, pulsed Doppler, and color or power Doppler. Although there are a few exclusions, the typical pattern of blood flow is as follows: arterioles–capillary–venule–vein.

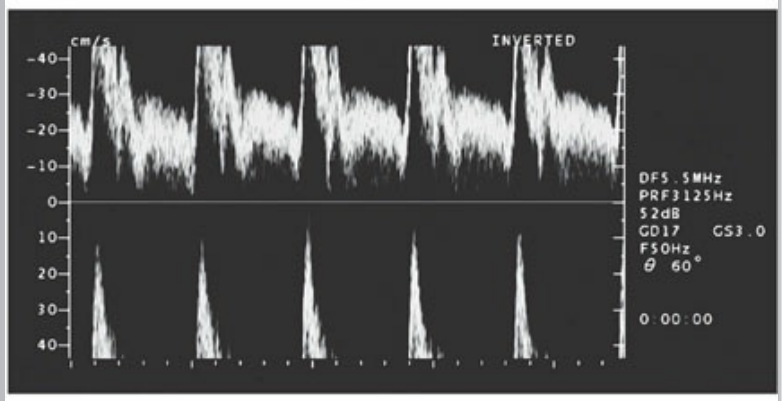
The digestive system can be evaluated with sonography for various indications. The esophagus may be seen while imaging the liver, especially in the sagittal plane when analyzing the left lobe of the liver. Although gastritis may be demonstrated, the adult stomach is not often analyzed specifically with sonography. However, the distal portion of the pediatric stomach can be evaluated for pyloric stenosis. The intestines may be examined for disorders such as intussusception, volvulus, diverticulitis, and appendicitis. Tumors of the gastrointestinal tract may be seen with sonography as well. Of course, the accessory organs of the digestive system, the liver, gallbladder, and pancreas are readily imaged with sonography.

The glands of the endocrine system, specifically the thyroid gland, parathyroid glands, adrenal glands, and testicles, are imaged by abdominal sonographers (Fig. 1-17). Endocrine glands release their hormones directly into the bloodstream. Exocrine glands, such as the salivary glands, release their enzymes through ducts. Some organs, such as the pancreas and testicles, have both exocrine and endocrine functions. Whereas the pancreatic endocrine function is to produce the hormones insulin, glucogan, and somatostatin, the exocrine function is to produce the digestive enzymes amylase, lipase, sodium bicarbonate, and others. The testicular endocrine function is to produce testosterone, whereas the testicular exocrine function is to produce and transport sperm.

TABLE 1-7 Doppler artifacts

Doppler Artifact	Explanation	Adjustment
Absent Doppler signal	Could be caused by low gain, low frequency, high wall filter, or too high velocity scale.	• Decrease PRF • Turn up spectral gain • Decrease the wall filter • Open the sample gate
Aliasing	Occurs when the Doppler sampling rate (pulse-repetition frequency) is not high enough to accurately display the Doppler frequency shift.	• Increase the pulse-repetition frequency. • Adjust the baseline. • Switch to a lower transmitted frequency. • Increase the angle of insonation to decrease Doppler shift (Figs. 1-13 and 1.14).





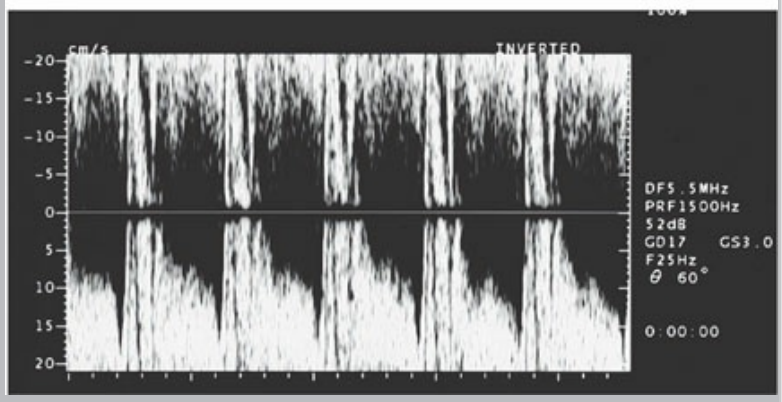


Figure 1-13 Pulsed Doppler Aliasing. A. Pulsed waveform of internal carotid shows normal systolic peaks. B. Sampling rate set too low demonstrating aliasing. C. Further decrease in sampling rate produces more aliasing.

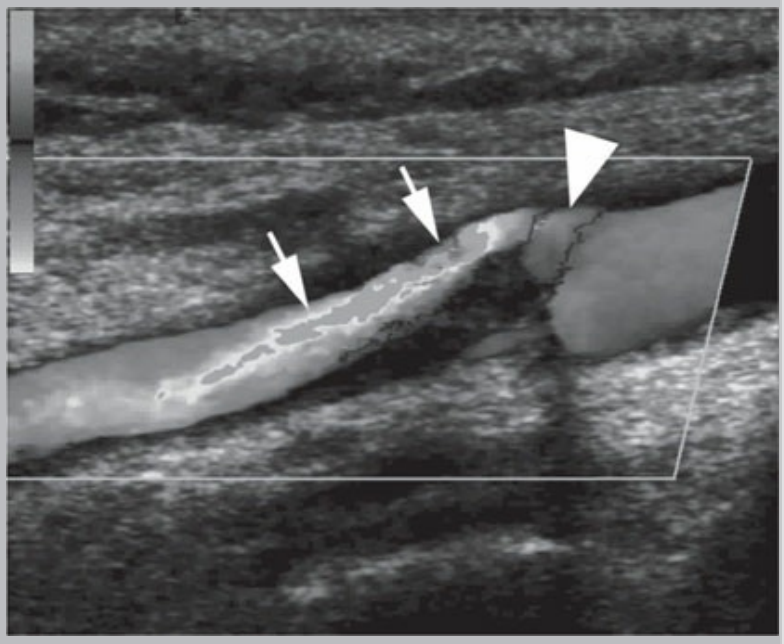


Figure 1-14 Color Doppler aliasing. The arrows demonstrate localized aliasing within a stenotic internal carotid artery. The arrowhead demonstrates a true reversal of flow. Color image provided online.

Doppler noise	Caused by inappropriately high Doppler settings.	Reduce color gain setting or adjust wall filter. (Fig. 1-15).

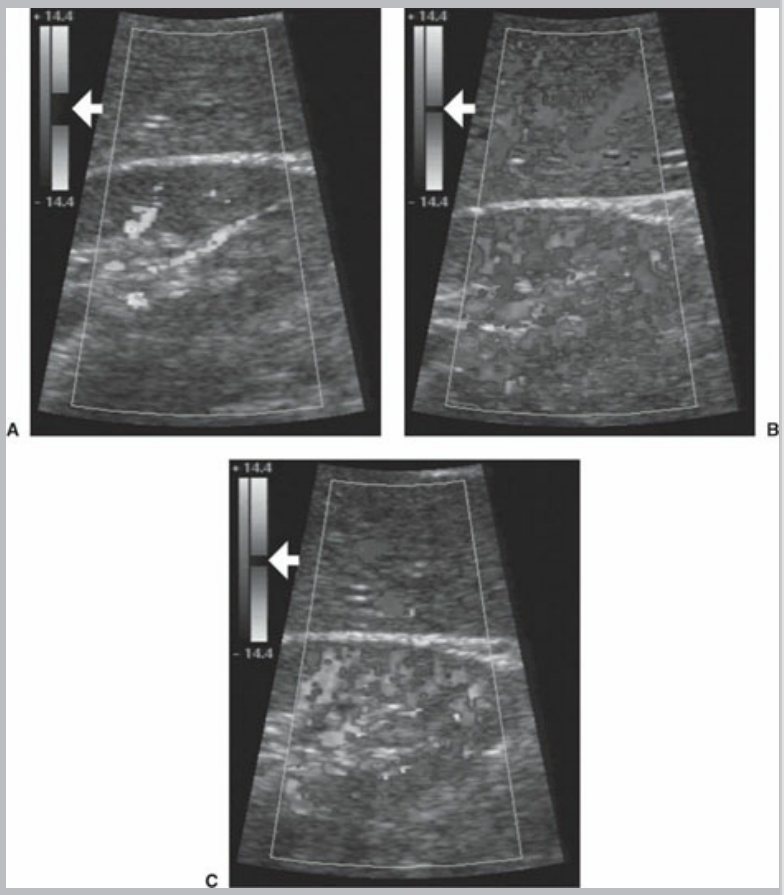


Figure 1-15 Doppler noise and the wall filter (arrow). A. High filter setting produces minimal flow detection. B. Low filter setting produces excessive noise. C. Medium filter setting eliminates noise and correctly depicts flow. Color image provided online.

Flow directional abnormalities	Caused by the sound beam striking a vessel at a 90-degree angle, producing an area void of color.	Change the angle of insonation.
Twinkle artifact	Occurs behind strong, granular, and irregular surfaces like crystals, calculi, or calcifications.	Artifact that is actually useful at identifying small kidney or biliary stones (Fig. 1-16).

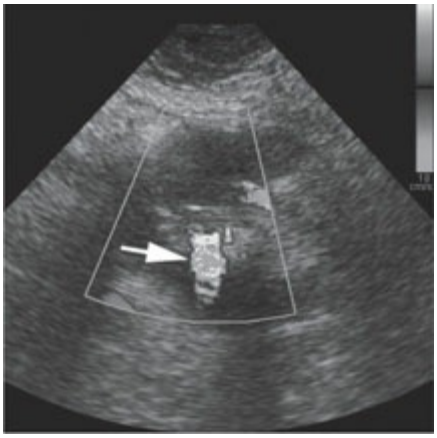


Figure 1-16 Twinkle artifact (arrow) seen posterior to a small kidney stone.

TABLE 1-8 Functions and structures of body systems

Body System	Primary Function	Organs or Structures
Cardiovascular	Supplies the body with oxygen, nutrients, hormones, and WBCs and removes waste and toxins by pumping and transferring blood.	Arteries and arterioles Capillaries Heart Veins and venules
Digestive	Provides metabolism, nutrient uptake, energy storage, and the excretion of waste.	Accessory digestive organs: Liver Gallbladder Pancreas Esophagus Mouth Small and large bowel Stomach
Endocrine	Secretion of hormones into the blood to control many different body functions. The hypothalamus in the brain controls the pituitary gland's secretion of various hormones, which in turn controls the secretion of hormones by endocrine organs or glands.	Adrenal glands Liver Ovaries Pancreas Parathyroid glands **Pineal gland** Pituitary gland (anterior and posterior) Testicles Thyroid gland
Exocrine	Secretes hormones or juices through ducts.	Breast Pancreas

		Salivary glands (parotid glands, submandibular glands, and sublingual glands) Liver
Lymphatic	Collection and transportation of excess fluid, absorption of fats (which are eventually sent to the liver), and immune response.	Adenoids Bone marrow Lymph nodes Spleen **Thymus gland** Tonsils
MSK	Provides the structural support system for the body.	Cartilage Connective tissue Joints Ligaments Muscles Tendons
Nervous	Controls almost every organ system and structure in the body.	Brain Spinal cord Nerves
Respiratory	Supplies the body with oxygen and removes carbon dioxide from the blood.	Bronchus Larynx Lungs Nasal cavity Pharynx Trachea
Reproductive	Produce new life.	Male: Epididymis Prostate gland Scrotum Testes Vas deferens Female: Fallopian tubes Ovaries Uterus Vagina
Urinary	Maintain chemical and water balance, regulate blood pressure, and filter waste products from the blood.	Kidneys Ureters Urethra Urinary bladder

MSK, musculoskeletal; WBC, white blood cells.

SOUND OFF
Endocrine organs release hormones into the bloodstream, whereas exocrine organs use ducts. Remember, *ex*ocrine *ex*it through ducts.

The lymphatic system plays a vital role in the immune response. Small structures known as lymph nodes are scattered throughout the body and serve the purpose of filtering lymphatic fluid from foreign material (Fig. 1-18). The lymphatic system also plays an important role in the transportation of lymphatic fluid or lymph, and thus fluid balance. This fluid makes its way through lymphatic channels to the thoracic duct, ultimately to be returned to the systemic circulation. A build-up of lymphatic fluid, most likely caused by obstruction of this drainage process with subsequent swelling, is referred to as lymphedema. Lymph nodes, which contain lymphocytes and macrophages, are commonly imaged by the sonographer in the neck, the groin, the armpit, and perhaps, when enlarged, they may be seen within the abdomen. Enlargement of a lymph node may be referred to as lymphadenopathy. The largest mass of lymphatic tissue is the spleen. Other lymphatic system components include the thymus gland in the chest, and the tonsils and adenoids in the neck.

The MSK system provides the framework for the human body. It comprises bones, muscles, tendons, ligaments, and joints. Although there is an additional certification covering MSK sonography offered by the ARDMS, the abdominal sonographer may be called upon to analyze some MSK structures, including the pediatric hip and the Achilles tendon. Sonography can be useful at detecting many pathologic complications of the MSK system, including joint effusions and tendon tears or ruptures.

The reproductive system of both the male and the female can be readily imaged with sonography. For abdominal sonography, one must have an understanding of the function and anatomy of male reproductive organs and structures, including the penis, scrotum, testes, and prostate gland. Testicular torsion and infection of the testicles and epididymis are among the common indications for scrotal sonography.

The urinary tract consists of an upper and a lower part. The upper urinary tract includes the kidney and ureters, whereas the lower part includes the bladder and urethra. The kidneys function to regulate blood volume, filter the blood, and regulate blood pressure. The kidneys produce urine, which comprises waste such as urea. Urine flows from the paired kidneys down the paired ureters and is temporarily stored in the urinary bladder before exiting the body. Sonography can be used to evaluate the urinary tract for obstruction, tumors, and renal calculi, as well as to perform an overall assessment of other disorders that can inhibit the system’s functions.

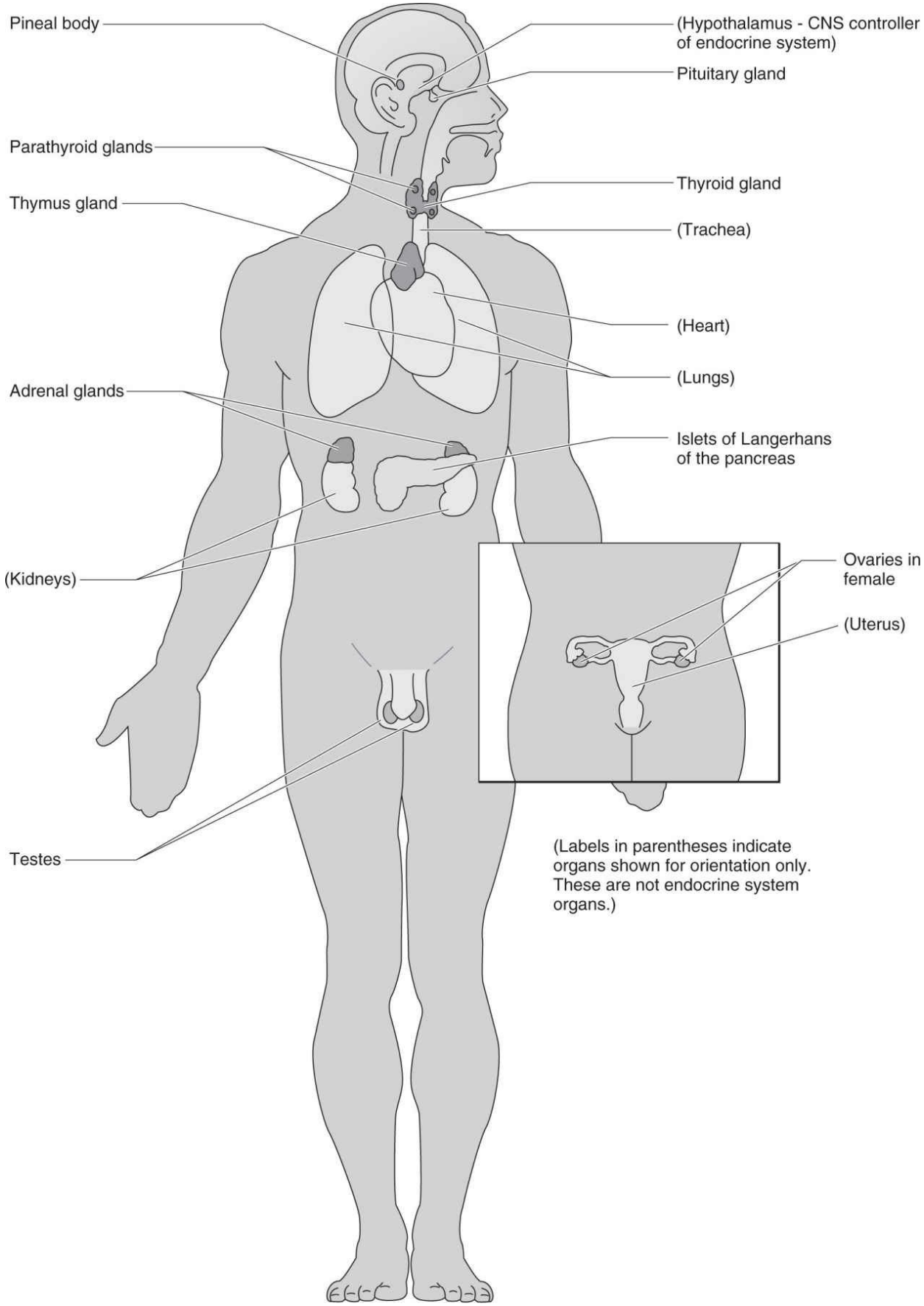


Figure 1-17 Endocrine system.

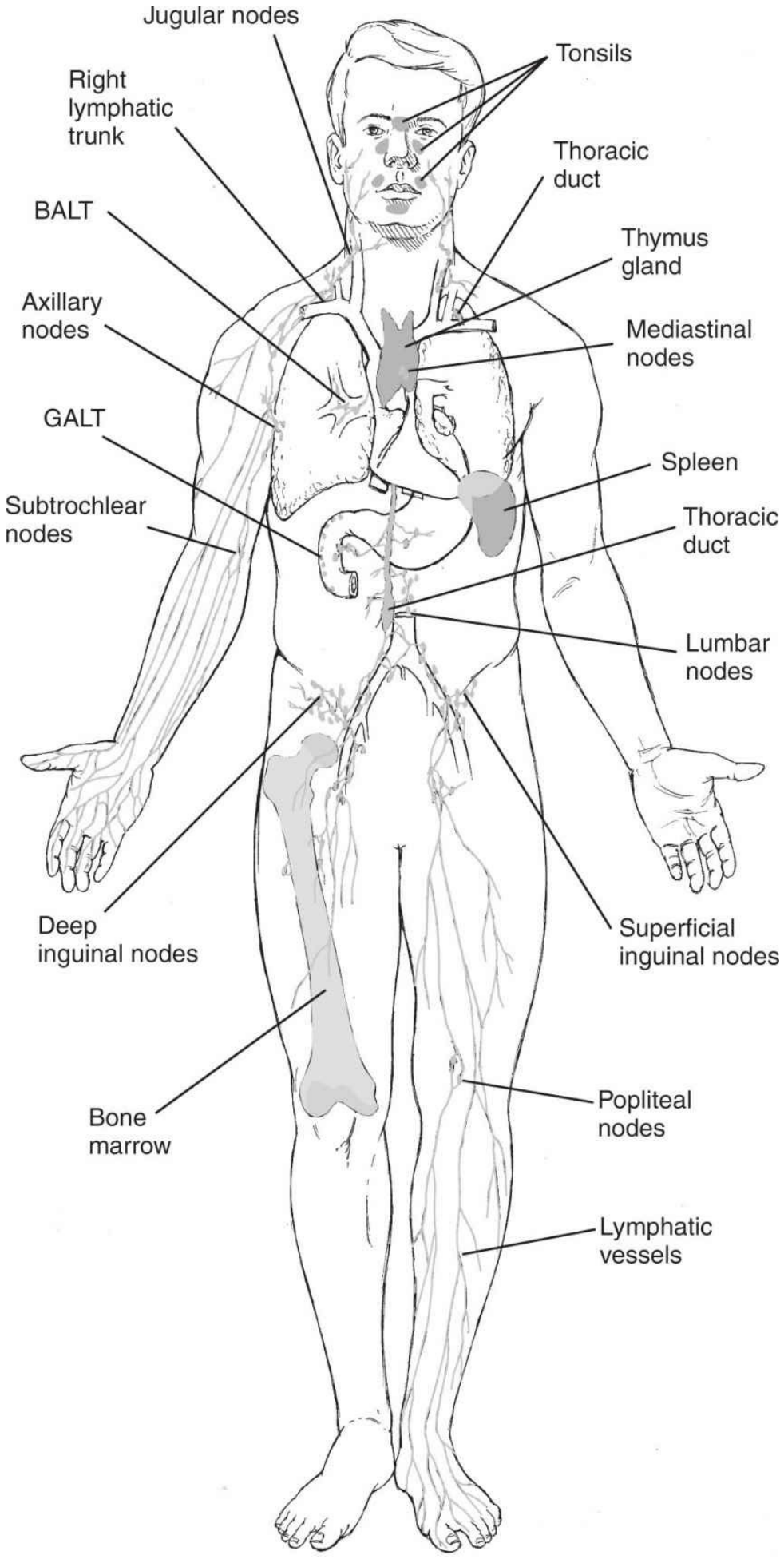

Jugular nodes
Tonsils
Right lymphatic trunk
Thoracic duct
BALT
Thymus gland
Axillary nodes
Mediastinal nodes
GALT
Spleen
Subtrochlear nodes
Thoracic duct
Lumbar nodes
Deep inguinal nodes
Superficial inguinal nodes
Bone marrow
Popliteal nodes
Lymphatic vessels

Figure 1-18 Lymphatic system. GALT is gut-associated lymphoid tissue and BALT is bronchus-associated lymphoid tissue.

Abdominal Cavity

The double lining of the abdominal cavity is the peritoneum. The peritoneum consists of a parietal and visceral layer. The parietal peritoneum forms a closed sac, except for two openings in the female pelvis, which permits passage of the fallopian tubes from the uterus to the ovaries. Furthermore, each organ is covered by a layer of visceral peritoneum, which is essentially the organ's serosal layer.

Some abdominal organs are considered intraperitoneal and others retroperitoneal (Tables 1-9 and 1-9). The retroperitoneal structures are only covered anteriorly with peritoneum. The abdominal parietal peritoneum can be divided into two sections: the greater sac and the lesser sac. The greater sac extends from the diaphragm to the pelvis, while the lesser sac is located posterior to the stomach. Potential spaces, which are essentially outpouching in the peritoneum, exist between the organs (Table 1-11).

These spaces provide an area for fluid to collect in the abdomen and pelvis. Ascites is an abnormal collection of abdominal fluid in these spaces. It can be found in association with several pathologies (Table 1-12). Ascites can be a single fluid, such as serosal fluid, pus, blood, or urine, or it may be a combination of fluids. Exudate ascites can be a malignant form of ascites. It may appear as complex fluid with loculations and produce matting of the bowel. Benign ascites, or transudate ascites, consists of serosal fluid, and typically appears simple and anechoic.

SONOGRAPHIC ABDOMINAL PATHOLOGY OVERVIEW

A mass, also referred to as a neoplasm or tumor, may be benign, potentially malignant (precancerous), or malignant. Whereas malignant, or cancerous, tumors both invade adjacent tissue and have the potential to metastasize to other parts of the body, a benign tumor, although certainly not normal, typically does not invade neighboring tissue and does not metastasize. However, some benign tumors have the potential for progressing to cancer. Tumors, whether benign or malignant, may also displace adjacent anatomy, termed mass effect, causing secondary clinical complaints such as pain.

A synopsis of the most common benign and malignant adult abdominal solid masses encountered with sonography is provided in Tables 1-13 and 1-13, respectively. Though a description of each mass and the most common abdominal location is provided, each of these masses will be further

discussed in the following chapters. A synopsis of the most common pediatric malignant abdominal masses encountered with sonography is provided in Table 1-15. A common theme that one can recognize is the presence of the word part "blast" in these childhood malignant tumors.



SOUND OFF

The word part "blast," as in hepato*blast*oma, often refers to a childhood malignancy.

TABLE 1-9 The list of intraperitoneal organs

Gallbladder
Liver (except for the bare area)
Ovaries
Spleen (except for splenic hilum)
Stomach

TABLE 1-10 The list of retroperitoneal organs

Abdominal lymph nodes
Adrenal glands
Aorta
Ascending and Descending Colon
Duodenum
IVC
Kidneys
Pancreas
Prostate gland
Ureters
Urinary bladder
Uterus

TABLE 1-11 The location and significance of the peritoneal cavity spaces

Peritoneal Cavity Spaces	Location and Significant Points
Subphrenic spaces	• Inferior to the diaphragm • Divided into right and left

Subhepatic spaces	• Divided into right (anterior and posterior) and left • Right is located between the right lobe of the liver and right kidney • Posterior right subhepatic space is also referred to as **Morrison pouch** • Left is located between the left lobe of liver and stomach
Retropubic space	• Between the pubic bone and urinary bladder • Also referred to as the **Space of Retzius**
Lesser sac	• Between the stomach and pancreas • Common location for pancreatic pseudocysts
Paracolic gutters	• Extend alongside the ascending and descending colon on both sides of the abdomen
Posterior cul-de-sac	• Male: between the urinary bladder and rectum; also referred to as the rectovesical pouch • Female: between the uterus and rectum; also referred to as pouch of Douglas and rectouterine pouch
Anterior cul-de-sac	• Between the urinary bladder and uterus • Also called the vesicouterine pouch in females

TABLE 1-12 Pathologies associated with ascites

Acute cholecystitis
Cirrhosis
Congestive heart failure
Ectopic pregnancy
Malignancy
Portal hypertension
Ruptured abdominal aortic aneurysm

As a screening modality, sonography has some challenges in regard to predicting whether a mass is benign or malignant. However, there are several clinical findings that can be indicators for the presence of malignancy. These indicators may present as signs or symptoms. A sign is something that can be observed by others and is therefore objective. An example of a sign is fever, vomiting, and elevated laboratory tests. A symptom is something felt by the person themselves, such as nausea, a headache, or abdominal pain, and is therefore subjective. In general, patients with cancer may present with vague

signs and symptoms, such as unexplained weight loss, fever, fatigue, pain, and possible skin changes. Throughout this text, you will see signs and symptoms placed together in tables and referred to as clinical findings. Clinical findings also include laboratory results. Some labs can be used as tumor markers. Tumor markers are substances produced by cancer cells or organs in response to cancer (Table 1-16).

TABLE 1-13 Common locations of benign abdominal/small part tumors

Benign Abdominal Tumor	Description	Common (Abdominal) Location
Adenoma	Tumor of glandular origin	Most organs
Adrenal rest tumor	Tumor containing adrenal tissue	Testicle
Angiomyolipoma	Tumor of blood vessels, muscle, and fat	Kidney
Focal nodular hyperplasia	Abnormal accumulation of cells within a focal region of an organ	Liver
Granuloma	Tumor consisting of a group of inflammatory cells	Liver and spleen
Gastrinoma	Tumor that secretes **gastrin**	Pancreas
Hamartoma	Tumor consisting of an overgrowth of normal cells of an organ	Kidney
Hemangioma	Tumor consisting of blood vessels	Liver, spleen, and kidney
Hematoma	Localized collection of blood	Anywhere an organ/tissue is affected by trauma
Insulinoma	Tumor that secretes insulin	Pancreas
Lipoma	Tumor that consists of fat	Liver, spleen, kidney, and superficial
Oncocytoma	Tumor consisting of **oncocytes**	Kidney
Pheochromocytoma	Tumor that consists of **chromaffin cells** of the adrenal gland	Adrenal gland
Teratoma	Tumor that consists of	Testicle/ovary

	tissue from all three germ cell layers	
Urinoma	Localized collection of urine	Adjacent to a kidney transplant

TABLE 1-14 Common locations of malignant abdominal/small part tumors

Malignant Abdominal Tumor	Description	Common (Abdominal) Location
Adenocarcinoma	Cancer of glandular origin	Pancreas and gastrointestinal tract
Angiosarcoma	Cancer in the lining of vessels (lymphatic or vascular)	Spleen
Choriocarcinoma	Cancer that consists of trophoblastic cells	Testicle
Cholangiocarcinoma	Cancer of the bile ducts	Biliary tree
Cystadenocarcinoma	Cancer that is fundamentally adenocarcinoma with cystic components	Pancreas
Embryonal cell carcinoma	Cancer that is of germ cell origin	Testicle
Follicular carcinoma	Cancer of aggressive abnormal epithelial cells	Thyroid
Hepatocellular carcinoma (Hepatoma)	Cancer that originates in the hepatocytes	Liver
Hypernephroma (Renal cell carcinoma)	Cancer that originates in the tubules of the kidney	Kidney
Leukemia (focal)	Cancer of the blood cells	Spleen, liver, and testicle
Lymphoma	Cancer of the lymphatic system	Spleen, kidney, and testicle
Medullary carcinoma	Cancer originating from the parafollicular cells of the thyroid	Thyroid
Papillary carcinoma	Cancer that has formation of many irregular, fingerlike projections	Thyroid
Seminoma	Cancer that originates in the seminiferous tubules	Testicle
Transitional cell carcinoma	Cancer that originates in the transitional epithelium of an	Bladder, ureter, and kidney

	organ or structure	
Yolk sac tumor	Cancer that is of germ cell origin	Testicle

TABLE 1-15 Common locations of malignant pediatric abdominal masses

Solid Pediatric Malignant Abdominal Mass	Common Location
Hepatoblastoma	Liver
Nephroblastoma (Wilms tumor)	Kidney
Neuroblastoma	Liver

There are many syndromes, multisystem disorders, and diseases that you will encounter as you study abdominal pathology. A summary of these is provided in Table 1-17. Keep in mind that a syndrome is a group of clinically observable findings that exist together and allow for classification, whereas a disease is the result of the incorrect functioning of an organ or body system that can result from many different issues, including genetic predisposition, infection, and environmental factors. Some diseases have associated syndromes.

TABLE 1-16 Basic overview of tumor markers relevant to abdominal imaging that may be elevated with some cancers

Abdominal/Small Part Tumor Marker	Possible Cancer Present[a]
alpha-Fetoprotein	Liver, ovarian, and testicular cancers
CA 15-3	Breast
CA 19-9	Pancreatic, biliary tract, stomach, and colon
CA-125	Ovarian
Calcitonin	Medullary thyroid cancer
beta-hCG	Testicular cancers and germ cell tumors
LDH	Testicular, ovarian, and other germ cell tumors

[a] Some benign conditions may cause an increase in these labs.
beta-hCG, human chorionic gonadotropin; LDH, Lactate dehydrogenase.

TABLE 1-17 Summary of multisystem disorders, diseases, or syndromes

Multisystem Disorder, Disease, or Syndrome	Synopsis	Affected Structures or Organs
Autosomal dominant polycystic kidney disease	Inherited condition that causes cysts in multiple organs; usually seen in adults later in life	Kidneys, liver, spleen, and pancreas
Autosomal recessive polycystic kidney disease	Inherited condition that causes cysts in the kidneys, renal failure, and hepatic fibrosis; usually discovered in utero or in newborns	Kidneys and liver
AIDS and HIV	Virus that attacks the immune system	Liver, spleen, lymph nodes, and skin tumors (**Kaposi sarcoma**)
Beckwith–Weidemann syndrome	Growth disorder that causes enlargement of many organs and structures; increased risk for kidney and liver cancer in children	Skull, abdominal visceromegaly, and tongue (macroglossia)
Budd–Chiari syndrome	Narrowing or occlusion of the hepatic veins and possibly IVC	Liver and IVC
Conn syndrome	Results from high levels of aldosterone; can be caused by adrenal adenoma	Adrenal glands
Crohn disease	Autoimmune disease that causes chronic inflammation of the gastrointestinal tract	Gastrointestinal tract
Cushing syndrome	Results from high levels of cortisol; can be caused by adrenal adenoma	Adrenal glands
Diabetes	Caused by hyposecretion or hypoactivity of insulin Type 1—Early onset (juvenile or young adult) Type 2—Adult onset	Multiple organs including eyes, extremities, kidneys, nerves, and vasculature
Fitz-Hugh–Curtis syndrome	Rare complication of pelvic inflammatory disease causing inflammation of the tissue around the liver	Liver
Graves disease	Associated with hyperthyroidism	Thyroid
Hashimoto disease	Associated with hypothyroidism	Thyroid

Klinefelter syndrome	Genetic condition in which a male has an extra X chromosome	Testicles and male breast
Marfan syndrome	Disorder of the connective tissue	Heart, vascular structures, and skeleton
Mirizzi syndrome	Jaundice, pain, and fever associated with a stone lodged in the cystic duct	Liver, gallbladder, and biliary tract
Nephrotic syndrome	Damaged filtration of kidneys causes excessive protein in the urine (proteinuria)	Kidneys, swelling of feet and ankles
Sarcoidosis	Inflammatory disease that results in scar tissue development in multiple organs	Liver, spleen, kidneys, testicles, lymphatics, and lungs
Tuberculosis	Infectious disease spread through the air	Lungs, lymphatics, and testicles
Tuberous sclerosis	Rare genetic disorder that leads to the development of tumors within various organs	Brain, heart, and kidneys (angiomyolipoma)
von Hippel–Lindau disease	Rare genetic disorder characterized by cysts and tumors in various organs	Pancreas, kidneys, and adrenal glands
Zollinger–Ellison syndrome	Tumor (gastrinoma) in the pancreas or intestine that causes an increase in the production of gastrin	Pancreas and stomach (produces excessive stomach acid)

Many of these diseases, syndromes, or conditions affect other organs. This is a condensed list for the purpose of focused study.
IVC, inferior vena cava.

REVIEW QUESTIONS

1. Transitional cell carcinoma is commonly found in all of the following locations except:
   a. Liver
   b. Renal pelvis
   c. Urinary bladder
   d. Ureter

2. A patient with cholecystitis most likely has an elevation in which of the following labs?

a. alpha-Fetoprotein
b. WBC count
c. Lactate dehydrogenase (LDH)
d. Chromaffin

3. The neuroblastoma is a malignant pediatric mass commonly found in the:
a. Kidney
b. Liver
c. Testicle
d. Adrenal gland

4. What is a substance produced by a cancerous tumor or an organ or structure in response to cancer?
a. Oncocyte
b. Tumor marker
c. Lymphadenopathy
d. Homeostatin

5. The pheochromocytoma is a benign mass commonly located in the:
a. Testicle
b. Thyroid gland
c. Adrenal gland
d. Liver

6. A tumor that is of similar echotexture to normal liver tissue is discovered in the liver of an asymptomatic patient. What is the echogenicity of the tumor?
a. Echogenic
b. Hypoechoic
c. Isoechoic
d. Hypodense

7. Which of the following is not considered to be an intraperitoneal organ?
a. Liver
b. Pancreas
c. Gallbladder
d. Spleen

8. Which of the following are not considered retroperitoneal organs?
a. Abdominal lymph nodes
b. Adrenal glands
c. Kidneys
d. Ovaries

9. What is another name for Morrison pouch?
    a. Posterior right subhepatic space
    b. Anterior subhepatic space
    c. Posterior cul-de-sac
    d. Anterior cul-de-sac

10. The hypernephroma may also be referred to as the:
    a. Nephroblastoma
    b. Neuroblastoma
    c. Hepatocellular carcinoma
    d. Renal cell carcinoma

11. A type of reverberation artifact caused by several small, highly reflective interfaces, such as gas bubbles, describes:
    a. Mirror image artifact
    b. Posterior shadowing
    c. Comet tail artifact
    d. Ring-down artifact

12. The term cholangiocarcinoma denotes:
    a. Bile duct carcinoma
    b. Hepatic carcinoma
    c. Pancreatic carcinoma
    d. Splenic carcinoma

13. Which of the following occurs when the Doppler sampling rate (pulse-repetition frequency) is not high enough to display the Doppler frequency shift?
    a. Doppler noise
    b. Aliasing
    c. Mirror image
    d. Twinkle artifact

14. The hepatoma is a:
    a. Benign tumor of the spleen
    b. Benign tumor of the liver
    c. Malignant tumor of the pancreas
    d. Malignant tumor of the liver

15. The hepatoblastoma is a:
    a. Benign tumor of the pediatric liver
    b. Malignant tumor of the adult liver

c. Malignant tumor of the pediatric liver
d. Malignant tumor of the pediatric adrenal gland

16. Which of the following is the space located between the pancreas and the stomach?
    a. Morrison pouch
    b. Lesser sac
    c. Space of Retzius
    d. Pouch of Douglas

17. Which of the following is another name for the Wilms tumor?
    a. Nephroblastoma
    b. Hepatoblastoma
    c. Neuroblastoma
    d. Hepatoma

18. An angiosarcoma would most likely be discovered in the:
    a. Rectum
    b. Gallbladder
    c. Spleen
    d. Pancreas

19. Which of the following is not an endocrine organ or structure?
    a. Thymus
    b. Pancreas
    c. Thyroid
    d. Spleen

20. Which of the following is an artifact that alters the echogenicity of a tendon?
    a. Acoustic enhancement
    b. Anisotropy
    c. Ring-down artifact
    d. Mirror image artifact

21. The gastrinoma would most likely be discovered in the:
    a. Pancreas
    b. Adrenal gland
    c. Stomach
    d. Spleen

22. Of the list below, which is considered to be an intraperitoneal organ?
    a. Left kidney

b. Aorta
c. IVC
d. Liver

23. Which of the following is considered to be a malignant testicular neoplasm?
    a. Neuroblastoma
    b. Hepatoma
    c. Yolk sac tumor
    d. Hamartoma

24. Which of the following is caused by the bending of the ultrasound beam when it passes through an interface between two tissues with vastly dissimilar speeds of sound and the angle of the approach is not perpendicular?
    a. Comet tail
    b. Refraction
    c. Reverberation
    d. Acoustic enhancement

25. These potential spaces extend alongside the ascending and descending colon on both sides of the abdomen.
    a. Paracolic gutters
    b. Periumbilical gutters
    c. Greater gutters
    d. Pericentric gutters

26. This common tumor of the kidney consists of blood vessels, muscle, and fat.
    a. Hemangioma
    b. Angiomyolipoma
    c. Oncocytoma
    d. Lipoma

27. Which of the following is not a salivary gland?
    a. Thyroid gland
    b. Parotid gland
    c. Submandibular gland
    d. Sublingual gland

28. Which of the following is not a pediatric malignant tumor?
    a. Hepatoblastoma
    b. Neuroblastoma

c. Pheochromocytoma
d. Nephroblastoma

29. A tumor that consists of tissue from all three germ cell layers is the:
    a. Pheochromocytoma
    b. Hamartoma
    c. Adrenal rest tumor
    d. Teratoma

30. Which of the following laboratory values would be most helpful in evaluating a patient who has suffered from recent trauma?
    a. WBC count
    b. alpha-Fetoprotein
    c. Blood urea nitrogen (BUN)
    d. Hematocrit

31. The insulinoma is a:
    a. Malignant pediatric adrenal tumor
    b. Benign pancreatic tumor
    c. Malignant pediatric tumor
    d. Benign liver tumor

32. A tumor that consists of a group of inflammatory cells best describes the:
    a. Hematoma
    b. Hepatoma
    c. Lymphoma
    d. Granuloma

33. A tumor that consists of a focal collection of blood best describes the:
    a. Hematoma
    b. Hamartoma
    c. Lipoma
    d. Angiomyolipoma

34. Which of the following is a tumor marker that may be used in cases of suspected testicular malignancy?
    a. BUN
    b. Creatinine
    c. Human chorionic gonadotropin (beta-hCG)
    d. Calcitonin

35. The malignant testicular tumor that consists of trophoblastic cells is the:
    a. Cholangiocarcinoma

b. Yolk sac tumor
c. Teratoma
d. Insulinoma

36. What is the artifact most likely encountered posterior to a gallstone?
a. Acoustic enhancement
b. Shadowing
c. Ring-down
d. Reverberation

37. A collection of abdominal fluid within the peritoneal cavity often associated with cancer is termed:
a. Transudate ascites
b. Chromaffin ascites
c. Peritoneal ascites
d. Exudate ascites

38. Which of the following is not a rule of surgical asepsis?
a. If you recognize that an item has become nonsterile, act immediately.
b. If one sterile person must pass another, they must pass face-to-face.
c. A sterile field must never be left unmonitored. If a sterile field is left unattended, it is considered nonsterile.
d. A sterile person does not lean across a sterile field.

39. Which of the following occurs behind strong, granular, and irregular surfaces like crystals, calculi, or calcifications such as a kidney stone?
a. Twinkle artifact
b. Refraction
c. Anisotropy
d. Side lobes

40. Which of the following has both an endocrine and an exocrine function?
a. Adrenal glands
b. Spleen
c. Pancreas
d. Duodenum

SUGGESTED READINGS

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2

The Liver

Introduction

The liver is a vital organ. Therefore, much attention should be paid to the significance of comprehending its function and the various pathologic changes that can distort its sonographic appearance. This chapter provides an overview of the normal sonographic anatomy, as well as many pathologic processes of the liver. Because there are numerous conditions that can involve the liver, pathology has been categorized as either focal or diffuse disease. Clinical findings and sonographic features of these pathologies are also provided.

Key Terms

amebic hepatic abscess—an abscess that develops from a parasite that grows in the colon and invades the liver via the portal vein

anastomosis—the surgical connection between two structures

arteriovenous fistula—an abnormal passageway between an artery and a vein

autoimmune disorders—disorders in which the body's immune system attacks and destroys health tissues and/or organs

autosomal dominant polycystic kidney disease—an inherited disease that results in the development of renal, liver, and pancreatic cysts late in life; also referred to as adult polycystic kidney disease

bare area—the region of the liver not covered by peritoneum

Beckwith–Wiedemann syndrome—a growth disorder syndrome

synonymous with enlargement of several organs, including the skull, tongue, and liver

Budd–Chiari syndrome—a syndrome described as the occlusion of the hepatic veins, with possible coexisting occlusion of the inferior vena cava

caput medusa—recognizable dilation of the superficial veins of the abdomen

cavernous hemangioma—the most common benign liver tumor

cholangitis—inflammation of the bile ducts

cirrhosis—condition defined as hepatocyte death, fibrosis and necrosis of the liver, and the subsequent development of regenerating nodules

cystic fibrosis—genetic disorder linked with the development of scar tissue accumulation within the lungs, liver, pancreas, kidneys, and/or intestines

diaphragmatic slip—a pseudomass of the liver seen on sonography resulting from hypertrophied diaphragmatic muscle bundles

dysentery—infection of the bowel which leads to diarrhea that may contain mucus and/or blood

echinococcal cyst—see key term hydatid liver cyst

***Echinococcus granulosus*—**a parasite responsible for the development of hydatid liver cysts

Epstein–Barr virus—the virus responsible for mononucleosis and other potential complications

fatty liver—a reversible disease characterized by deposits of fat within the hepatocytes; also referred to as hepatic steatosis

fibrosis—the formation of excessive fibrous tissue; the development of scar tissue within an organ

focal fatty infiltration—manifestation of fatty liver disease in which fat deposits are localized

focal fatty sparing—manifestation of fatty liver disease in which an area of the liver is spared from fatty infiltration

focal nodular hyperplasia—a benign liver mass composed of a combination of hepatocytes and fibrous tissue that typically contains a central scar

gastroesophageal junction—the junction between the stomach and the esophagus

Glisson capsule—the thin fibrous casing of the liver

hematemesis—vomiting blood

hematoma—a localized collection of blood

hemochromatosis—an inherited disease characterized by disproportionate absorption of dietary iron

hemopoiesis—the formation and development of blood cells

hepatic candidiasis—a hepatic mass that results from the spread of fungus in the blood to the liver

hepatic encephalopathy—a condition in which a patient becomes confused or suffers from intermittent loss of consciousness secondary to the overexposure of the brain to toxic chemicals that the liver would normally remove from the body

hepatic steatosis—see fatty liver

hepatitis—inflammation of the liver

hepatocellular adenoma—a benign liver mass often associated with the use of oral contraceptives

hepatocellular carcinoma—the primary form of liver cancer

hepatofugal—blood flow away from the liver

hepatoma—the malignant tumor associated with hepatocellular carcinoma

hepatomegaly—enlargement of the liver

hepatopetal—blood flow toward the liver

hepatosplenomegaly—enlargement of the spleen and liver

hydatid liver cyst—a liver cyst that develops from a tapeworm that lives in dog feces; also referred to as an echinococcal cyst because it originates from the parasite *Echinococcus granulosus*

hyperlipidemia—abnormally high levels of fats within the blood (i.e., high cholesterol and high triglycerides)

hypovolemia—decreased blood volume

idiopathic—no recognizable cause; from an unknown origin

immunocompromised—a patient who has a weakened immune system

jaundice—the yellowish discoloration of the skin, mucous membranes, and sclerae; found with liver disease and/or biliary obstruction

kernicterus—brain damage from bilirubin exposure in a newborn with jaundice

Kupffer cells—specialized macrophages within the liver that engulf pathogens and damaged cells

leukocytosis—an elevated white blood cell count

lipoma—a benign fatty tumor

liver hilum—the area of the liver where the common bile duct exits the liver and portal vein and hepatic artery enter the liver; also referred to as the porta hepatis

low-resistance flow—a flow pattern that characteristically has antegrade flow throughout the cardiac cycle

malaise—feeling of uneasiness

malignant degeneration—the deterioration of a benign mass into a malignancy

mass effect—the displacement or alteration of normal anatomy that is located adjacent to a tumor

monophasic—vascular flow yielding a single phase

necrosis—death of tissue

periportal cuffing—an increase in the echogenicity of the portal triads as seen in hepatitis and other conditions

porta hepatis—the area of the liver where the portal vein and hepatic artery enter and the hepatic duct exit; also referred to as the liver hilum

portal hypertension—the elevation of blood pressure within the portal venous system

portal triads—an assembly of a small branch of the portal vein, bile duct, and hepatic artery that surround each liver lobule

portal vein thrombosis—the development of clot within the portal vein

pseudocirrhosis—nodular appearance of the liver caused by multiple metastatic tumors

pseudomass—false mass

pyogenic liver abscess—a liver abscess that can result from the spread of infection from inflammatory conditions such as appendicitis, diverticulitis, cholecystitis, cholangitis, and endocarditis

quadrate lobe—the medial segment of the left lobe

recanalization—the reopening of canals or pathways

Riedel lobe—a tonguelike extension of the right hepatic lobe

sequela—an illness resulting from another disease, trauma, or injury

serpiginous—twisted or snakelike pattern

situs inversus—condition in which the organs of the abdomen and chest are on the opposite sides of the body (e.g., the liver is within the left upper quadrant instead of the right upper quadrant)

splenomegaly—enlargement of the spleen

starry sky sign—the sonographic sign associated with the appearance of periportal cuffing in which there is an increased echogenicity of the walls of the portal triads

steatohepatitis—a type of fatty liver disease that causes inflammation of the liver

total parental hyperalimentation—procedure in which an individual receives vitamin and nutrients through a vein, often the subclavian vein

transjugular intrahepatic portosystemic shunt (TIPS)—the therapy for portal hypertension that involves the placement of a stent between the portal veins and hepatic veins to reduce portal systemic pressure

triphasic—vascular flow yielding three phases

von Gierke disease—condition in which the body does not have the ability to break down glycogen; also referred to as glycogen storage disease type 1

von Hippel–Lindau disease—a inherited disease that includes the development of cysts within the liver, pancreas, and other organs

Wilson disease—a congenital disorder that causes the body to accumulate excess copper

ANATOMY AND PHYSIOLOGY OF THE LIVER

The liver is an essential organ (Table 2-1). In early embryonic life, the liver is responsible for hemopoiesis. The function of the liver can be analyzed with certain laboratory tests (Table 2-2). It is the largest parenchymal organ in the body, with the majority of its bulk—the right lobe—located in the right upper quadrant, whereas the left lobe is positioned within the epigastrium and may traverse the midline and extend into the left hypochondrium (Fig. 2-1). In some persons, the liver may actually come in contact with the spleen.

The liver is considered an intraperitoneal organ, with only a small portion left uncovered, including the bare area, the area of the falciform ligament, the gallbladder fossa, the porta hepatis, and an area adjacent to the inferior vena cava (IVC). The liver is also covered by Glisson capsule, a thin fibrous casing. It is composed of three main hepatic lobes—right, left, and caudate. Each hepatic lobe can be further divided into thousands of liver lobules. Lobules contain hepatocytes, biliary epithelial cells, and Kupffer cells. Each lobule is also surrounded by portal triads, which are composed of small branches of the portal vein, bile duct, and hepatic artery.

TABLE 2-1 Vital functions of the liver

1. Carbohydrate metabolism
2. Fat (lipid) metabolism
3. Amino acid metabolism
4. Removal of waste products
5. Vitamin and mineral storage
6. Drug inactivation
7. Synthesis and secretion of bile
8. Blood reservoir

9. Lymph production
10. Detoxification

LOBES OF THE LIVER

The Couinaud system is used to separate the liver into eight surgical segments. However, fundamentally, the liver can be divided into three primary hepatic lobes: right, left, and caudate (Table 2-3). An additional anatomic lobe, the quadrate lobe, is located between the gallbladder fossa and the round ligament. However, sonographically this lobe is referred to as the medial segment of the left lobe, and thus it is usually not considered one of the main hepatic lobes.



SOUND OFF
The liver is composed of a right lobe, left lobe, and caudate lobe.

The right hepatic lobe is the largest lobe. It takes up most of the right upper quadrant. The right lobe can be divided into an anterior and posterior segment by the right hepatic vein, which lies within the right intersegmental fissure. The right lobe can be separated from the left lobe by the middle hepatic vein, which lies within the main lobar fissure. The right and left lobes are also separated by the gallbladder fossa.

The left lobe is much smaller than the right lobe. It is located within the epigastrium and may extend to the left hypochondrium. The left lobe may be divided into a medial and lateral segment by the left hepatic vein, which lies within the left intersegmental fissure. These segments can also be separated by the ligamentum teres and falciform ligament.

The caudate lobe, which has its own separate blood supply and venous drainage, is the smallest hepatic lobe. It is also located within the epigastrium, and is bounded anteriorly by the ligamentum venosum and posteriorly by the IVC. Thus, the caudate lobe can be separated from the left lobe by the ligamentum venosum.



SOUND OFF
The medial segment of the left lobe may also be referred to as the quadrate lobe.

PORTAL VEINS

The main portal vein enters the liver at the porta hepatis, also referred to as the liver hilum. The main portal vein is created by the union of the superior mesenteric vein and splenic vein (Fig. 2-2). The merger of these two vessels and the inferior mesenteric vein, which typically takes place posterior to the neck of the pancreas and anterior to the IVC, is an area referred to as the portal confluence or portal splenic confluence. The portal vein provides the liver with approximately 75% of its total blood supply. The blood within the portal vein is partially oxygenated because it is derived from the intestines. The remainder of hepatic perfusion is via the hepatic artery.

TABLE 2-2 Specific liver function test, results, and associated abnormalities

Liver Function Test	Result	Associated Abnormality
Albumin	Decrease	Chronic liver disease[a] **Cirrhosis**
ALP	Increase	Cirrhosis Extrahepatic biliary obstruction Gallstones **Hepatitis** Metastatic liver disease Pancreatic carcinoma
ALT	Increase	Biliary tract obstruction Hepatitis Hepatocellular disease Obstructive **jaundice**
AST	Increase	Cirrhosis **Fatty liver** Hepatitis Metastatic liver disease
gamma-Glutamyl transferase	Increase	Diffuse liver disease Posthepatic obstruction
LDH	Increase	Cirrhosis Hepatitis Obstructive jaundice
Serum bilirubin	Increase	Unconjugated (direct) bilirubin: acute hepatocellular disease Conjugated (indirect) bilirubin: biliary tract obstruction Total bilirubin: cirrhosis, hepatitis, and other liver cell diseases

PT		Prolonged PT: metastasis of the liver and hepatitis Shortened PT: extrahepatic duct obstruction
AFP	Increase	**Hepatocellular carcinoma** (**hepatoma**) Hepatoblastoma

[a]This is an abbreviated list of complications for review purposes, as other complications may exist.
AFP, α-Fetoprotein; ALP, alkaline phosphatase; ALT, alanine aminotransferase; AST, aspartate aminotransferase; LDH, lactate dehydrogenase; PT, prothrombin.

As the main portal vein enters the liver, it splits into the right and left portal veins. The right portal vein, like the right hepatic lobe, is separated into an anterior and posterior division. The left portal vein, like the left hepatic lobe, is separated into a medial and lateral division. These vessels supply blood to their related segments. The diameter of the main portal vein can vary with respiration, although typically it measures less than 13 mm in the anteroposterior dimension. Enlargement of the portal vein is often indicative of portal hypertension. Normal portal veins decrease in size as they approach the diaphragm. They are also considered intrasegmental because they course within the segments of the liver. On a sonogram, their walls appear much brighter than those of the hepatic veins (Fig. 2-3). This may be because of an increase in the amount of collagen within their walls. Normal flow within the portal veins should be hepatopetal and monophasic, with some variation noted with respiratory changes (Fig. 2-4). In addition, scanning after a meal will often demonstrate an increase in portal vein flow.

SOUND OFF
The portal veins branch into corresponding branches that match the segments of the liver (right portal = anterior and posterior branches; left portal = medial and lateral branches). The portal veins also typically have brighter walls compared to the hepatic veins.

HEPATIC VEINS

Most persons have three hepatic veins: right, middle, and left. These veins drain into the IVC. They are considered both intersegmental and interlobar because they are located between the segments and the lobes (Fig. 2-5). As mentioned earlier, they are readily used to distinguish the hepatic segments. Unlike the portal veins, the hepatic veins increase in size as they approach

the diaphragm. Hepatic veins have a triphasic blood flow pattern secondary to their association with the right atrium and atrial contraction (Fig. 2-6). Enlargement of the hepatic veins and IVC is seen with right-sided heart failure, and occlusion or narrowing of the hepatic veins is seen with Budd–Chiari syndrome.

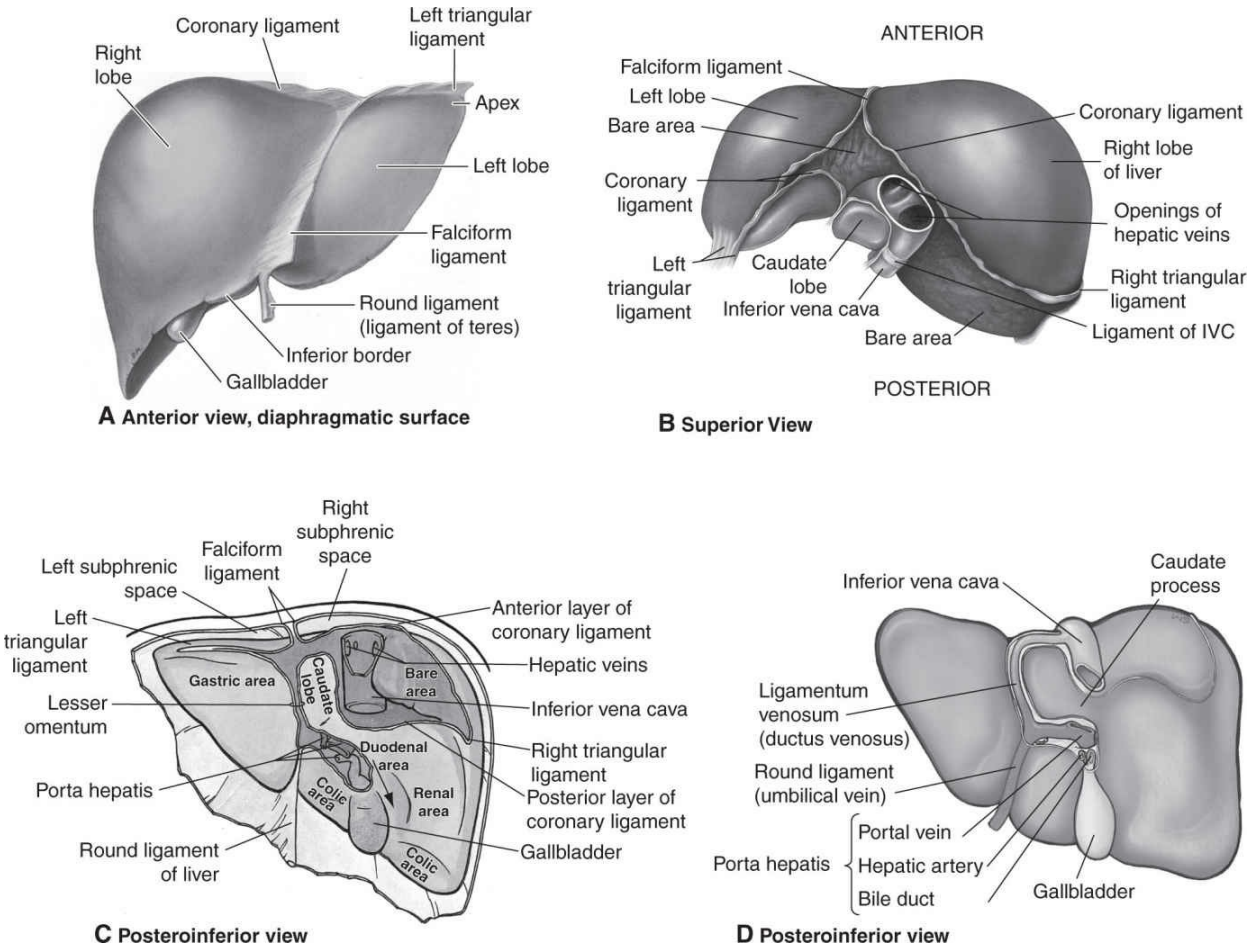


Figure 2-1 The surfaces of the liver.

TABLE 2-3 Useful landmarks for separating the hepatic segments and lobes	
Right hepatic vein Right intersegmental fissure	Separates the anterior segment of the right lobe from the posterior segment of the right lobe
Middle hepatic vein Main lobar fissure Gallbladder fossa	Separates the right lobe from the left lobe (these are located between the anterior segment of the right lobe and the medial segment of the left lobe)
Left hepatic vein Left intersegmental fissure Ligamentum teres Falciform ligament	Separates the left lateral segment of the left lobe from the left medial segment of the left lobe

THE PORTA HEPATIS

The porta hepatis may also be referred to as the liver hilum. The three

structures located within the porta hepatis are the main portal vein, common bile duct, and hepatic artery. The common hepatic artery carries oxygenated blood to the liver from the abdominal aorta. It is a branch of the celiac trunk, the first main branch of the abdominal aorta as it passes below the diaphragm. The normal low-resistance flow pattern of the hepatic artery can be noted with Doppler imaging (Fig. 2-7). Typically, the hepatic artery takes a course anterior to the main portal vein in the porta hepatis. When a longitudinal-oriented image is obtained of this area, the artery can be noted anterior to the main portal vein and posterior to the common bile duct (Fig. 2-8). The “Mickey” sign describes the transverse image taken of the porta hepatis (Fig. 2-9). In some persons, the relationship of the artery and common bile duct is reversed.

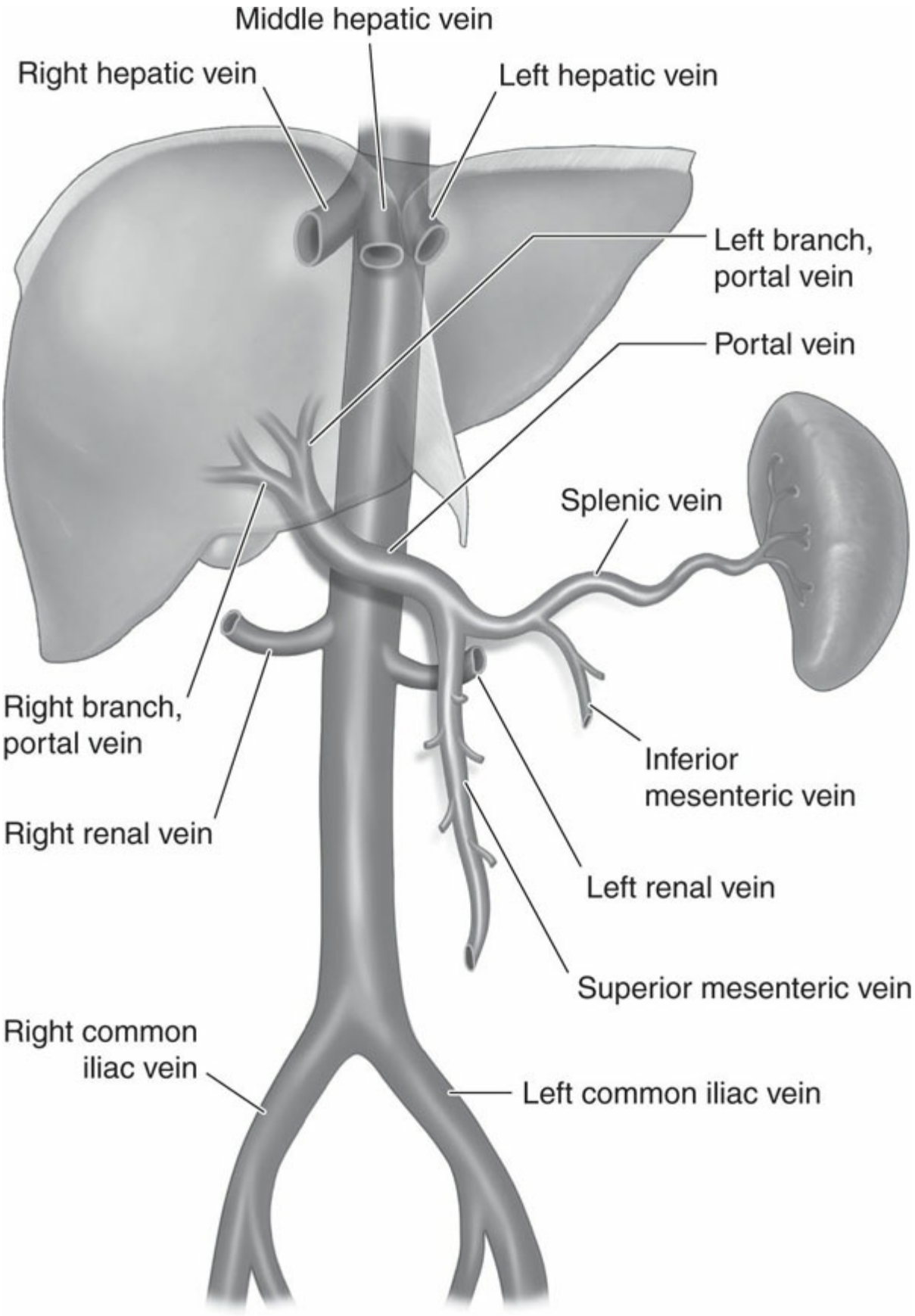


Figure 2-2 The construction of the portal venous system.

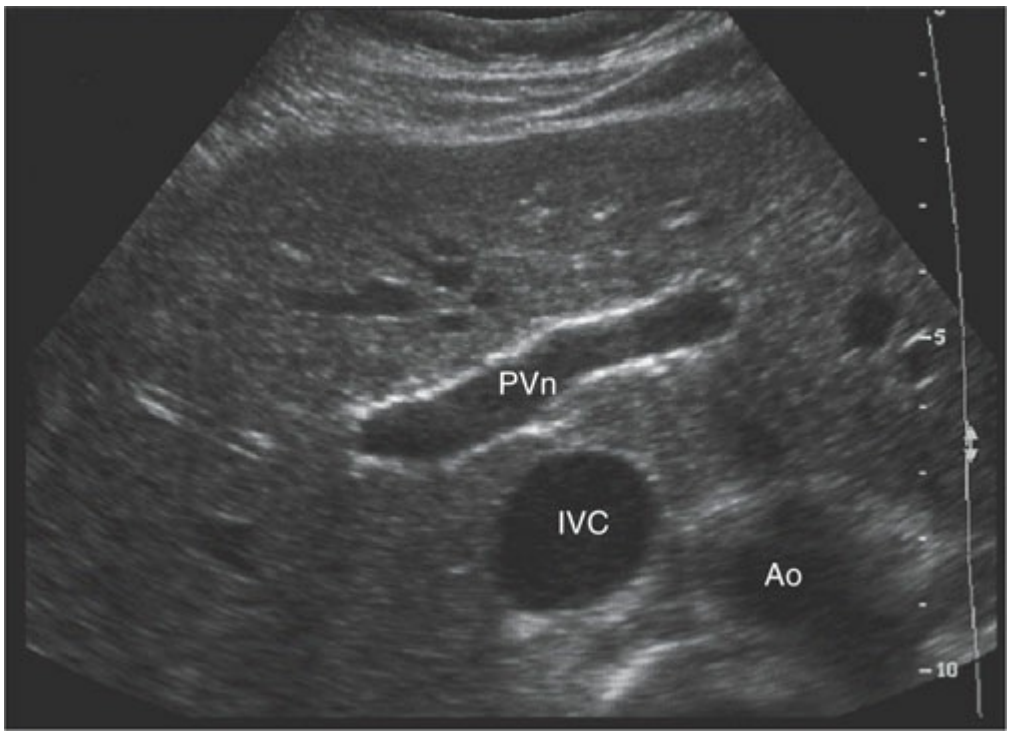


Figure 2-3 Portal veins. The portal veins (Pvn) are easily identified by their echogenic wall.

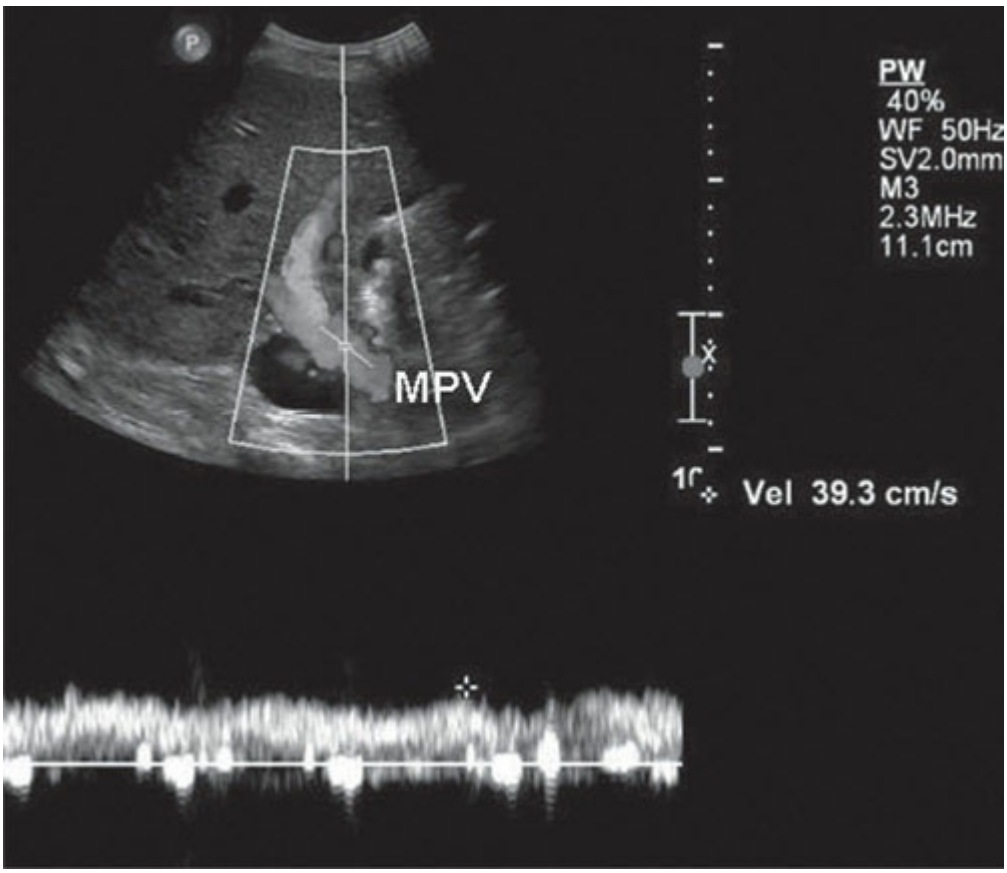


Figure 2-4 Normal hepatopetal flow within the main portal vein (MPV) with some respiratory variation. (Color image provided online.)

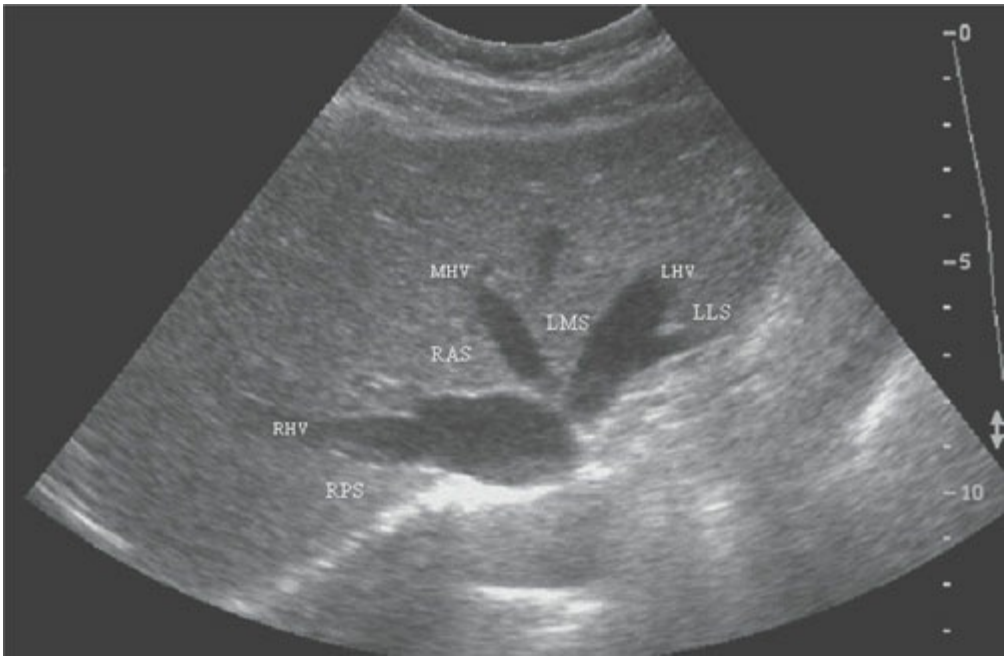


Figure 2-5 Hepatic veins. The left hepatic vein (*LHV*), middle hepatic vein (*MHV*), and right hepatic vein (*RHV*) are noted in this image. The LHV can be used to separate the left lateral segment (*LLS*) from the left medial segment (*LMS*). The RHV can be used to separate the right anterior segment (*RAS*) from the right posterior segment (*RPS*). The MHV can be used to separate the left lobe from the right lobe.

LIGAMENTS AND FISSURES OF THE LIVER

Two readily identifiable ligaments may be noted within the normal liver during a sonogram: the ligamentum venosum and the falciform ligament. In utero, the umbilical vein supplies the fetus with oxygenated blood. The umbilical vein travels to the liver and bifurcates into a left and a right branch. The right branch, also referred to as the ductus venosus, shunts blood directly into the fetal IVC. Shortly after birth, the ductus venosus collapses and becomes the ligamentum venosum. The left umbilical vein connects directly to the left portal vein. After birth, it becomes a fibrous cord referred to as the ligamentum teres or round ligament. The ligamentum teres ascends along the falciform ligament. Recanalization of the paraumbilical vein in the ligamentum teres can occur in the presence of portal hypertension.

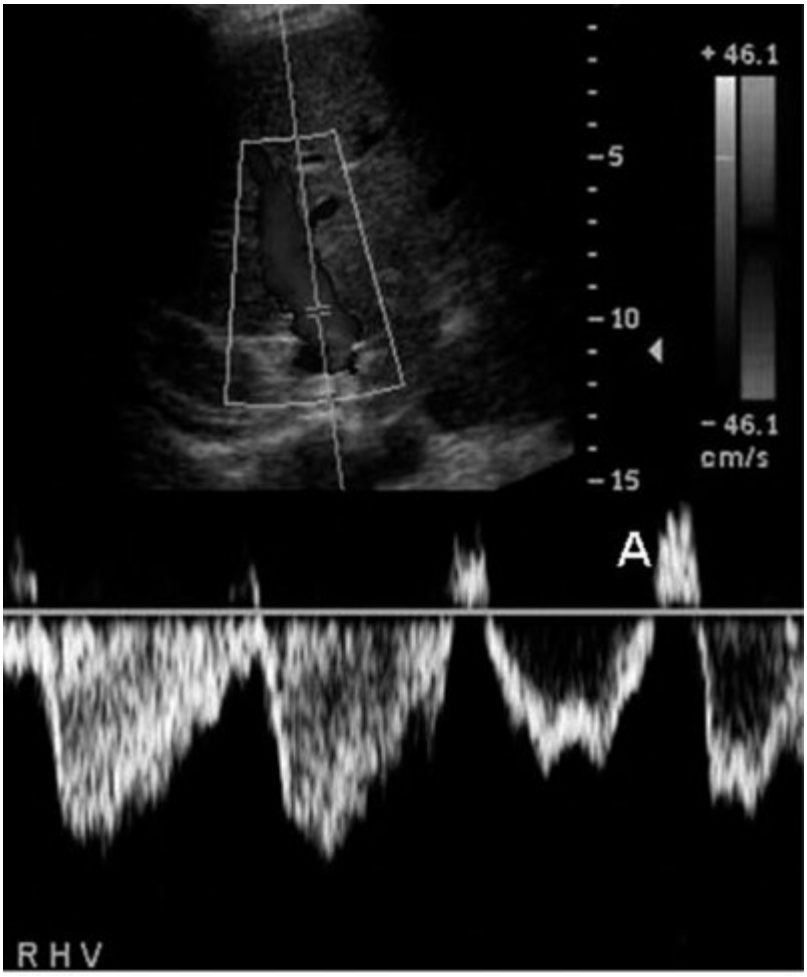


Figure 2-6 Doppler signal of the normal right hepatic vein. (Color image provided online.)

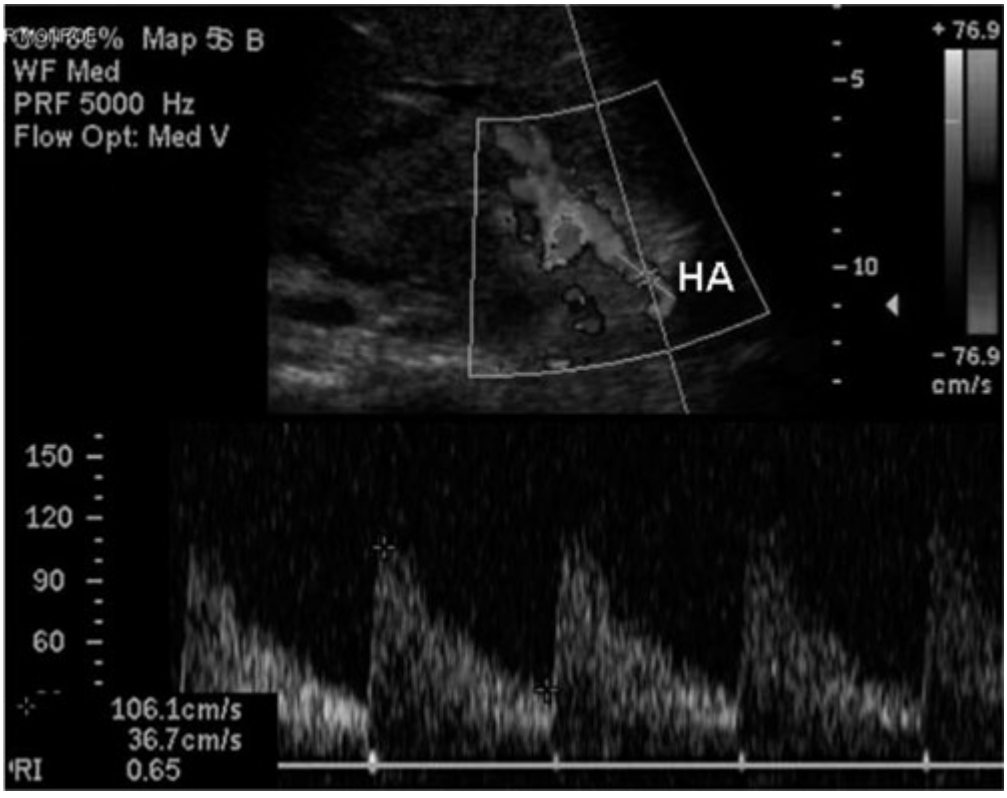


Figure 2-7 Doppler signal of the hepatic artery (HA). (Color image provided online.)

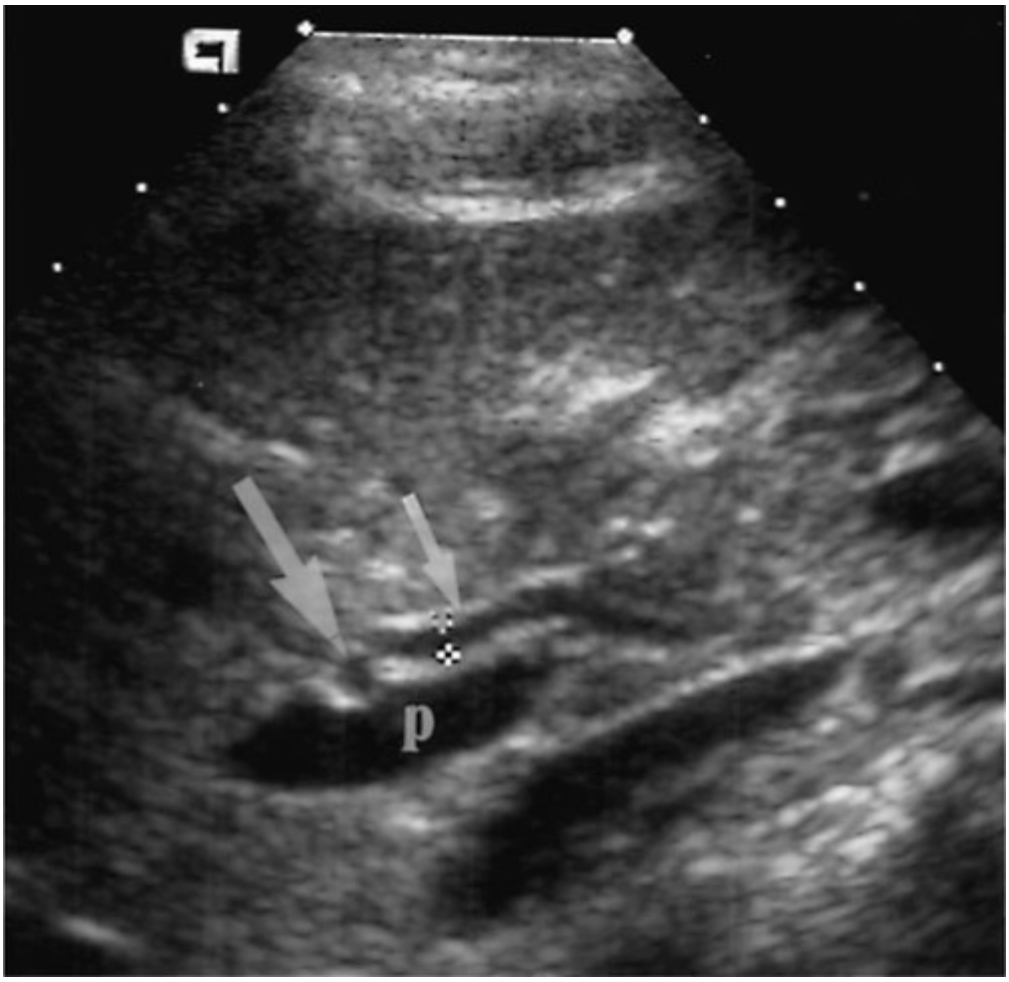


Figure 2-8 The portal vein (*p*), common bile duct (*short arrow*), and hepatic artery (*large arrow*) comprise the porta hepatis.

Sonographically, ligaments appear hyperechoic because of the fat located within and around them. The ligamentum venosum, which appears as a hyperechoic linear structure, can be noted anterior to the caudate lobe, between the caudate lobe and left hepatic lobe (Fig. 2-10). The falciform ligament can be appreciated near the left portal vein in most persons. In the transverse scan plane, it often appears as a hyperechoic, triangular-shaped structure between the left and right hepatic lobes (Fig. 2-11). It is important to note that some texts may refer to the area of the falciform ligament as the ligamentum teres. And thus it is vital to understand that the ligementum teres is potentially identifiable with sonography within the lower margins of the falciform ligament. The main lobar fissure, which houses the middle hepatic vein, may also be identifiable in many persons. It is seen in the sagittal oblique plane as a hyperechoic line, which seems to connect the neck of the gallbladder to the right portal vein (Fig. 2-12). The main lobar fissure may be used to separate the right and left hepatic lobes. Finally, although not a true

fissure, occasionally, a diaphragmatic slip or diaphragmatic muscular bundles may present as a pseudomass on sonography. Diaphragmatic slip, which typically occurs in older patients, is caused by hypertrophied diaphragmatic muscle bundles. It appears as hyperechoic strands extending from the diaphragm in the sagittal plane, and may be confused for a hyperechoic mass in the transverse plane.

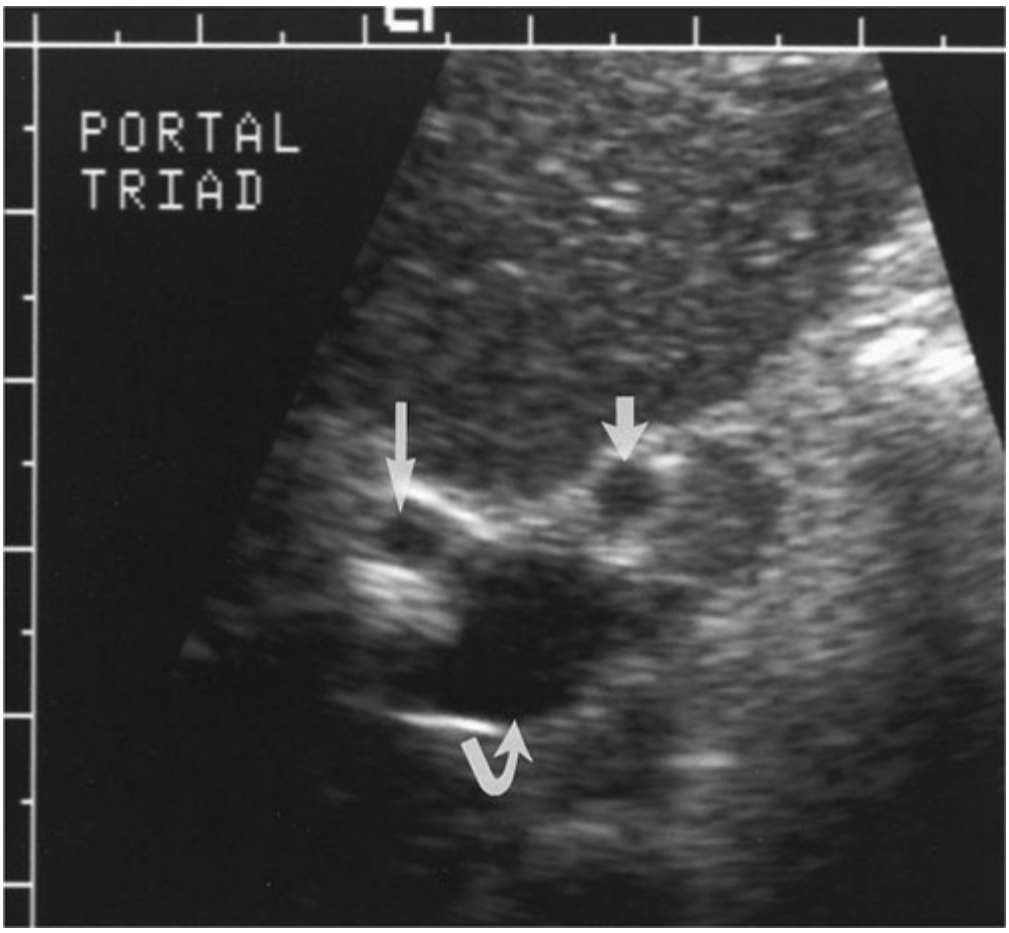


Figure 2-9 Mickey mouse sign. Transverse image of the porta hepatis. The face of Mickey is the portal vein (*curved arrow*), the hepatic artery is the left ear (*short arrow*), and the common bile duct is the right ear (*long arrow*).

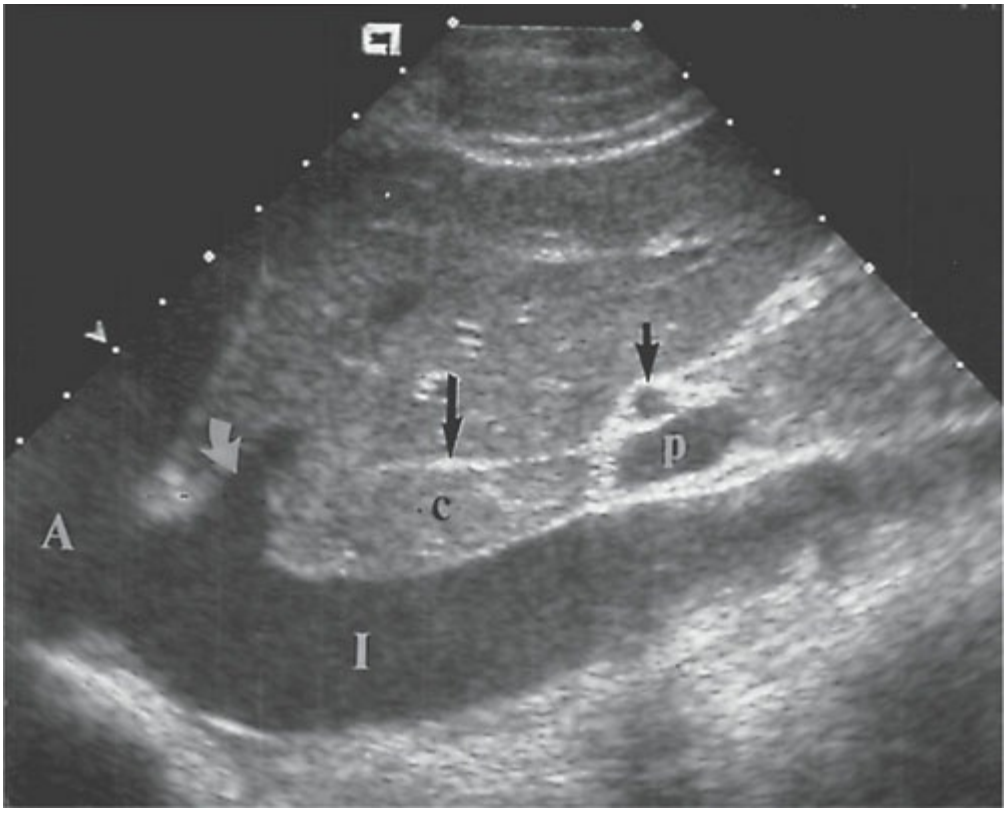


Figure 2-10 Caudate lobe. The caudate lobe (*c*) is located between the ligamentum venosum (*long arrow*) and the inferior vena cava (*I*). The inferior vena cava terminates at the heart's right atrium (*A*). The *curved arrow* indicates the right hepatic vein. Also seen are the portal vein (*p*) and hepatic artery (*short arrow*).

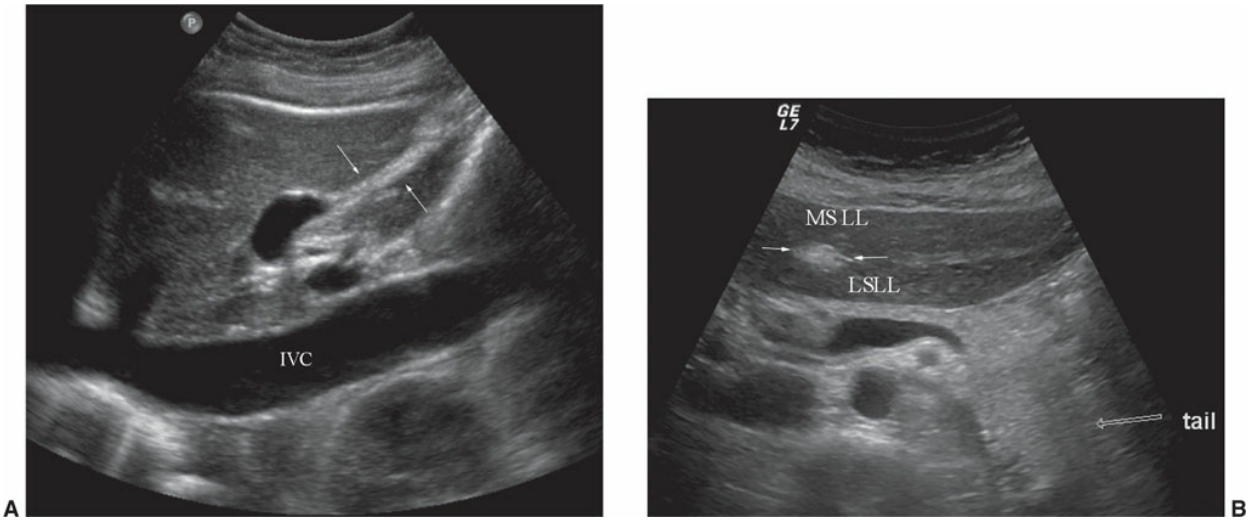


Figure 2-11 The falciform ligament is seen in sagittal (*A*) *between the arrows* and transverse (*B*) *between the arrows*. MSLL, medial segment left lobe and LSLL, lateral segment left lobe.

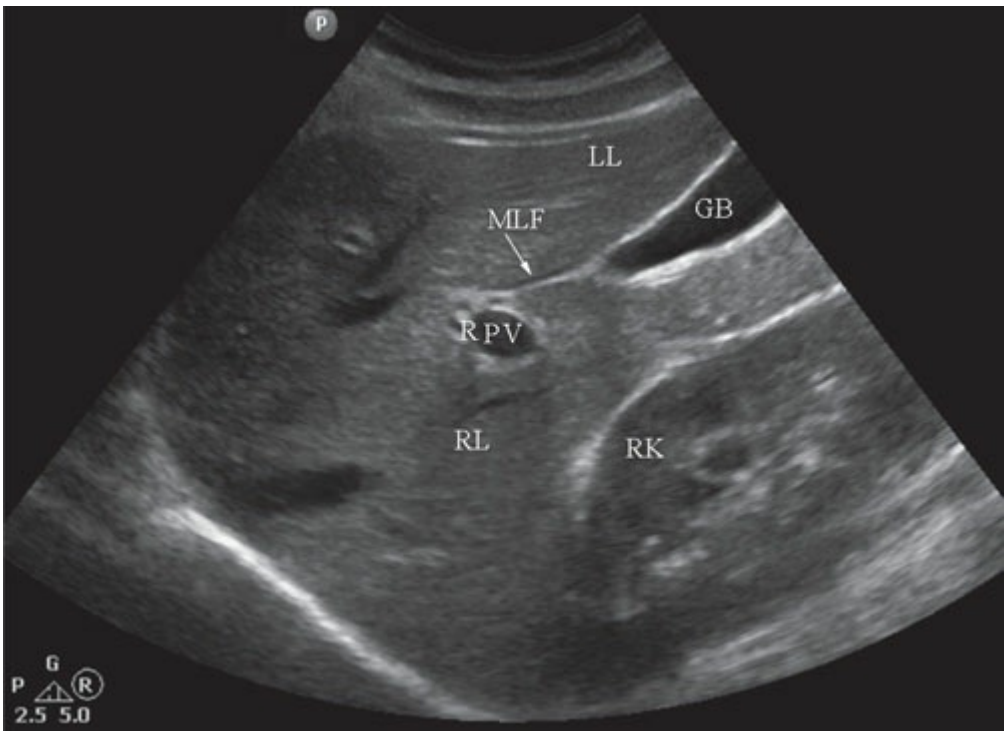


Figure 2-12 Sagittal oblique image of the liver demonstrating the right lobe (*RL*), left lobe (*LL*), and right kidney (*RK*). The main lobar fissure (*MLF*), the right portal vein (*RPV*), and gallbladder (GB) can be visualized well.

ANATOMIC VARIANTS OF THE LIVER

A Riedel lobe can be described as a tonguelike extension of the right hepatic lobe. This anatomic variant is more often seen in women. Riedel lobe may extend inferiorly as far as the iliac crest. To differentiate Riedel lobe from hepatomegaly, one could examine the left lobe for coexisting enlargement. An additional variant of the liver is the papillary process of the caudate lobe. This inferior extension of the caudate lobe can resemble a mass. If a papillary process is suspected, care to evaluate the caudate lobe in both transverse and sagittal scan planes is warranted. Other anomalies of the liver include situs inversus, agenesis of a lobe, and there are many vascular variations.

SONOGRAPHY OF THE LIVER

A sonogram of the liver can be ordered for several reasons. The patient should fast for a period of 8 hours if the entire right upper quadrant is to be evaluated. While some facilities may only require 4 hours of fasting, some may not require any special patient preparation if only the liver is being examined with sonography, as in the situation where a brief follow-up for findings identified with other imaging modalities such as computed tomography (CT) or magnetic resonance imaging (MRI).

The normal liver is homogeneous. Its echogenicity is either equal to or slightly greater than the parenchyma of the normal right kidney, and slightly less echogenic than the normal spleen. In addition, when compared with the pancreas, the liver is slightly less echogenic in an adult. The liver measures approximately 13 to 15 cm in length in an adult. Although many authors differ, hepatomegaly is often suspected if the liver measures greater than 15.5 cm in the midhepatic line. One recent study suggested that the most accurate measurement of the right lobe can be obtained from the uppermost right hemidiaphragm to the inferior tip of the right lobe using a horizontal plane parallel to the anterior liver wall through the midaxillary line. Conversely, there are indirect sonographic signs that have been suggested (Table 2-4). And as mentioned earlier, in some individuals, particularly females, Riedel lobe can mistakenly suggest hepatomegaly, so careful correlation with clinical history is strongly warranted when hepatomegaly is suspected sonographically.



SOUND OFF

Careful correlation with clinical history—especially an analysis of current laboratory findings—is strongly warranted when hepatomegaly is suspected sonographically.

TABLE 2-4 Indirect signs of hepatomegaly

- Extension of right lobe beyond the lower pole of the right kidney (without evidence of Riedel lobe).
- Rounding of the inferior tip of the right lobe.
- Extension of left lobe well into the left upper quadrant.

LIVER PATHOLOGY

Diffuse Liver Disease

Fatty Liver Disease

Fatty liver disease, also referred to as hepatic steatosis, is a disorder characterized by fatty deposits (triglycerides) within the hepatocytes. It can be classified as nonalcoholic fatty liver disease and alcoholic fatty liver disease. Nonalcoholic fatty liver disease has been cited as the most common liver disorder in the Western World, and subsequently the most common cause of chronic liver disease. In general, nonalcoholic fatty liver disease is both acquired and reversible. The causes of nonalcoholic fatty liver include

starvation, obesity, chemotherapy, diabetes mellitus, hyperlipidemia, pregnancy, glycogen storage disease or von Gierke disease (glycogen storage disease type 1), total parental hyperalimentation, severe hepatitis, cystic fibrosis, intestinal bypass surgery for obesity, and the use of some drugs such as corticosteroids. Fatty liver disease is also the hepatic manifestation of a disorder known as metabolic syndrome and can lead to steatohepatitis. Steatohepatitis, whether caused by alcoholic or nonalcoholic conditions-termed nonalcoholic steatohepatitis, is inflammation of the liver that has been shown to be a precursor for chronic liver disease, leading to fibrosis, cirrhosis, and hepatocellular carcinoma (HCC) in some individuals.

Although fatty liver is typically asymptomatic, patients may present clinically with elevated liver function tests. Fatty liver can be described as mild, moderate, or severe based on the sonographic visualization of both the hepatic vasculature and diaphragm. Fatty changes within the liver can also be diffuse or focal. Diffuse infiltration will cause the liver to appear diffusely echogenic, and it will be more difficult to penetrate. Frequently, in the presence of diffuse fatty infiltration, the walls of the hepatic vasculature and diaphragm will not be easily imaged, secondary to the attenuation of the sound beam (Fig. 2-13).

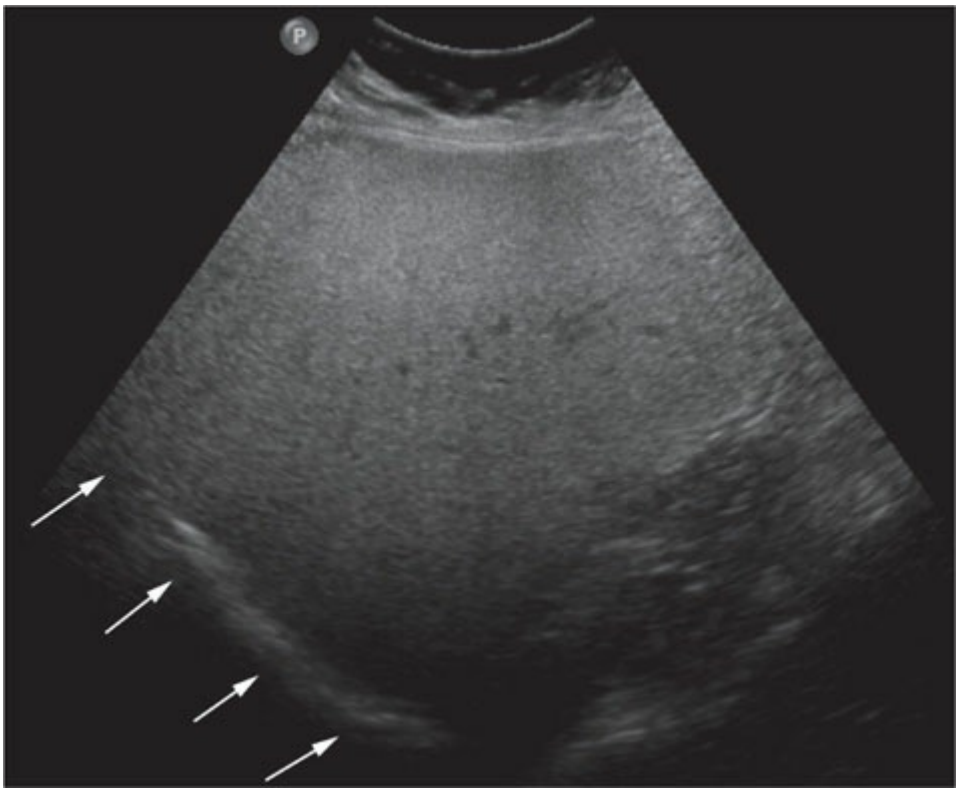


Figure 2-13 Sagittal image of a diffusely fatty liver that demonstrates the inability to clearly visualize the diaphragm (*arrows*).

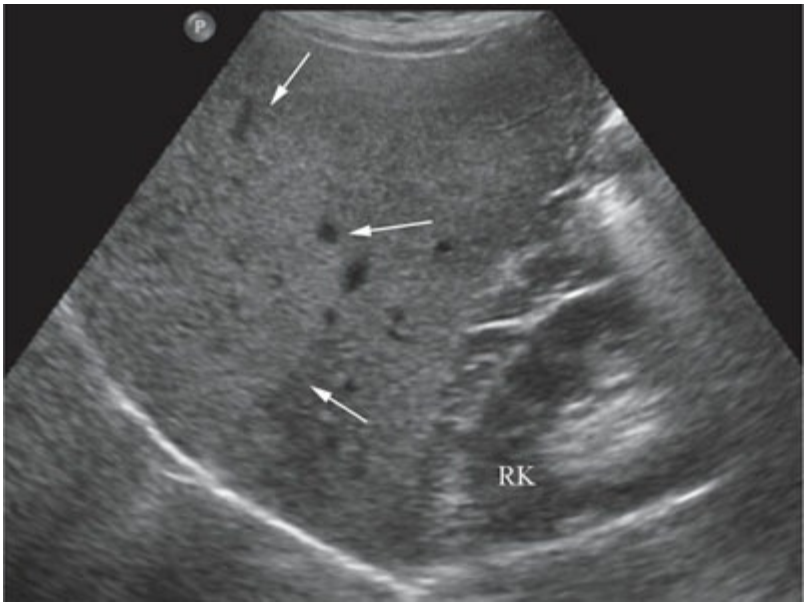


Figure 2-14 Sagittal image of the liver demonstrating an area of focal fatty infiltration (*arrows*).

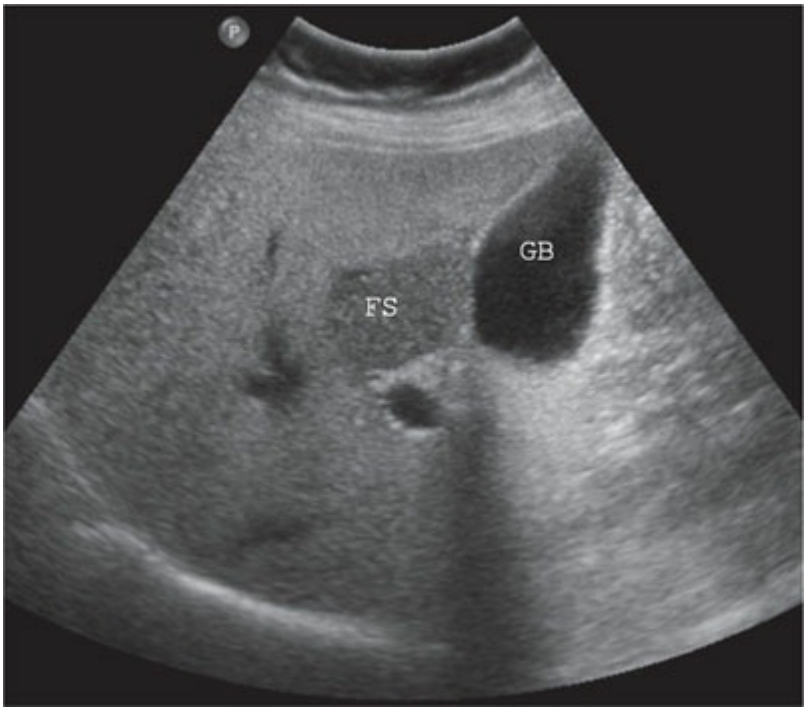


Figure 2-15 Focal fatty sparing (*FS*) is noted in this sagittal image of the liver adjacent to the gallbladder (*GB*).

Sonographically, the liver segment affected by focal fatty infiltration will appear as an area of increased echogenicity and can thus appear much like a solid, hyperechoic mass (Fig. 2-14). Alternatively, focal fatty sparing of the liver can occur. In this circumstance, the liver is involved with diffuse fatty infiltration, with certain areas spared. This area of sparing can appear much like a solid, hypoechoic mass or possibly even fluid (Fig. 2-15).

Both focal fatty infiltration and focal fatty sparing occur in essentially the

same places. It is much more likely that the signs of sparing and infiltration are seen adjacent to the gallbladder, near the porta hepatis, and the left medial segment. Although both of these abnormalities may mimic solid masses, they will not produce mass effect and therefore will not distort adjacent anatomy.

Clinical Findings of Fatty Liver Disease

1. Asymptomatic
2. Alcohol abuse
3. Chemotherapy
4. Diabetes mellitus
5. Elevated liver function test (specifically AST and ALT)
6. Hyperlipidemia
7. Obesity
8. Pregnancy

Sonographic Findings of Diffuse Fatty Liver Disease

1. Diffusely echogenic liver
2. Increased attenuation of the sound beam
3. Wall of the hepatic vasculature and diaphragm will not be easily imaged

Sonographic Findings of Focal Fatty Infiltration

1. Hyperechoic area adjacent to the gallbladder, near the porta hepatis, or part of a lobe may appear echogenic

Sonographic Findings of Focal Fatty Sparing

1. Hypoechoic area adjacent to the gallbladder, near the porta hepatis, or part of a lobe or an entire lobe may be spared
2. Can appear much like pericholecystic fluid when identified adjacent to the gallbladder

Hepatitis

Hepatitis is inflammation of the liver, which can ultimately lead to cirrhosis, portal hypertension, and HCC. Hepatitis can be acute or chronic. Acute hepatitis is said to resolve in within 4 months, whereas chronic hepatitis persists beyond 6 months. Hepatitis comes in many forms, including hepatitis A, B, C, D, E, and G. The two most common forms are hepatitis A and B.

Hepatitis A is spread by fecal–oral route in contaminated water or food. Hepatitis B is spread by contact with contaminated body fluids, mother-to-infant transmission, or inadvertent blood contact, as seen in the case of

intravenous drug abuse or occupational exposure. An additional concern for health care workers is work-related exposure to hepatitis C. This form of hepatitis is also spread by means of contact with blood and body fluids. Currently, hepatitis C is the leading indication for liver transplantation in the United States. Fortunately, new drug regimens exist that are having a high success rate for removing hepatitis C from the body.

Hepatitis may also be triggered by reactions to systemic viruses such as herpes simplex virus and Epstein–Barr virus. Chronic hepatitis can be caused by Wilson disease, hemochromatosis, autoimmune disorders, or be drug induced. Both Wilson disease and hemochromatosis are inherited conditions. Wilson disease causes the body to accumulate excess copper, whereas hemochromatosis is characterized by disproportionate absorption of dietary iron.



SOUND OFF

Wilson disease results from excessive copper accumulation, whereas hemochromatosis results from excessive iron. If a patient has either of these diseases, sonographers should evaluate the liver for signs of chronic hepatitis.

Hepatitis is often a clinical diagnosis. Patients with any form of hepatitis can experience a wide range of clinical troubles, including fever, chills, nausea, vomiting, fatigue, hepatosplenomegaly, dark urine, and jaundice. However, the jaundice related to hepatitis is on a cellular level and is not associated with biliary obstruction. This is referred to as nonobstructive jaundice. Elevation in the liver function tests—specifically prothrombin, alkaline phosphatase (ALP), aspartate aminotransferase (AST), alanine aminotransferase (ALT), lactate dehydrogenase (LDH), and serum bilirubin levels—is often apparent as well. Impaired liver function, as a result of hepatitis and other hepatic diseases, may lead to hepatic encephalopathy, a condition in which a patient becomes confused or suffers from intermittent loss of consciousness secondary to the overexposure of the brain to toxic chemicals that the liver would normally remove from the body. In newborns, brain damage can occur with severe jaundice as a result of bilirubin exposure, a condition referred to as kernicterus.

Sonographically, a patient with hepatitis may initially have a completely normal-appearing liver. With time, hepatomegaly and splenomegaly, termed hepatosplenomegaly, can be observed with sonography. As the liver enlarges, it tends to become more hypoechoic. Periportal cuffing may be seen in some patients with hepatitis, although this is not always a specific finding. Periportal cuffing is described as an increase in the echogenicity of

the walls of the portal triads. The sonographic manifestation of this phenomenon is referred to as the "starry sky" sign (Fig. 2-16). The gallbladder wall may also be thickened in the presence of hepatitis.

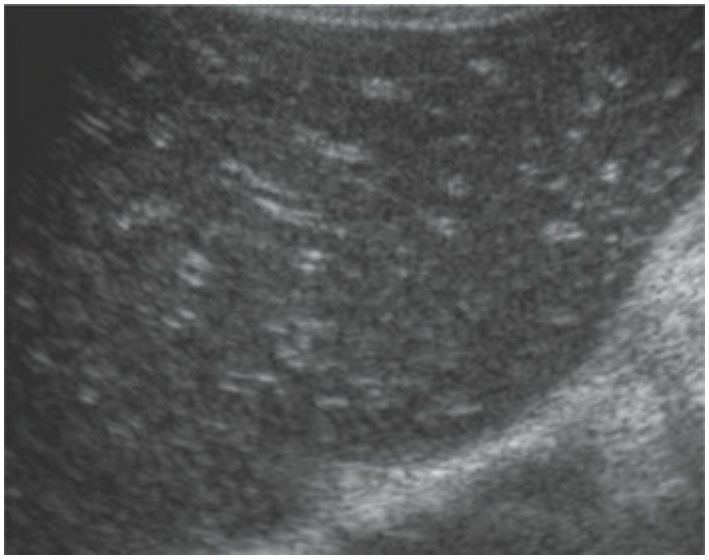


Figure 2-16 Transverse image of the liver demonstrates the "starry sky" appearance frequently associated with hepatitis.

CLINICAL FINDINGS OF HEPATITIS

1. Chills
2. Dark urine
3. Elevated liver function tests (specifically ALP, ALT, AST, LDH, total bilirubin, prothrombin [PT])
4. Fatigue
5. Fever
6. Hepatosplenomegaly
7. Jaundice
8. Nausea
9. Vomiting

SONOGRAPHIC FINDINGS OF HEPATITIS

1. Normal liver
2. Enlarged, hypoechoic liver
3. Periportal cuffing with "starry sky"
4. Gallbladder wall thickening

Cirrhosis

Cirrhosis is a devastating liver disorder that is defined as hepatocyte death, fibrosis and necrosis of the liver, and the subsequent development of regenerating nodules. Common sequela of cirrhosis includes portal

hypertension, the development of varicosities within the abdomen, portal vein thrombosis, splenomegaly, and HCC. The most common cause of cirrhosis is alcoholism. However, cirrhosis can also be caused by Wilson disease, primary biliary cirrhosis, hepatitis, cholangitis, and hemochromatosis.

Patients may have normal laboratory findings until cirrhosis advances into end-stage liver disease. However, when laboratory abnormalities are evident, they include elevation in AST, LDH, ALT, and bilirubin. Patients may also present with jaundice, fatigue, weight loss, diarrhea, initial hepatomegaly, and ascites.



SOUND OFF

Remember this possibly pathway of disease:

Alcoholism → hepatic steatosis (fatty liver) → steatohepatitis → cirrhosis → portal hypertension → portal vein thrombosis → hepatocellular carcinoma

Sonographic findings of cirrhosis include an echogenic, small right lobe, an enlarged caudate and left lobe, nodular surface irregularity, coarse echotexture ascites, and splenomegaly (Figs. 2-17 and 2-18). Cirrhosis caused by alcoholism will lead to the development of nodules that typically measure less than 1 cm (termed micronodular), whereas cirrhosis caused by hepatitis will lead to the development of larger nodules that measure between 1 and 5 cm (termed macronodular). Larger nodules may be readily seen when ascites surrounds the liver. If ascites is not present, a high-frequency linear transducer can be used to analyze the liver surface for evidence of surface nodularity or lumps. In recent years, transient elastography, which is used to evaluate the stiffness of the liver, has been used to stage liver fibrosis. It has been demonstrated that liver stiffness (i.e., the stiffer the liver tissue the more fibrosis present) correlates with cirrhosis complication, including variceal hemorrhage, ascites, and HCC, all of which are signs of advanced cirrhosis and portal hypertension.



Figure 2-17 Ascites (*A*) is noted surrounding this liver that is affected by cirrhosis. Note the irregular, nodular contour of the liver.

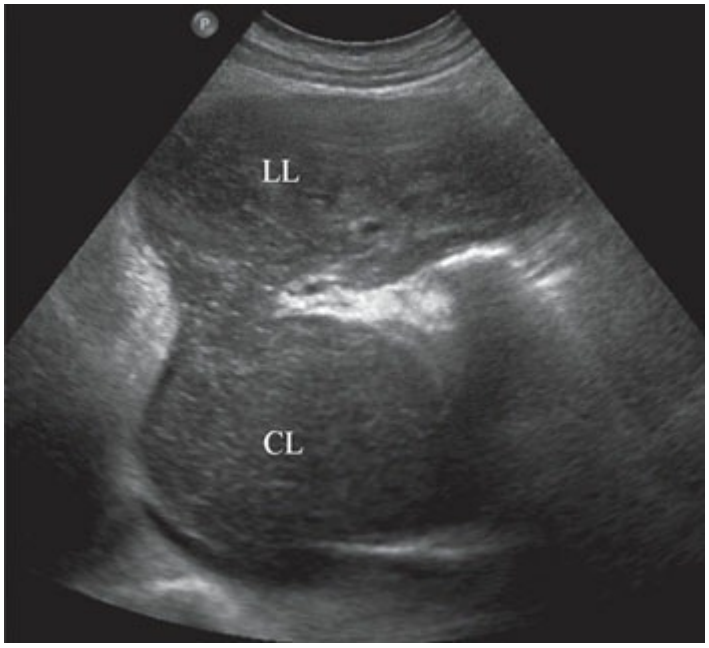


Figure 2-18 Enlargement of the caudate lobe (*CL*) compared to the left lobe (*LL*) is noted in this patient with cirrhosis.

Possible Doppler findings in patients with cirrhosis include monophasic flow within the hepatic veins and hepatofugal flow within the portal veins. These are both findings consistent with advanced cirrhosis and portal hypertension. With these findings, the sonographer is encouraged to further investigate the liver and abdomen for further signs of portal hypertension, portal vein thrombosis, and HCC.

CLINICAL FINDINGS OF CIRRHOSIS

1. Ascites

2. Diarrhea
3. Abnormal liver function tests (specifically elevated ALP, ALT, AST, bilirubin, PT, partial prothrombin time [PTT], total protein, and decreased albumin)
4. Fatigue
5. Hepatomegaly (initial)
6. Jaundice
7. Splenomegaly
8. Weight loss

SONOGRAPHIC FINDINGS OF CIRRHOSIS

1. Hepatosplenomegaly (initial)
2. Shrunken, echogenic right lobe of the liver
3. Enlarged caudate and left lobes
4. Nodular surface irregularity
5. Coarse echotexture
6. Splenomegaly
7. Ascites
8. Monophasic flow within the hepatic veins
9. Hepatofugal flow within the portal veins



SOUND OFF

When you suspect cirrhosis, always look for signs of portal hypertension, portal vein thrombosis, and hepatocellular carcinoma.

Portal Hypertension

Portal hypertension is the elevation of blood pressure within the portal venous system. The pressure within the portal vein can be altered by several abnormalities. The most common cause of portal hypertension is cirrhosis. However, portal hypertension can also result from portal vein thrombosis, hepatic vein thrombosis, IVC thrombosis, or compression of the portal veins by a tumor in an adjacent organ.

Recall that normal flow toward the liver within the portal vein is termed hepatopetal. With cirrhosis, the liver becomes fibrotic or scarred and more difficult to perfuse. Consequently, the blood traveling into the liver via the main portal vein meets greater vascular resistance. Therefore, the pressure within the portal veins increases, resulting in portal hypertension. The hepatic artery, which also brings blood into the liver, has to increase its supply as well, and will consequently enlarge. The flow within the portal vein can eventually become reversed—termed hepatofugal. Portosystemic collaterals and varicosities can consequently develop within the abdomen as a result of the body's attempt to repair itself by channeling blood away from

the damaged liver (Table 2-5).

SOUND OFF
Because the liver becomes so scarred with cirrhosis, the blood flowing to the liver meets greater vascular resistance, resulting in portal hypertension or high blood pressure within the portal veins.

TABLE 2-5 Examples of portosystemic collaterals that may result from portal hypertension

1. Coronary vein
2. Short gastric vein
3. Gastrorenal pathway
4. Splenorenal pathway
5. Umbilical vein
6. Anterior abdominal wall vein
7. Superior mesenteric vein

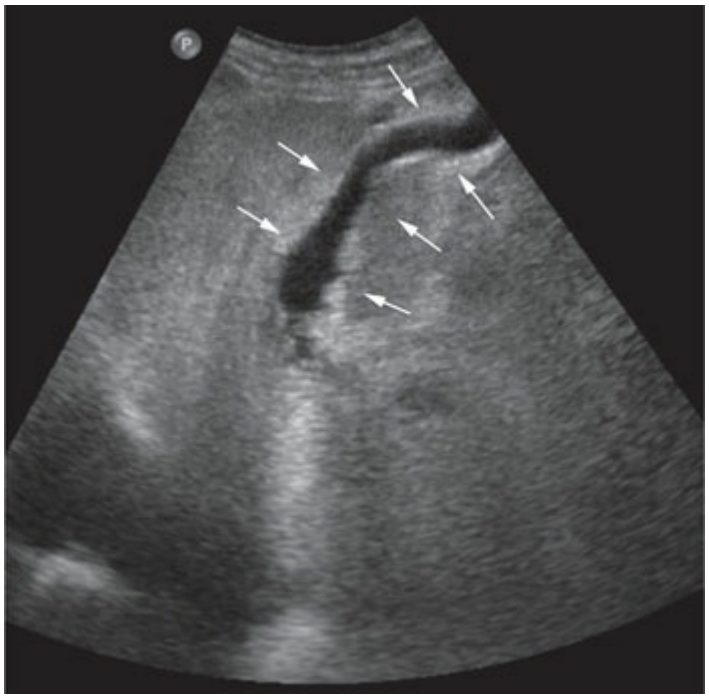


Figure 2-19 A patent or recanalized paraumbilical vein (*arrows*) is noted extended from the left lobe of this patient who is suffering from cirrhosis and portal hypertension.

One of the most common sonographically identifiable collaterals in portal hypertension is the recanalization of the paraumbilical vein, also termed a

patent paraumbilical vein (Figs. 2-19 and 2-20). The umbilical vein, which is associated with the left portal vein, ligamentum teres, and falciform ligament, becomes open again (as it once was in utero) and shunts blood away from the liver and into the inferior epigastric veins or superior epigastric vein—termed Cruveilhier–Baumgarten syndrome.

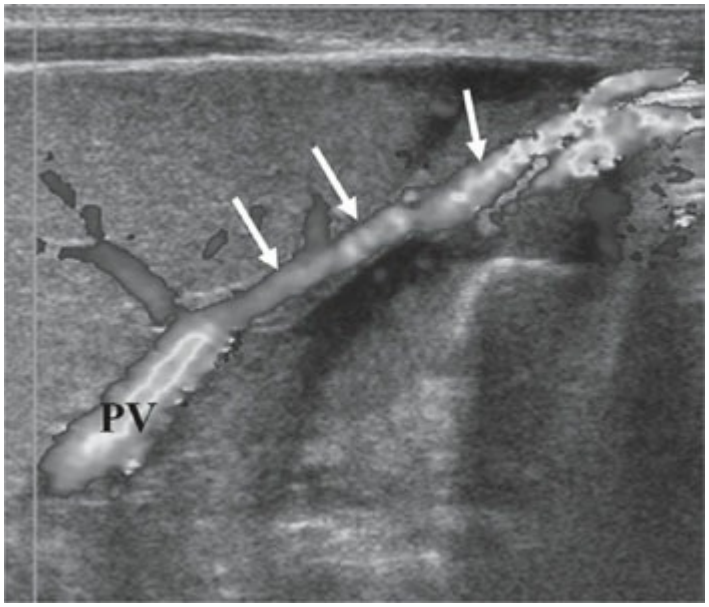


Figure 2-20 Recanalized paraumbilical vein (*arrows*) is demonstrated extended from the left portal vein (*PV*) toward the anterior abdominal wall in a patient with portal hypertension. (Color image provided online.)

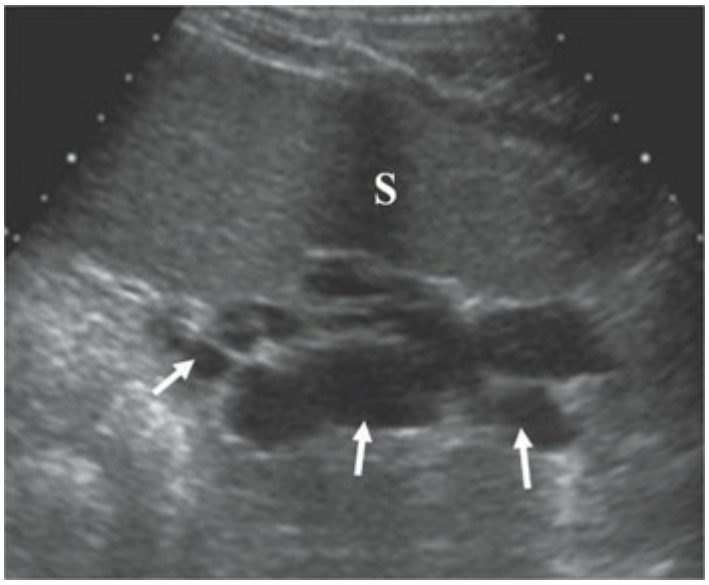


Figure 2-21 In a patient with portal hypertension, splenic varices (*arrows*) are noted adjacent to the spleen (*S*) in the area of the splenic hilum.

Abdominal varicosities may be noted near the splenic hilum, renal hilum, and gastroesophageal junction (Fig. 2-21). Furthermore, sonographic evidence of enlargement and reversed flow within the coronary vein, also

referred to as the left gastric vein, may be seen with portal hypertension (Fig. 2-22). In some individuals, the normal coronary vein can be seen arising from the splenic vein and extending superiorly toward the left. With portal hypertension, the coronary vein will demonstrate abnormal flow toward the esophagus and will measure greater than 6 mm. Unfortunately, shunting of blood toward the esophagus increases the risk for esophageal hemorrhage and death.

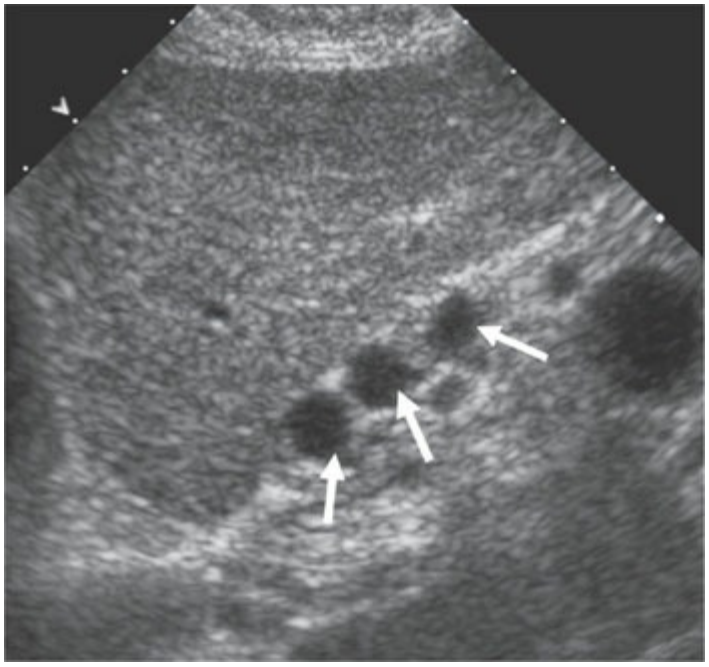


Figure 2-22 Enlarged coronary vein (*arrows*) can be seen posterior to the left lobe in a patient with portal hypertension.

Enlargement of the portal vein with portal hypertension is often apparent, especially prior to collateral development. Along with hepatofugal flow, the portal vein diameter will exceed 13 mm in the anteroposterior dimension, and the superior mesenteric vein will exceed 10 mm. This irregular, and often stagnant flow, increases the patient's likelihood of developing portal vein thrombosis. Essentially, patients with portal hypertension will have many of the same sonographic findings of cirrhosis, including ascites and splenomegaly, with the addition of portal vascular and shunting abnormalities and the development of collaterals channels.

Clinical features of portal hypertension often mimic cirrhosis. Hematemesis, if present, is an ominous sign of ruptured esophageal varices because it markedly increases mortality and morbidity. Other clinical findings of portal hypertension include hepatic encephalopathy, recognizable dilation of the superficial veins of the abdomen (termed caput medusa), and tremors.

Surgical shunts may be placed to reduce the likelihood of complications

resulting from portal hypertension. Surgically placed shunts include the portocaval shunt, splenorenal shunt, and mesocaval shunt. A common, minimally invasive interventional treatment for portal hypertension is by means of a transjugular intrahepatic portosystemic shunt (TIPS). Although it is only a temporary treatment for portal hypertension, this therapy involves the placement of a stent between the portal veins and hepatic veins to shunt blood and reduce portal systemic pressure. The TIPS is often evaluated for patency with Doppler sonography (see "Liver Doppler, TIPS Evaluation, and Liver Transplant Assessment" section in this chapter).



SOUND OFF

If you suspect cirrhosis, be sure to closely analyze the *left portal vein* for evidence of recanalization of the paraumbilical vein. The recanalized paraumbilical vein will extend from the left portal vein, continue through the left lobe, and may travel inferiorly toward the umbilicus.

CLINICAL FINDINGS OF PORTAL HYPERTENSION

1. Abnormal liver function tests
2. Ascites
3. Diarrhea
4. Fatigue
5. Hepatomegaly (initially)
6. Hepatic encephalopathy
7. Caput medusa
8. Tremors
9. Gastrointestinal bleeding

SONOGRAPHIC FINDINGS OF PORTAL HYPERTENSION

1. Hepatomegaly (initially)
2. Shrunken right lobe of the liver
3. Enlarged caudate lobe of the liver
4. Nodular surface irregularity
5. Coarse echotexture
6. Splenomegaly
7. Ascites
8. Monophasic flow within the hepatic veins
9. Hepatofugal flow within the portal veins
10. Enlargement of the portal vein (diameter will exceed 13 mm in the anteroposterior dimension)
11. Enlargement of the superior mesenteric vein
12. Enlargement and reversed flow within the coronary vein

13. Enlarged hepatic arteries
14. Abdominal varicosities at the splenic hilum, renal hilum, and gastroesophageal junction
15. Patent paraumbilical vein (also called a recanalized paraumbilical vein)

Portal Vein Compression and Portal Vein Thrombosis

Portal vein compression, which subsequently leads to portal vein obstruction, is most commonly caused by tumors from adjacent organs or lymphadenopathy. Portal vein thrombosis is the development of clot within the portal vein. Portal vein thrombosis is seen in conditions such as HCC, portal hypertension, pancreatitis, cholecystitis, pregnancy, oral contraceptive use, and surgery. Thrombus can completely occlude the portal vein. In this case, the development of collaterals within the portal vein region will occur. These small vessels try to shunt blood around the clot. This results in a mesh of tiny blood vessels in the area of the portal vein, termed cavernous transformation of the portal vein. In addition, as the disease progresses, larger collaterals can develop.

Patients may complain of abdominal pain, low-grade fever, leukocytosis, hypovolemia, elevated liver function tests, and nausea and vomiting. Initial sonographic evaluation of portal vein thrombus may be difficult because clot can be isoechoic to the surrounding circulating blood. With time, thrombus will become more echogenic and may be more noticeable within the portal vein (Fig. 2-23). The cavernous transformation of the portal veins will appear as wormlike or serpiginous vessels within the region of the portal vein (Fig. 2-24). Portal occlusion can also be the result of tumor invasion within the portal vein. Because of the compromise to hepatic blood flow, color Doppler should be used to evaluate the vascularity of liver.



SOUND OFF

Cavernous transformation of the portal vein is a sequela of portal vein thrombosis. With cavernous transformation of the portal vein, you will find multiple serpiginous or tortuous vessels in the porta hepatis.

CLINICAL FINDINGS OF PORTAL VEIN THROMBOSIS

1. Abdominal pain
2. Elevated liver function tests
3. Hypovolemia
4. Leukocytosis
5. Low-grade fever
6. Nausea
7. Vomiting

SONOGRAPHIC FINDINGS OF PORTAL VEIN THROMBOSIS

1. Echogenic thrombus within the portal vein
2. Cavernous transformation of the portal veins will appear as wormlike or serpiginous vessels within the region of the portal vein

Portal Venous Gas

Gas within the portal veins or mesenteric veins that results from ischemic bowel disease is typically fatal. However, portal venous gas may also be associated with diverticulitis, appendicitis, inflammatory bowel disease, bowel obstructions, ulcers within the bowel, gastrointestinal cancer, and invasive procedures that involve stent placement or endoscopic analysis of the bowel. The sonographic findings of portal venous gas are consistent with evidence of small, bright reflectors noted within the circulating blood inside the portal vein. Larger air collections may produce ring-down artifact. Care should be taken to not confuse portal venous gas with pneumobilia, which is air located within the biliary ducts.

CLINICAL FINDINGS OF PORTAL VENOUS GAS

1. Recent bout of diverticulitis, appendicitis, inflammatory bowel disease, bowel obstruction, ulcers within the bowel, gastrointestinal cancer, and invasive procedures that involve stent placement (TIPS) or endoscopic analysis of the bowel

SONOGRAPHIC FINDINGS OF PORTAL VENOUS GAS

1. Small, bright reflectors noted within the circulating blood inside the portal vein.
2. Larger air collections may produce ring-down artifact.

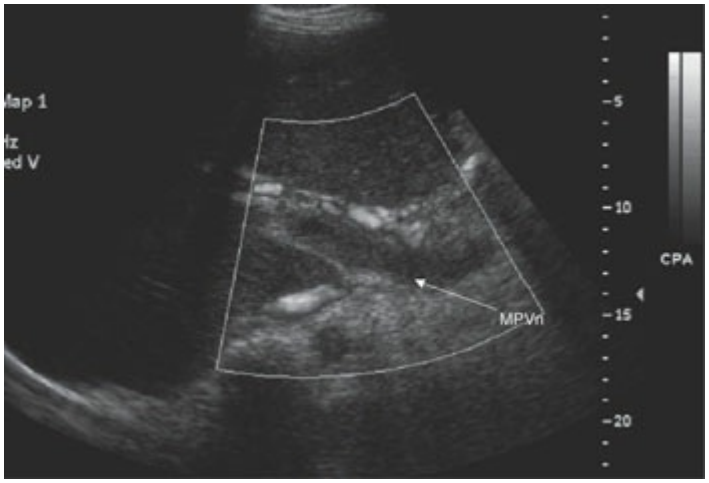


Figure 2-23 Sagittal, color Doppler image of the main portal vein (*MPVn*) reveals portal vein thrombosis and the development of collateral vessels diverting blood

around the clot. (Color image provided online.)

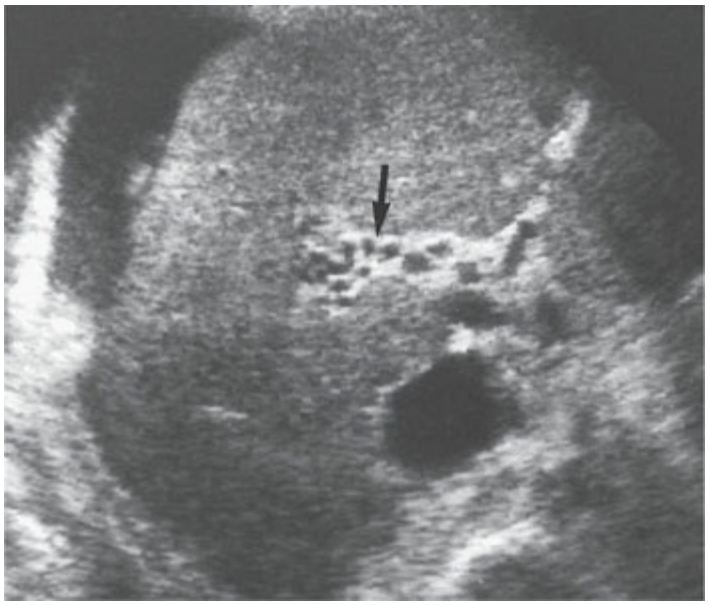


Figure 2-24 Cavernous transformation of the portal vein. Transverse image through the porta hepatis demonstrates multiple, small collateral vessels (*arrow*) in the area of the portal vein.

Budd–Chiari Syndrome

Budd–Chiari syndrome is described as the occlusion of the hepatic veins, with possible coexisting occlusion of the IVC. Budd–Chiari syndrome can be seen secondary to a congenital webbing disorder, coagulation abnormalities, tumor invasion from HCC, thrombosis, oral contraceptive use, pregnancy, and trauma. Clinical symptoms of this abnormality, when found in female patients on oral contraception, include ascites, right upper quadrant pain, hepatomegaly, and possibly splenomegaly. Other patients may suffer from extensive upper abdominal pain and elevated liver function test. Sonographic findings include the nonvisualization or reduced visualization of the hepatic veins. Thrombus may be noted within the hepatic veins, the caudate lobe may be enlarged, and color Doppler will often yield evidence of absent flow within the hepatic veins. The IVC may also be narrowed.

CLINICAL FINDINGS OF BUDD–CHIARI SYNDROME

1. Ascites
2. Elevated liver function test
3. Hepatomegaly
4. Splenomegaly
5. Upper abdominal pain

SONOGRAPHIC FINDINGS OF BUDD–CHIARI SYNDROME

1. Nonvisualization or reduced visualization of the hepatic veins
2. Thrombus within the hepatic veins
3. Enlarged caudate lobe
4. Lack of flow within the hepatic veins with color Doppler
5. Narrowing of the IVC

SOUND OFF
Budd–Chiari syndrome is characterized by occlusion of the hepatic veins and possibly the IVC.

Focal Liver Disease

Hepatic Cysts

True hepatic cysts are usually not encountered until middle age (Fig. 2-25). They are often associated with autosomal dominant polycystic kidney disease (ADPKD). Clinically, hepatic cysts associated with ADPKD are often asymptomatic and they do not alter liver function tests. They may be multiple, and they may not always conform to the sonographic appearance of a simple cyst because their shape can be somewhat irregular. Clusters of cysts with jagged walls may be noted, which may produce a complex appearance (Fig. 2-26). However, all other simple cyst criteria should be present, including a smooth wall and the presence of posterior acoustic enhancement, and they should be entirely anechoic. Complex hepatic cysts are often due to hemorrhage and may have internal echoes, thick walls, calcification, or solid components. When pain occurs because of hepatic cysts, it may be due to hemorrhage, infection, or secondary to mass effect. Hepatic cysts may also be noted in patients with von Hippel–Lindau disease, or be solitary and idiopathic.

CLINICAL FINDINGS OF HEPATIC CYSTS

1. Asymptomatic
2. Possible normal liver function tests
3. ADPKD
4. Hemorrhagic or large cysts may cause right upper quadrant pain

SONOGRAPHIC FINDINGS OF HEPATIC CYSTS

1. Anechoic mass or masses with posterior enhancement
2. May have irregular shapes
3. Clusters of cysts may be noted

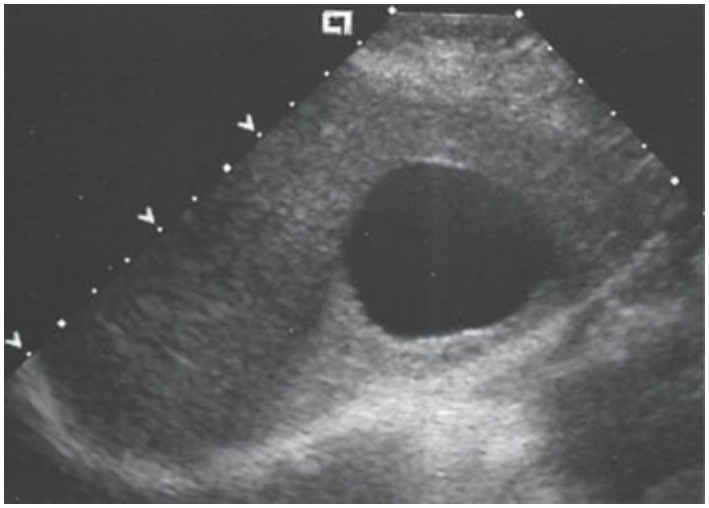


Figure 2-25 Benign hepatic cyst. This liver mass has well-defined borders, is completely anechoic, has thin walls, and demonstrates posterior enhancement.

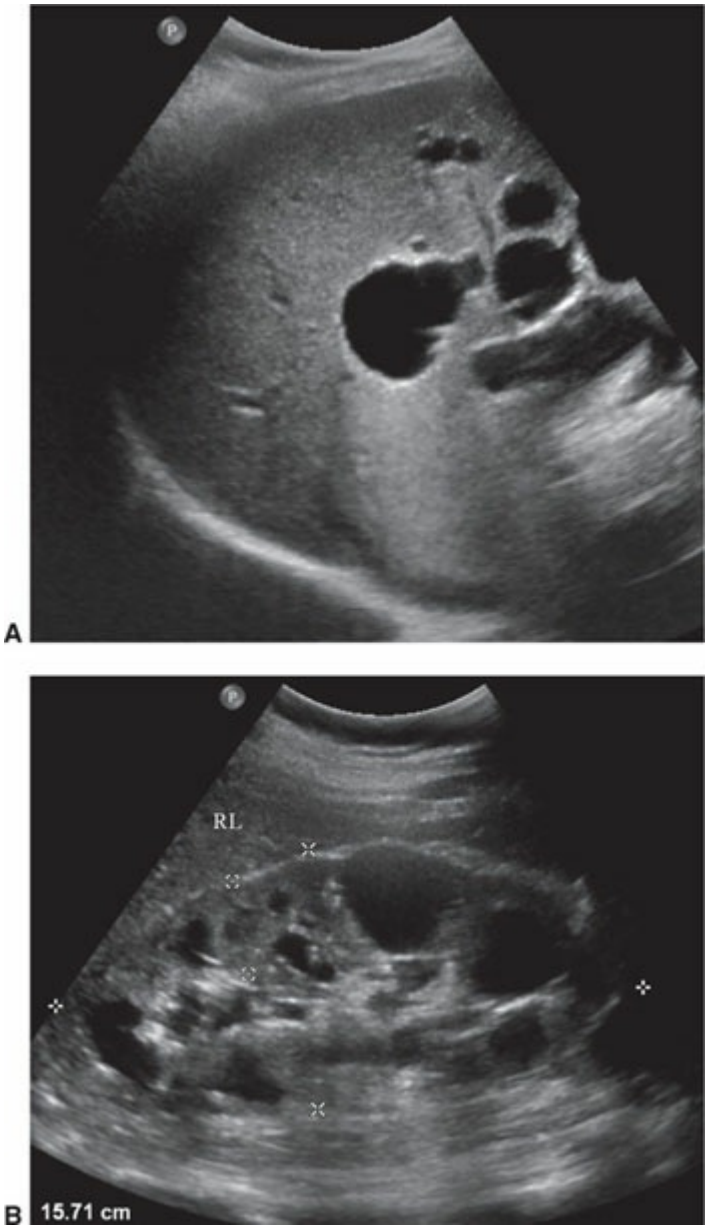


Figure 2-26 ADPKD cysts. This appearance of hepatic cysts (image A) is commonly

associated with cysts of the kidney affected by ADPKD (image B). ADPKD, autosomal dominant polycystic kidney disease. RL, right lobe.

Hydatid Liver Cyst

A hydatid liver cyst may also be referred to as an echinococcal cyst. These cysts develop most commonly from a parasite referred to as Echinococcus granulosus. This parasite is a tapeworm that lives in dog feces. Food, such as vegetables, contaminated by the infected feces is consumed indirectly by sheep, cattle, goat, and possibly humans. Therefore, there is a higher prevalence of hydatid disease in sheep- and cattle-raising countries such as the Middle East, Australia, and the Mediterranean. The parasite moves from the bowel through the portal vein to enter the liver.

Clinically, patients present with a low-grade fever and right upper quadrant tenderness. Other signs and symptoms include nausea, obstructive jaundice, leukocytosis, and a slight raise in alkaline phosphatase. The sonographic appearance is variable. Hydatid cysts may appear as an anechoic mass containing some debris. This debris is referred to as hydatid sand. The cyst is composed of an endocyst, and a pericyst or ectocyst. The endocyst, contained within the pericyst, may disconnect from the pericyst, and its wall may be clearly identified floating within the larger cyst. This has been referred to as the "water lily" sign.

Hydatid cysts may also appear as cysts within a cyst. This has been described as a "mother" cyst containing "daughter" cysts. This sonographic description is highly specific for hydatid disease (Fig. 2-27). The mass may also contain some elements of dense calcification. Surgical resection, catheter drainage, or medical treatment may be used to manage a hydatid liver cyst. Unfortunately, cyst ruptures could lead to anaphylactic shock.

Clinical Findings of a Hydatid Liver Cyst

1. Leukocytosis
2. Low-grade fever
3. Nausea
4. Obstructive jaundice
5. Right upper quadrant tenderness
6. Possible recent travel abroad

Sonographic Findings of A Hydatid Liver Cyst

1. Anechoic mass containing some debris (hydatid sand)
2. "Water lily" sign appears as an endocyst floating within the pericyst
3. "Mother" cyst containing one or more smaller "daughter" cyst
4. Mass may contain some elements of dense calcification

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Amebic Hepatic Abscess

An amebic hepatic abscess comes from the parasite Entamoeba histolytica that grows in the colon and invades the liver via the portal vein. It is typically transmitted through contaminated water found in places such as Mexico, Central America, South America, Asia, India, and Africa. Therefore, patients who present with amebic abscesses may have traveled out of the country recently. Clinical features may be hepatomegaly, right upper quadrant pain, general malaise, or signs of dysentery, which include bloody diarrhea, abdominal pain, and fever.

Laboratory findings may include leukocytosis, elevated liver function tests, and mild anemia. Like other abscesses, amebic abscesses have variable sonographic appearances. They are typically round, hypoechoic or anechoic, contain debris, and have some acoustic enhancement. Amebic abscesses are most often noted within the right lobe of the liver near the capsule. They may also be multiple and appear hypoechoic or contain a fluid-debris level (Fig. 2-28). Often, they are indistinguishable sonographically from a pyogenic liver abscess and therefore require a serologic confirmation. These masses are typically treated medically, although aspiration may be performed. Complications include rupture or extension into the chest or peritoneal cavity, resulting in a high mortality rate if not treated efficiently.

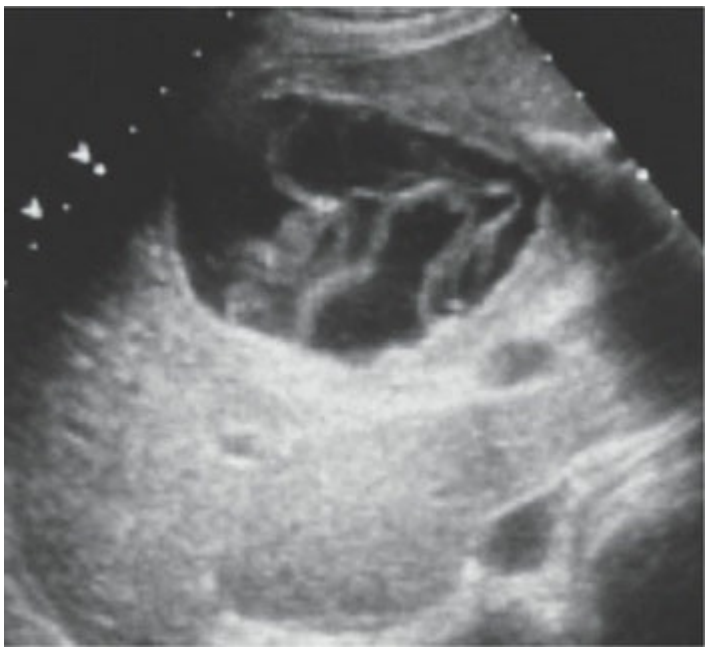


Figure 2-27 Hydatid disease. Transverse image of the liver demonstrates a complex mass containing a detached membrane, which is the typical appearance of a hydatid cyst.

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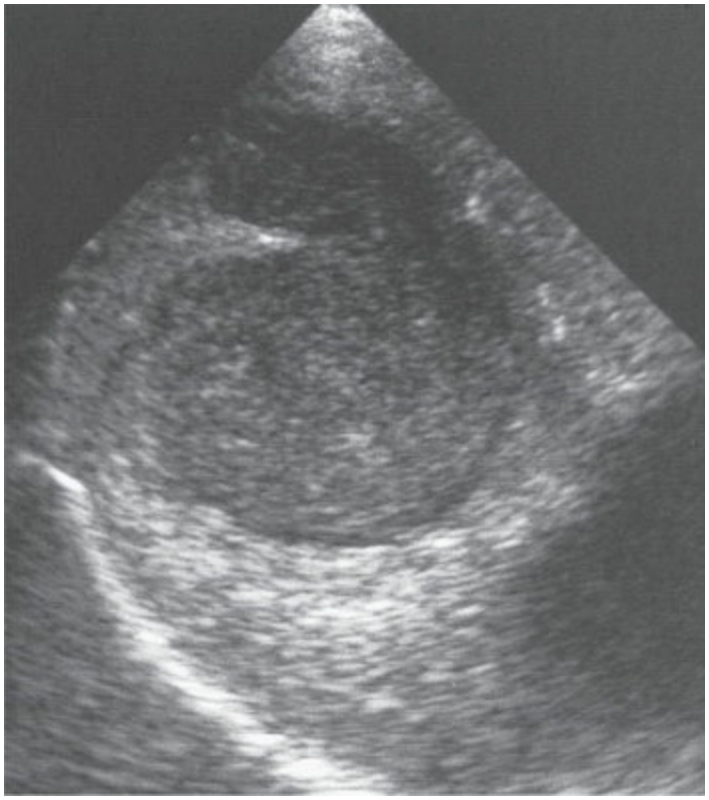


Figure 2-28 Amebic abscess. This amebic abscess appears as a hypoechoic mass surrounded by a hypoechoic wall.

CLINICAL FINDINGS OF AN AMEBIC HEPATIC ABSCESS

1. Hepatomegaly
2. Right upper quadrant or general abdominal pain
3. General malaise
4. Diarrhea (possibly bloody)
5. Fever
6. Leukocytosis
7. Elevated liver function tests
8. Mild anemia
9. Possible recent travel abroad

SONOGRAPHIC FINDINGS OF AN AMEBIC HEPATIC ABSCESS

1. Round, hypoechoic or anechoic mass or masses
2. May contain debris (with fluid-debris layering)
3. Acoustic enhancement

Pyogenic Hepatic Abscess

A pyogenic hepatic abscess can result from the spread of infection from inflammatory conditions such as appendicitis, diverticulitis, cholecystitis, cholangitis, or endocarditis. The bacteria enter the liver through the portal vein, hepatic artery, biliary tree, or from an operative procedure. Clinical

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symptoms of a pyogenic abscess include fever, leukocytosis, possible abnormal liver function tests, right upper quadrant pain, and hepatomegaly. The sonographic findings of a hepatic abscess are variable (Fig. 2-29). It may appear as a complex cyst with thick walls. It may also contain debris, septations, and/or gas. The air within the abscess may produce dirty shadowing or ring-down artifact.

CLINICAL FINDINGS OF A PYOGENIC HEPATIC ABSCESS

1. Fever
2. Hepatomegaly
3. Leukocytosis
4. Possible abnormal liver function tests
5. Right upper quadrant pain

SONOGRAPHIC FINDINGS OF A PYOGENIC HEPATIC ABSCESS

1. Complex cyst with thick walls
2. Mass may contain debris, septations, and/or gas
3. The air within the abscess may produce dirty shadowing or ring-down artifact

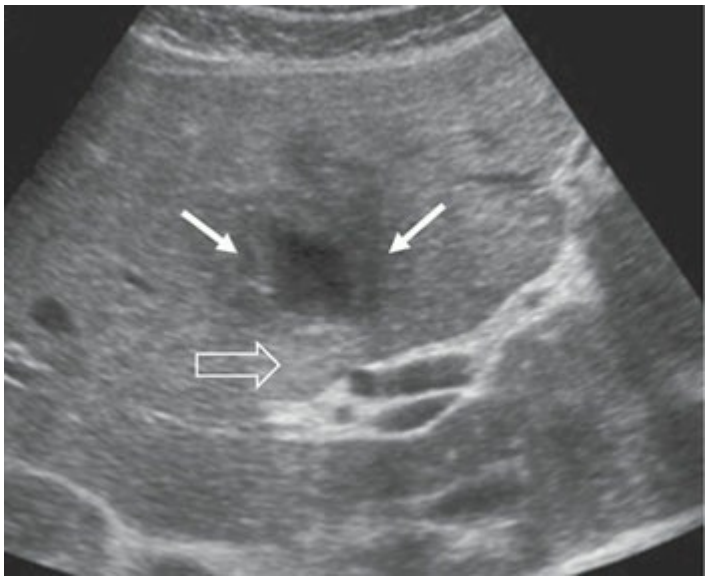


Figure 2-29 Pyogenic abscess. Longitudinal image of the liver containing a hypoechoic mass with indistinct borders (*solid arrows*) and posterior enhancement (*open arrow*).

Hepatic Candidiasis

Hepatic candidiasis results from the spread of fungus, namely Candida albicans, in the blood to the liver. Those who are prone to develop hepatic candidiasis are typically immunocompromised in some way. For example, cancer patients, recent organ transplant patients, and those with human

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immunodeficiency virus are more prone to develop this type of fungal abscess within their liver. Besides being immunocompromised, patients may have right upper quadrant pain, fever, and hepatomegaly. Sonographic findings include multiple hyperechoic (central portion) masses with hypoechoic borders. These masses may be described as "target," "halo," or "bull's-eye" lesions and are typically 1 cm or smaller in size (Fig. 2-30). Older lesions may calcify.

CLINICAL FINDINGS OF HEPATIC CANDIDIASIS

1. Immunocompromised patients including cancer patients, recent organ transplant patients, and patients with human immunodeficiency virus
2. Right upper quadrant pain
3. Fever
4. Hepatomegaly

SONOGRAPHIC FINDINGS OF HEPATIC CANDIDIASIS

1. Multiple masses with hyperechoic central portions and hypoechoic borders (may be described as "target," "halo," or "bull's-eye" lesions)
2. These masses are typically 1 cm or smaller in size
3. Older lesions may calcify

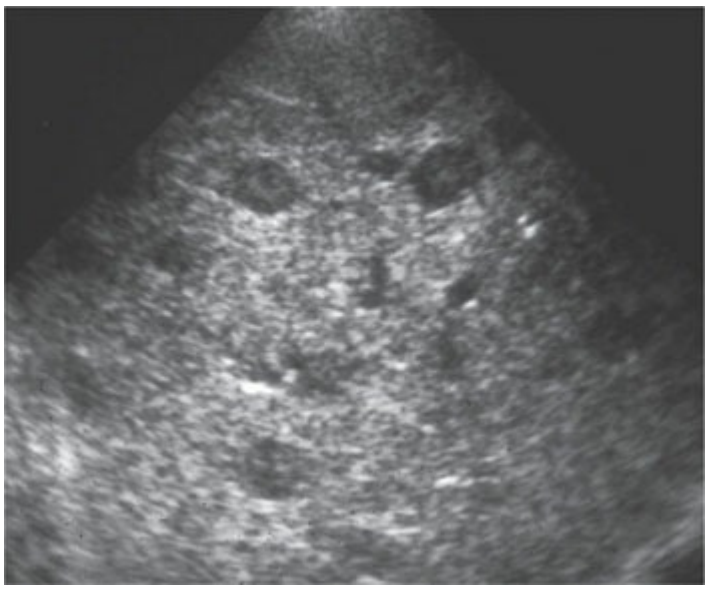


Figure 2-30 Candidiasis. This transverse image of the liver demonstrates multiple hypoechoic lesions that appear as small bull's-eyes scattered throughout the organ.

Cavernous Hemangioma

The most common benign liver tumor is the cavernous hemangioma. Although they can be found in men, they are more commonly discovered in women. Hepatic hemangiomas are usually incidentally detected and

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asymptomatic. The most common location of the cavernous hemangioma is within the right lobe of the liver. They characteristically appear as a small, hyperechoic mass measuring less than 3 cm, although some may be quite large and referred to as giant hemangiomas (Fig. 2-31). Occasionally, posterior enhancement may be seen. Although hemangiomas are comprised of blood vessels, detectable flow may not be seen with color Doppler because the flow within the vessels tends to be exceedingly slow. Unfortunately, hemangiomas may also appear hypoechoic or complex, and therefore they can be sonographically indistinguishable from metastatic liver disease. There may also be multiple hemangiomas present, further complicating the sonographic diagnosis and consequently leading to other imaging or biopsy.

SOUND OFF
The cavernous hemangioma is the most common benign liver mass. It is most often found in the right hepatic lobe.

CLINICAL FINDINGS OF A CAVERNOUS HEMANGIOMA

1. Asymptomatic

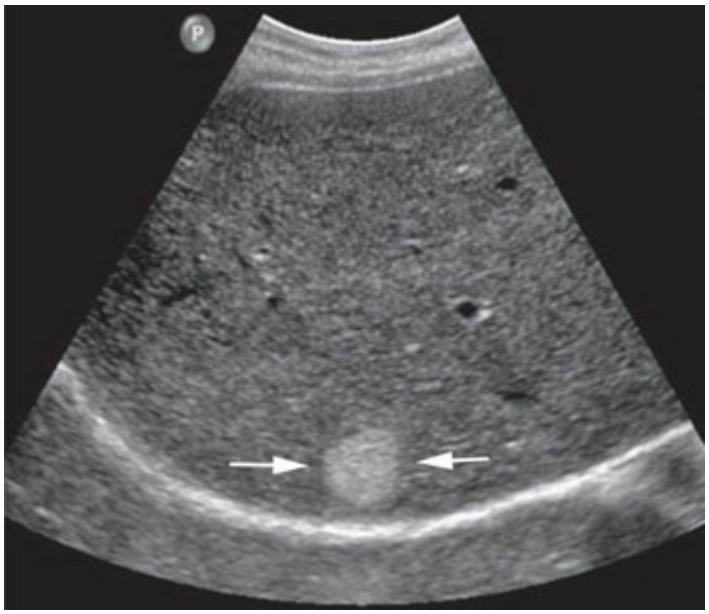


Figure 2-31 Cavernous hemangioma. A hyperechoic mass (*arrows*) is noted within the right lobe of the liver.

SONOGRAPHIC FINDINGS OF A CAVERNOUS HEMANGIOMA

1. Small, hyperechoic mass
2. Typically in the right lobe

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Focal Nodular Hyperplasia

Focal nodular hyperplasia (FNH) has been cited as the second most common benign liver tumor and more commonly incidentally discovered in women. The mass is composed of a combination of hepatocytes and fibrous tissue. Patients who have FNH are most often asymptomatic, but if the mass impinges upon surrounding anatomy or hemorrhage occur, pain will most likely ensue. Although the mass is not caused by oral contraceptive use, it may enlarge because of oral contraceptive use as a result of estrogen exposure.

Sonographically, FNH may have varying sonographic appearances, including isoechoic, echogenic, and hypoechoic (Fig. 2-32). It typically contains a central stellate (star-like) scar that is not always detected with sonography but is readily identified with CT and MRI. The central scar, when seen, will appear as a hypoechoic or hyperechoic, linear structure within the mass. Hypervascularity within the scar can be identified by using color Doppler. FNH has been referred to as a "stealth lesion" because it may be difficult to identify secondary to its slight sonographic disparity from normal liver parenchyma.

CLINICAL FINDINGS OF FOCAL NODULAR HYPERPLASIA

1. Asymptomatic

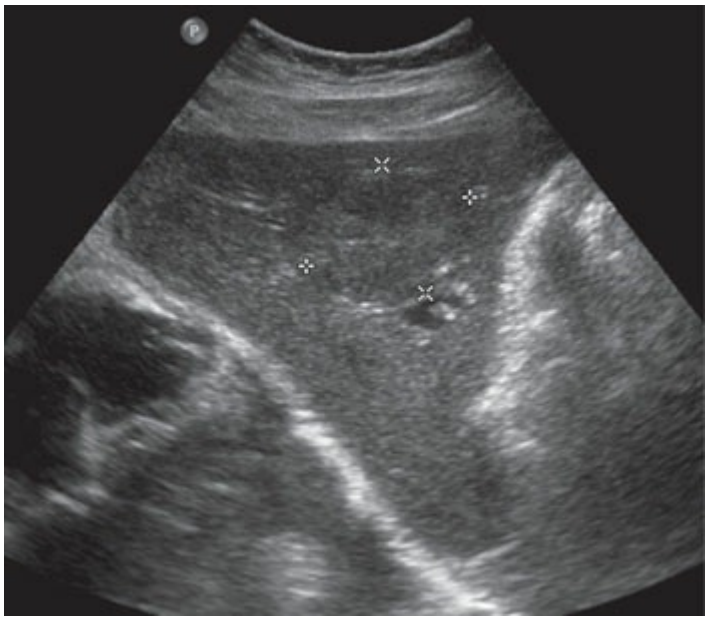


Figure 2-32 Focal nodular hyperplasia. An isoechoic mass (*between calipers*) is noted within the left lobe of the liver.

SONOGRAPHIC FINDINGS OF FOCAL NODULAR HYPERPLASIA

1. Isoechoic, hyperechoic, or hypoechoic mass

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2. Central scar may appear as hyperechoic or hypoechoic linear structure within the mass and will often reveal hypervascularity with color Doppler

SOUND OFF
Although FNH is not caused by oral contraceptive use, the mass tends to be estrogen dependent, and thus can grow as the result of oral contraceptive use.

Hepatocellular Adenoma

The hepatocellular adenoma, which may also be referred to as a hepatic adenoma or liver cell adenoma, is a rare benign liver tumor. It is often associated with the use of oral contraceptives. Patients are typically asymptomatic with an adenoma, but hemorrhage of the tumor leads to abdominal pain. Because of hemorrhage, and a small propensity to become malignant (termed malignant degeneration), hepatic adenomas are often surgically removed. There may be multiple adenomas present at the time of discovery. The sonographic appearance of a hepatic adenoma is variable, and although a solid, hypoechoic echogenicity is common, they may be hyperechoic, isoechoic, or have mixed echogenicities (Fig. 2-33).

SOUND OFF
Hepatic adenomas can be caused by oral contraceptive use.

CLINICAL FINDINGS OF A HEPATOCELLULAR ADENOMA

1. Asymptomatic
2. Oral contraceptive use
3. Pain occurs with hemorrhage

SONOGRAPHIC FINDINGS OF A HEPATOCELLULAR ADENOMA

1. Mostly hypoechoic
2. May be hyperechoic, isoechoic, or be comprised of mixed echogenicities

Hepatic Lipoma

The hepatic lipoma is rarely encountered. Patients are asymptomatic, and its sonographic appearance is that of a hyperechoic mass.

CLINICAL FINDINGS OF HEPATIC LIPOMA

1. Asymptomatic

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SONOGRAPHIC FINDINGS OF HEPATIC LIPOMA

1. Hyperechoic mass

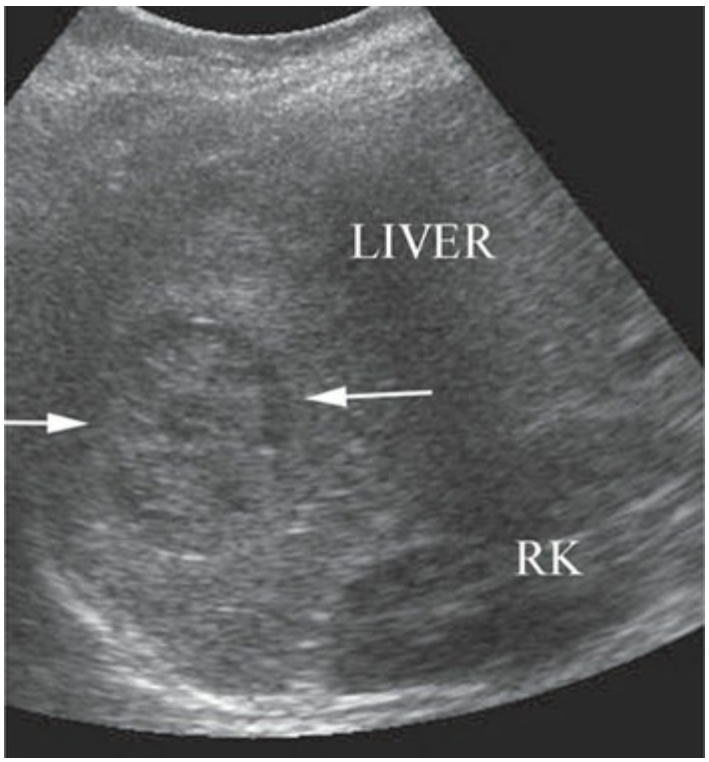


Figure 2-33 Hepatic adenoma. This well-circumscribed mass (*between arrows*) is a hepatic adenoma located within the right lobe of the liver, superior to the right kidney (*RK*).

Hepatic Hematoma

A hepatic hematoma can be a consequence of trauma or surgery. Patients will have pain and a decreased hematocrit. Hematomas can be located within the liver parenchyma, termed intrahepatic, or around the liver, which is termed subcapsular (under Glisson capsule). Hematomas can appear solid or complex depending on their age. Initial hemorrhage appears echogenic with the development of clot, and over time as it resolves, it may appear more cystic or complex. Focal hematomas have been known to calcify as well. Therefore, in the acute stage, an intrahepatic hematoma adjacent to the liver may be difficult to visualize with sonography because it may be isoechoic to the normal hepatic tissue. When the subcapsular hematoma is anechoic, it may appear similar to ascites surrounding the liver (Fig. 2-34). Following trauma to the liver, an abnormal passageway between an artery and vein—termed arteriovenous fistula—can result. Arteriovenous fistulas may also be discovered following a liver biopsy, cholangiography, or hepatic surgery. Multiple anechoic spaces will be noted in the area of the fistula, and color Doppler can be used to prove that the mass is vascular in origin.

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Clinical Findings of Hepatic Hematoma

1. Trauma
2. Recent surgery
3. Pain
4. Decreased hematocrit

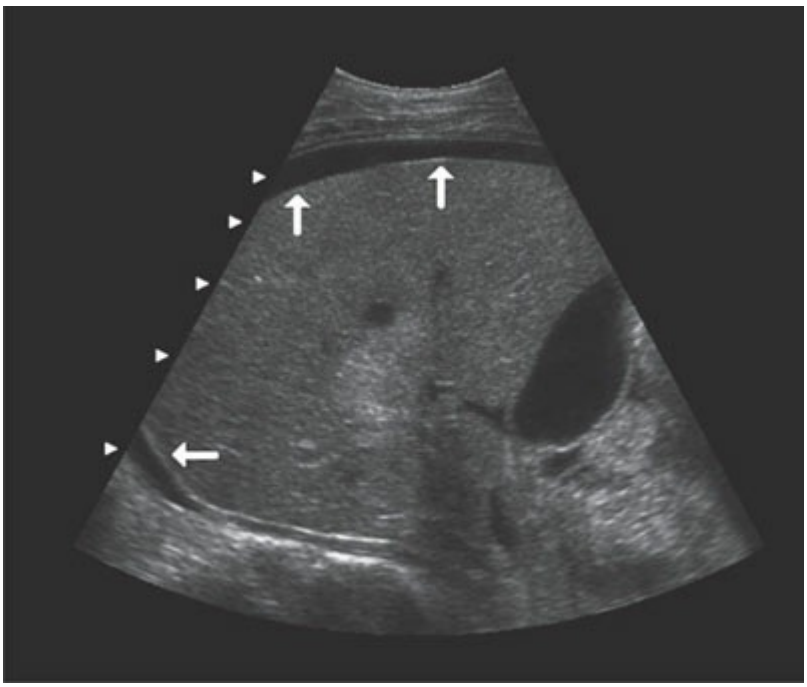
Sonographic Findings of Hepatic Hematoma

1. Fresh clot may appear hyperechoic
2. Older hemorrhage can appear anechoic or complex
3. May be intrahepatic or subcapsular

Liver Cancer

Hepatocellular Carcinoma

HCC is the most common primary form of liver cancer, although it is not encountered as often as metastatic liver disease. HCC is most often seen in men, and frequently accompanied by cirrhosis or chronic hepatitis. The malignant mass associated with HCC is referred to as a hepatoma. Other causes include hemochromatosis, von Gierke disease, and Wilson disease. Hepatomas can invade the portal veins or hepatic veins. Occlusion of the hepatic veins, with possible tumor invasion into the IVC, is termed Budd–Chiari syndrome, and thus the sonographic evaluation of pertinent vasculature is warranted for evidence of tumor thrombus. Color Doppler may yield evidence of hypervascularity within the mass, although this is not a specific indicator for malignancy.



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Figure 2-34 This older hematoma (anechoic fluid, *arrows*) has become sonolucent. Fresh hematomas may appear isoechoic to normal liver tissue.

Clinically, patients with HCC will have possible abnormal liver function tests, signs of cirrhosis, history of chronic hepatitis, unexplained weight loss, hepatomegaly, fever, abdominal swelling with ascites, and perhaps a palpable mass. A tumor marker for HCC is serum alpha-fetoprotein (AFP). In the fetus, AFP is produced in large amounts by the liver, whereas in the adult, low levels of AFP exist. Most patients with HCC will have an elevated AFP. This occurs because AFP is produced in excess by the malignant hepatocytes that make up the tumor.

The sonographic findings of HCC are unpredictable. There may be an individual mass or multiple masses present at the time of diagnosis. HCC may appear as a solitary, small, hypoechoic mass, or as heterogeneous masses scattered throughout the liver (Fig. 2-35). A hypoechoic halo may be noted around the hepatoma as well, yielding the "target" or "bull's-eye" pattern. The target lesion will yield a hypoechoic rim, with the center of the mass often isoechoic to normal liver tissue.

SOUND OFF
The tumor marker for hepatocellular carcinoma is AFP.

CLINICAL FINDINGS OF HEPATOCELLULAR CARCINOMA

1. Elevated AFP
2. Abnormal liver function tests (possibly)
3. Cirrhosis
4. Chronic hepatitis
5. Unexplained weight loss
6. Hepatomegaly
7. Fever
8. Palpable mass
9. Abdominal swelling with ascites

SONOGRAPHIC FINDINGS OF HEPATOCELLULAR CARCINOMA

1. Solitary, hypoechoic mass
2. Heterogeneous masses scattered throughout the liver
3. Mass with a hypoechoic halo and central echogenic portion ("target" or "bull's-eye" lesion)
4. Possible ascites

Hepatic Metastasis

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The liver is a common location for metastatic disease to manifest in the abdomen. Metastatic liver disease is the most common form of liver cancer. Because it is much more common than primary liver cancer (cancer that starts in the liver). The malignant cells from other sites enter the liver through the portal veins or lymphatic channels. Primary cancers that metastasize to the liver include the gallbladder, colon, stomach, pancreas, breast, and lung, with the latter being the most common primary source. Patients with hepatic metastasis may present with weight loss, jaundice, right upper quadrant pain, hepatomegaly, and ascites. However, in about half of patients there are no clinical signs or symptoms, including the possibility of normal liver function tests.

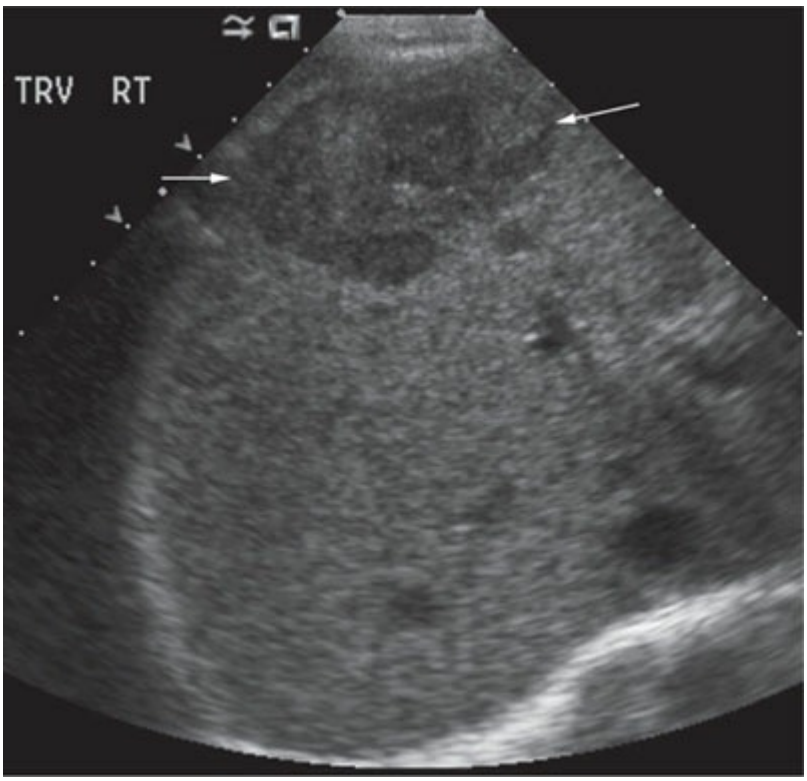


Figure 2-35 Hepatoma. This solid, hypoechoic mass (*between arrows*) was found to be hepatocellular carcinoma.

The sonographic findings of metastatic liver disease are variable, often depending on the location of the primary cancer. Metastatic cancer from the gastrointestinal tract and pancreas tends to be calcified tumors. Hyperechoic masses tend to arise from the gastrointestinal tract as well, most commonly the colon, but they may also be from the kidney, pancreas, or biliary tree. Hypoechoic masses may be from the breast, lung, or lymphoma. Cystic metastatic masses within the liver have also been seen with ovarian cancers. Metastatic disease in the liver can appear as an individual mass, several large masses, or diffuse involvement (Figs. 2-36 and 2-37). Target lesions are also common with metastasis and may be the expression of lung or colon

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metastasis within the liver, although they may be the manifestation of many forms of cancer. Diffuse metastasis can produce an appearance of a nodular liver—termed pseudocirrhosis. Thus, a high-frequency linear transducer can be employed when surface irregularity is suspected to identify smaller lesions.

SOUND OFF

Although HCC is the most common primary form of liver cancer—meaning that it develops in the liver—the most common cancer discovered in the liver is metastasis from some other primary location.

Clinical Findings of Hepatic Metastasis

1. Abnormal liver function test (possibly)
2. Weight loss
3. Jaundice
4. Right upper quadrant pain
5. Hepatomegaly
6. Abdominal swelling with ascites

Sonographic Findings of Hepatic Metastasis

1. Hyperechoic, hypoechoic, calcified, cystic, or heterogeneous masses
2. Mass or masses demonstrating a hypoechoic rim and central echogenic region
3. Diffusely heterogeneous liver
4. Possible ascites



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Figure 2-36 Metastatic liver disease. These masses were found in a patient with metastatic liver disease originating in the rectum.

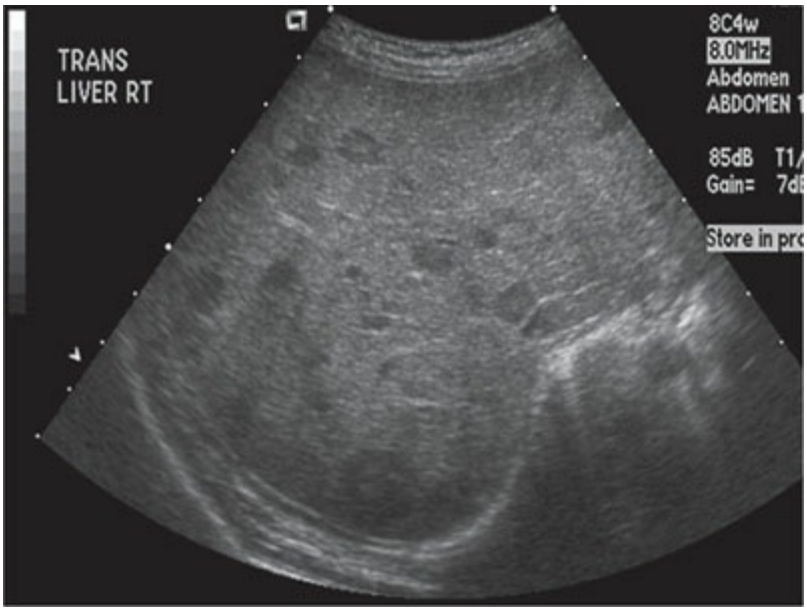


Figure 2-37 Metastatic liver disease. This image is of a 1-year-old patient with metastatic liver disease originating in the adrenal gland as a neuroblastoma.

LIVER DOPPLER, TIPS EVALUATION, AND LIVER TRANSPLANT ASSESSMENT

Doppler assessment of the liver can be performed using both color Doppler and spectral Doppler. Normal flow within the portal veins should be hepatopetal, continuous, monophasic, and have low velocity—typically between 20 and 40 cm per second. Some variation of flow may be seen with variations in breathing. Because of their close association with left atrium, the hepatic veins typically demonstrate a triphasic flow pattern. Flow assessment should be obtained at the end of respiration if possible, because deep inspiration may result in blunting or complete loss of hepatic vein pulsatility. The hepatic artery should demonstrate a continuous, low-resistance wave form pattern, with a quick upstroke, and gradual deceleration with diastole. The normal resistive index of the hepatic artery is said to be between 0.5 and 0.8.

In patients with advanced cirrhosis and portal hypertension, a TIPS stent may be inserted via the jugular vein and ultimately placed between a hepatic vein and intrahepatic portion of the portal vein. Most often, the shunt is created between the right portal vein and the right hepatic vein, and a bridging stent is left in place. This procedure reduces the amount of blood flow to the liver by rerouting the blood coming from the portal vein to the hepatic vein, ultimately sending the blood back to the heart. The primary

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goal of TIPS is to prevent the rupture and hemorrhage of gastroesophageal and other varices, an occurrence that is often fatal. On sonography, TIPS appears as a highly echogenic tube within the liver (Fig. 2-38). The sonographer may be asked to perform both preoperative and postoperative imaging, including a liver Doppler evaluation. For pre-TIPS assessment, care should be taken to analyze each vascular structure for evidence of abnormal flow patterns and thrombosis. Postoperative imaging of TIPS should include an evaluation of the shunt for patency throughout (Fig. 2-39). A baseline study, including Doppler interrogation, is vital to establish the patient's individualized standard. It may be noted that flow within the right and left portal veins typically reverse after stent placement. The normal flow velocity within the shunt ranges between 90 and 190 cm per second. The signs of TIPS failure include signs of clot within the shunt, stenosis of the shunt, stenosis of the hepatic vein, reversal of intrahepatic flow, flow void next to the stent, reversal of hepatic venous flow, drop in shunt velocity between examinations, and abnormally high or low shunt velocity (Fig. 2-40).

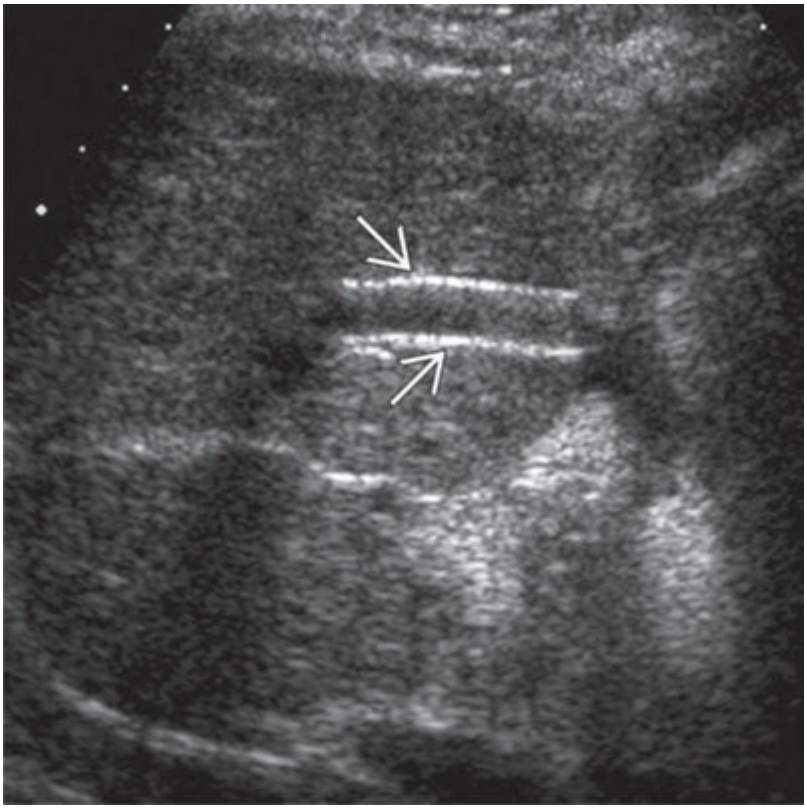


Figure 2-38 TIPS sonographic appearance. The wall of the TIPS appears highly echogenic. TIPS, transjugular intrahepatic portosystemic shunt.

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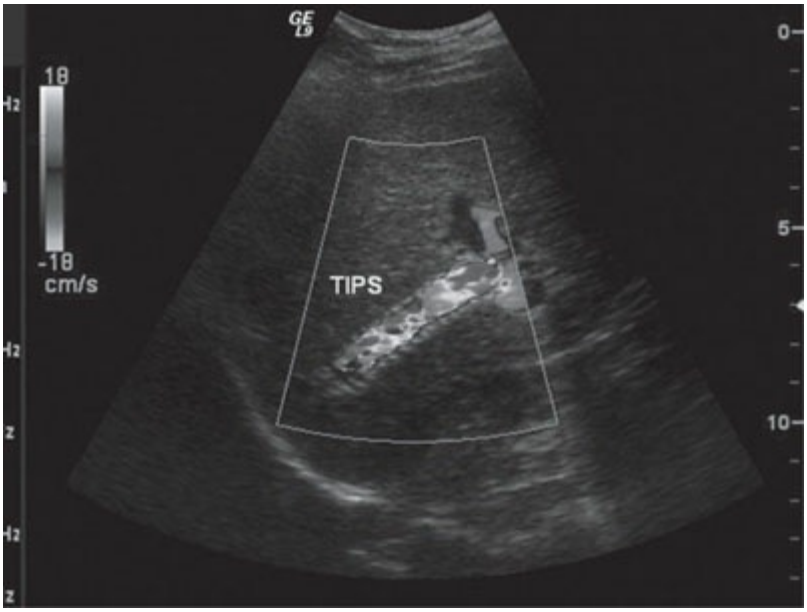


Figure 2-39 Color image of a normal TIPS. TIPS, transjugular intrahepatic portosystemic shunt. (Color image provided online.)

Recall that hepatitis C is the most common disease requiring a liver transplant, closely followed by alcoholic liver disease and cirrhosis. Although techniques may vary, typically the transplanted liver is attached end to end to the native portal vein and hepatic artery—termed anastomosis—and a "piggy back" attachment is made between the donor and recipient IVC (Fig. 2-41). With sonography, a liver transplant should appear similar to a normal native liver. All vasculature, including the portal veins, hepatic veins, hepatic artery, and IVC, should be evaluated with color and spectral Doppler and appear patent and have normal waveforms.

Although often with acute rejection the liver appears normal, suspicion should arise when the liver appears diffusely heterogeneous. Hepatic artery thrombosis is the most common vascular complication of a liver transplant (Fig. 2-42). When hepatic artery thrombosis is suspected, the sonographer should closely evaluate the liver for signs of infarction, which appears as hypoechoic wedge-shaped area scattered throughout the periphery of the liver. Other complications include biliary strictures, cholangitis, biliary sludge and stones, hepatic artery stenosis, hepatic artery pseudoaneurysms, celiac artery stenosis, portal vein stenosis and thrombosis, and fluid collections, including ascites, hematomas, bilomas, and abscesses. If present, stenoses, strictures, and pseudoaneurysms are often discovered at the anastomotic site.

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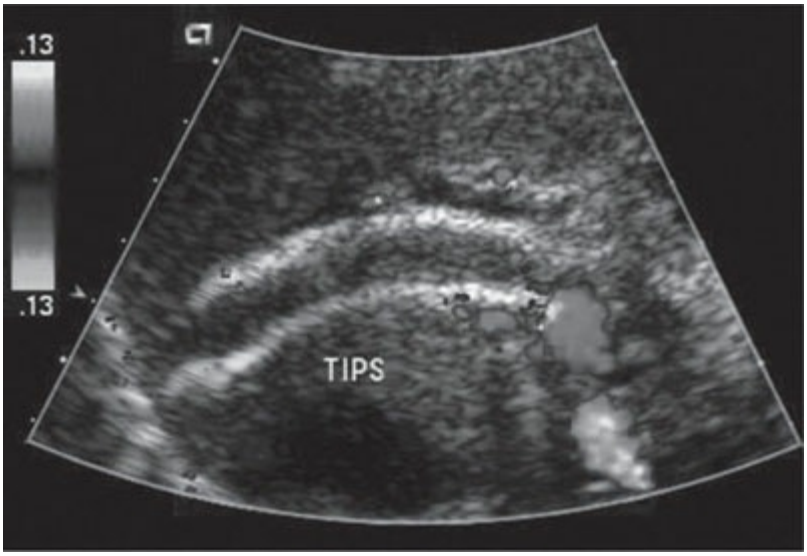


Figure 2-40 TIPS failure. This occluded TIPS lacks color-flow filling, and echogenic material (clot) can be noted within the shunt. TIPS, transjugular intrahepatic portosystemic shunt. (Color image provided online.)

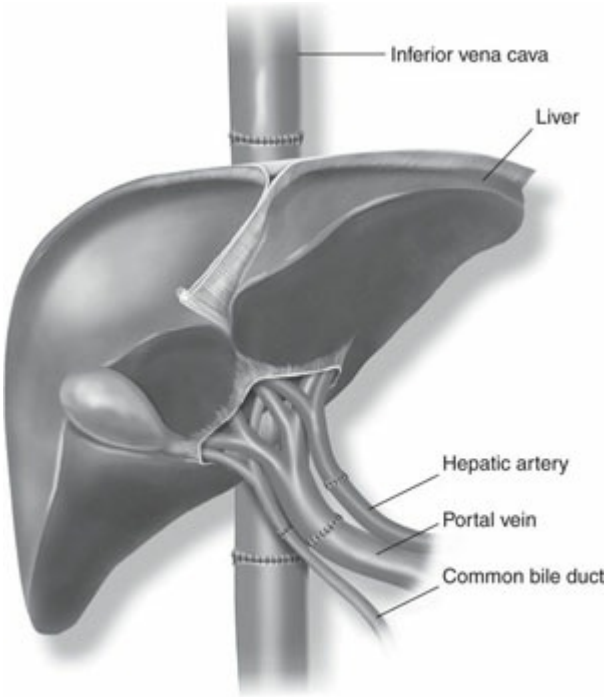


Figure 2-41 Liver transplant. Diagram demonstrating the most common surgical anatomy following liver transplantation with an interposition IVC graft. IVC, inferior vena cava.

PEDIATRIC LIVER PATHOLOGY

Infantile Hemangioendothelioma

Infantile hemangioendothelioma is the most common benign liver childhood tumor. These masses are typically identified in the first few weeks or months of life because they may cause hepatomegaly or be accompanied by

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hemangiomas of the skin. The sonographic findings of these masses are variable.

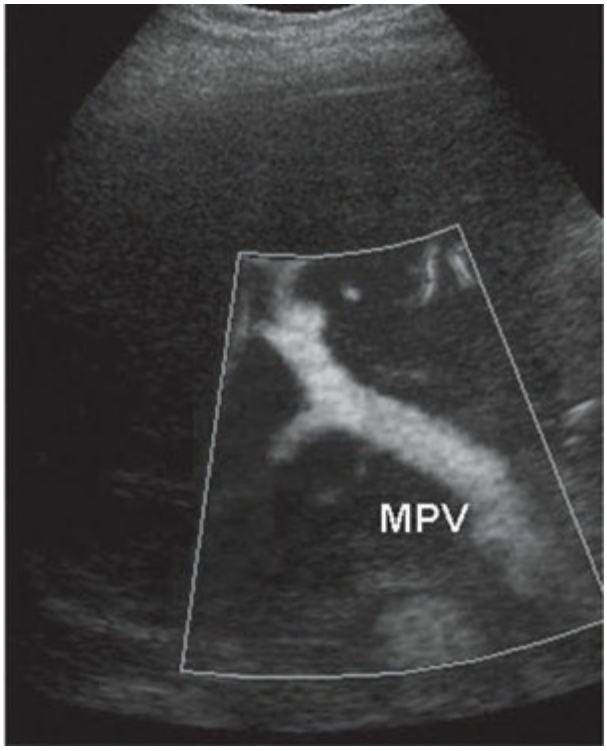


Figure 2-42 Hepatic artery thrombosis. Power Doppler image reveals flow with the main portal vein (*MPV*) but not detectable flow within the hepatic artery, yielding a diagnosis of hepatic artery thrombosis. (Color image provided online.)

CLINICAL FINDINGS OF INFANTILE HEMANGIOENDOTHELIOMA

1. Pediatric patient
2. May cause hepatomegaly
3. May be accompanied by hemangiomas of the skin

SONOGRAPHIC FINDINGS OF INFANTILE HEMANGIOENDOTHELIOMA

1. Homogeneous or complex hepatic mass
2. May contain calcification or cystic spaces

Hepatoblastoma

The hepatoblastoma is a malignant pediatric liver tumor. It has been cited as the most common malignant tumor of childhood. These aggressive tumors are most often discovered before age 5, with half of the cases identified in children less than 2 years old. There is a high incidence of hepatoblastoma in children who have Beckwith–Wiedemann syndrome. Like liver carcinoma in the adult, hepatoblastomas will often cause an elevation in AFP. These

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tumors can invade surrounding vasculature and may also obstruct the biliary tree. Clinically, these young patients may be asymptomatic or present with hepatomegaly and/or a palpable abdominal mass. They may also suffer from jaundice, abdominal pain, weight loss, and anorexia. The sonographic findings of a hepatoblastoma are that of a solid, hyperechoic, or heterogeneous mass. This mass may also contain calcifications.

CLINICAL FINDINGS OF HEPATOBLASTOMA

1. Pediatric patient
2. May be asymptomatic
3. Palpable abdominal mass
4. Hepatomegaly
5. Abdominal pain
6. Weight loss
7. Anorexia
8. Elevated AFP
9. Jaundice

SONOGRAPHIC FINDINGS OF HEPATOBLASTOMA

1. Solid, hyperechoic, or heterogeneous mass
2. Mass may contain some calcifications



SOUND OFF

Children with Beckwith–Weidemann syndrome are often screened with sonography in order for the early detection of hepatoblastomas.

REVIEW QUESTIONS

1. Which of the following benign liver masses is typically isoechoic and contains a central scar?
   a. Hepatoblastoma
   b. Cavernous hemangioma
   c. Hamartoma
   d. Focal nodular hyperplasia

2. The covering of the liver is referred to as:
   a. Glisson capsule
   b. Gerota fascia
   c. Morison pouch

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d. Hepatic fascia

3. The left lobe of the liver can be separated from the right lobe by the:
   a. Right hepatic vein
   b. Middle hepatic vein
   c. Left hepatic vein
   d. Falciform ligament

4. The TIPS shunt is placed:
   a. Between the main hepatic artery and main portal vein
   b. Between a portal vein and hepatic vein
   c. Between the common hepatic duct and common bile duct
   d. Between a portal vein and hepatic artery

5. The right lobe of the liver is divided into segments by the:
   a. Middle lobar fissure
   b. Middle hepatic vein
   c. Right hepatic vein
   d. Left hepatic vein

6. The right intersegmental fissure contains the:
   a. Right hepatic vein
   b. Middle hepatic vein
   c. Left portal vein
   d. Right portal vein

7. The main portal vein divides into:
   a. Middle, left, and right branches
   b. Left and right branches
   c. Anterior and posterior branches
   d. Medial and lateral branches

8. The ligamentum teres can be used to separate the:
   a. Medial and lateral segments of the left lobe
   b. Medial and posterior segments of the right lobe
   c. Anterior and medial segments of the left lobe
   d. Anterior and posterior segments of the right lobe

9. The main lobar fissure contains the:
   a. Right hepatic vein
   b. Middle hepatic vein
   c. Main portal vein
   d. Right portal vein

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10. All of the following are located within the porta hepatis except:
    a. Main portal vein
    b. Common bile duct
    c. Hepatic artery
    d. Middle hepatic vein

11. Right-sided heart failure often leads to enlargement of the:
    a. Abdominal aorta
    b. IVC and hepatic veins
    c. IVC and portal veins
    d. Portal veins and spleen

12. Which of the following is typically transmitted through contaminated water found in places such as Mexico, Central America, South America, Asia, India, and Africa?
    a. Amebic liver abscess
    b. Hydatid liver cyst
    c. Candidiasis
    d. Hepatoma

13. The right portal vein divides into:
    a. Middle, left, and right branches
    b. Left and right branches
    c. Anterior and posterior branches
    d. Medial and lateral branches

14. The diameter of the portal vein should not exceed:
    a. 4 mm
    b. 8 mm
    c. 10 mm
    d. 13 mm

15. The right lobe of the liver can be divided into:
    a. Medial and lateral segments
    b. Medial and posterior segments
    c. Anterior and medial segments
    d. Anterior and posterior segments

16. Which of the following is true about the portal veins?
    a. Portal veins carry deoxygenated blood away from the liver.
    b. Portal veins have brighter walls than the hepatic veins.
    c. Portal veins should demonstrate hepatofugal flow.
    d. Portal veins increase in diameter as they approach the diaphragm.

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17. The left lobe of the liver can be divided into:
    a. Medial and lateral segments
    b. Medial and posterior segments
    c. Anterior and medial segments
    d. Anterior and posterior segments

18. Normal flow within the hepatic artery should demonstrate a:
    a. High-resistance wave form pattern, with a slow upstroke, and gradual deceleration with diastole
    b. Low-resistance wave form pattern, with a quick upstroke, and gradual deceleration with diastole
    c. Low-resistance wave form pattern, with a slow upstroke, and gradual acceleration with diastole
    d. High-resistance wave form patter, with a quick upstroke, and gradual deceleration with diastole

19. Budd–Chiari syndrome leads to a reduction in the size of the:
    a. Hepatic arteries
    b. Portal veins
    c. Hepatic veins
    d. Common bile duct

20. A tonguelike extension of the right lobe of the liver is termed:
    a. Papillary lobe
    b. Focal hepatomegaly
    c. Riedel lobe
    d. Morison lobe

21. The left portal vein divides into:
    a. Middle, left, and right branches
    b. Left and right branches
    c. Anterior and posterior branches
    d. Medial and lateral branches

22. The left umbilical vein after birth becomes the:
    a. Falciform ligament
    b. Main lobar fissure
    c. Ligamentum teres
    d. Ligamentum venosum

23. Normal flow within the hepatic veins is said to be:
    a. Biphasic

b. Irregular
c. High resistant
d. Triphasic

24. The inferior extension of the caudate lobe is referred to as:
    a. Papillary process
    b. Focal hepatomegaly
    c. Riedel process
    d. Morison lobe

25. Which of the following is the most common reason for a liver transplant?
    a. Hepatocellular carcinoma
    b. Hepatitis C
    c. Hepatitis B
    d. Hepatic metastasis

26. Clinical findings of fatty infiltration of the liver include:
    a. Elevated liver function tests
    b. Fever
    c. Fatigue
    d. Weight loss

27. Shortly after birth, the ductus venosus collapses and becomes the:
    a. Falciform ligament
    b. Main lobar fissure
    c. Ligamentum teres
    d. Ligamentum venosum

28. Sonographically, when the liver is difficult to penetrate and diffusely echogenic, this is indicative of:
    a. Portal vein thrombosis
    b. Metastatic liver disease
    c. Primary liver carcinoma
    d. Fatty liver disease

29. The most common cause of cirrhosis is:
    a. Portal hypertension
    b. Hepatitis
    c. Alcoholism
    d. Cholangitis

30. Clinical findings of hepatitis include all of the following except:
    a. Jaundice

b. Fever
c. Chills
d. Pericholecystic fluid

31. What form of hepatic abnormality are immunocompromised patients more prone to develop?
    a. Hepatic adenoma
    b. Amebic abscess
    c. Hydatid liver abscess
    d. Candidiasis

32. All of the following are sequela of cirrhosis except:
    a. Portal vein thrombosis
    b. Hepatic artery contraction
    c. Portal hypertension
    d. Splenomegaly

33. Normal flow toward the liver in the portal veins is termed:
    a. Hepatopetal
    b. Hepatofugal

34. Which of the following masses would be most worrisome for malignancy?
    a. Echogenic mass
    b. Cystic mass with posterior enhancement
    c. Isoechoic mass with a central scar
    d. Hyperechoic mass with a hypoechoic halo

35. Which of the following is the most common form of liver cancer?
    a. Hepatocellular carcinoma
    b. Adenocarcinoma
    c. Metastatic liver disease
    d. Hepatoblastoma

36. Which hepatic mass is closely associated with oral contraceptive use?
    a. Hepatic adenoma
    b. Hepatic hypernephroma
    c. Hepatic hamartoma
    d. Hepatic hemangioma

37. Which of the following is considered the most common benign childhood hepatic mass?
    a. Hepatoblastoma

b. Hepatoma
c. Hematoma
d. Hemangioendothelioma

38. All of the following are clinical findings of HCC except:
    a. Reduction in AFP
    b. Unexplained weight loss
    c. Fever
    d. Cirrhosis

39. The childhood syndrome Beckwith–Weidemann is associated with an increased risk for developing:
    a. Hepatoblastoma
    b. Cirrhosis
    c. Portal hypertension
    d. Hepatitis

40. Which of the following is associated with *E. granulosus*?
    a. Candidiasis
    b. Amebic liver abscess
    c. Hydatid liver cyst
    d. Hepatocellular carcinoma

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3

The Gallbladder

Introduction

Sonography is often the initial imaging modality of choice for the identification of biliary disease. Therefore, patients who present with clinical signs and symptoms suggesting biliary disease must be systematically examined by the sonographer. This chapter reviews gallbladder anatomy, physiology, and pathology.

Key Terms

acalculous cholecystitis—the inflammation of the gallbladder without associated gallstones

acute cholecystitis—the sudden onset of gallbladder inflammation

adenomyomatosis—benign hyperplasia of the gallbladder wall

biliary colic—pain located in the right upper quadrant in the area of the gallbladder

champagne sign—the effect of dirty shadowing, reverberation, or ring down artifact caused by gas or gas bubbles produced by bacteria within the nondepedent gallbladder wall

cholecystectomy—the surgical removal of the gallbladder

cholecystokinin—the hormone produced by the duodenum that causes the gallbladder to contract

choledocholithiasis—the presence of a gallstone or gallstones within the biliary tree

cholelithiasis—gallstone(s)

cholesterolosis—a condition that results from the disturbance in cholesterol metabolism and accumulation of cholesterol typically within a focal region of the gallbladder wall; may be diffuse and referred to as a strawberry gallbladder

chronic cholecystitis—cholecystitis that results from the intermittent obstruction of the cystic duct by gallstones

chyme—partially digested food from the stomach

comet tail artifact—a form of reverberation artifact in which there is a band of echoes that taper distal to a strong reflector

Courvoisier gallbladder—the clinical detection of an enlarged, palpable gallbladder caused by a biliary obstruction in the area of the pancreatic head; typically caused by a pancreatic head mass

Crohn disease—chronic inflammatory bowel disease that leads to thickening and scarring of the bowel walls leading to chronic pain and recurrent bowel obstructions

cystic duct—the duct that connects the gallbladder to the common hepatic duct

emphysematous—abnormal distention of an organ with air or gas

empyema—the presence or collection of pus

gallbladder torsion—the twisting of the vascular supply to the gallbladder

Hartmann pouch—an outpouching of the gallbladder neck

hemolytic anemia—a condition that results in the destruction of red blood cells

hepatization of the gallbladder—situation in which the gallbladder is completely filled with tumefactive studge, causing the gallbladder to appear isoechoic to the liver tissue

hydropic gallbladder—an enlarged gallbladder; also referred to as mucocele of the gallbladder

hyperalimentation—the intravenous administration of nutrients and vitamins

hyperplastic cholecystosis—a group of proliferative and degenerative gallbladder disorders which includes both adenomyomatosis and cholesterolosis

hypoalbuminemia—abnormal low level of albumin in the blood; albumin is a protein produced in the liver

junctional fold—a fold in the neck of the gallbladder

Kawasaki disease—a condition associated with vasculitis and can affect the

lymph node, skin, and mucous membranes; also referred to as mucocutaneous lymph node syndrome

leukocytosis—an elevated white blood cell count

Murphy sign—pain directly over the gallbladder with applied probe pressure

parity—the total number of completed pregnancies that have reached the age of viability

pericholecystic fluid—fluid around the gallbladder

peritonitis—inflammation of the peritoneal lining

Phrygian cap—gallbladder variant when the gallbladder fundus is folded onto itself

porcelain gallbladder—the calcification of all or part of the gallbladder wall

postprandial—after a meal

Rokitansky–Aschoff sinuses—tiny pockets within the gallbladder wall

sepsis—a life-threatening condition caused by the body's response to a systemic infection

sequela—an illness resulting from another disease, trauma, or injury

sickle cell disease—form of hemolytic anemia typically found in Africans or people of African descent; characterized by dysfunctional sickle-shaped red blood cells

spiral valves of Heister—folds located within the cystic duct that prevent it from collapsing and distending

suppurative cholecystitis—complication of acute cholecystitis characterized by pus accumulation within the gallbladder

total parenteral nutrition—the feeding of a person intravenously

tumefactive sludge—thick sludge

wall-echo-shadow sign—shadowing from the gallbladder fossa produced by a gallbladder that is completely filled with gallstones

ANATOMY AND PHYSIOLOGY OF THE GALLBLADDER

The gallbladder, which is located posterior to the right lobe of the liver within the gallbladder fossa, is considered an intraperitoneal organ. Although the location of the gallbladder relies on the position of the patient, a useful landmark to locate the gallbladder fossa is the main lobar fissure. This pear-shaped sac is used to store and concentrate bile that is produced by the liver. It has three distinct layers within its walls. The mucosal layer is the

innermost layer. It consists of multiple folds and rugae. The middle layer of the wall is the fibromuscular layer, whereas the outer is the serosal layer.

The gallbladder has a neck, body, and fundus. The neck is contiguous with the cystic duct, which connects the gallbladder to the rest of the biliary system at the level of the common hepatic duct. The portion of the biliary tree that lies distal to the union of the cystic duct with the hepatic duct is the common bile duct. The fundus is the most dependent portion of the gallbladder and therefore is a common location for gallstones to collect.



SOUND OFF

The most common location of gallstones is in the fundus because it is the most dependent part of the gallbladder.

Blood supply to the gallbladder is via the cystic artery, typically a small branch of the right hepatic artery. As chyme leaves the stomach, the hormone cholecystokinin is released by the duodenum, causing the gallbladder to contract. Bile consequently flows from the gallbladder through the cystic duct and into the common bile duct. Although the most common variant in gallbladder shape is the Phrygian cap, other variants may be noted (Table 3-1). Other positional and developmental anomalies of the gallbladder include duplication, floating gallbladder, agenesis, and hypoplasia. Although the occurrence is rare, the floating variant does have potential for twisting off of the blood supply, resulting in a condition termed gallbladder torsion or gallbladder volvulus, in which the patient will present with right upper quadrant pain.

TABLE 3-1 Normal variants of the gallbladder

Normal Variants in Gallbladder Shape	Description
Bilobed gallbladder	Hourglass appearance
Septated gallbladder	Appears as thin separations within the gallbladder
Phrygian cap (most common variant)	Gallbladder fundus is folded onto itself
Hartmann pouch	Outpouching of gallbladder neck
Junctional fold	Prominent fold located at the junction of the gallbladder neck

SOUND OFF
Cholecystokinin, produced by the duodenum, causes the gallbladder to contract.

SONOGRAPHY OF THE GALLBLADDER

A gallbladder sonogram should be performed after the patient has had nothing to eat for at least 4 hours, although a period of 8 hours is optimal. The normal gallbladder appears sonographically as an anechoic, pear-shaped structure in the sagittal plane (Fig. 3-1). A true transverse image of the gallbladder will typically yield an anechoic circle (Fig. 3-2). It is helpful in most situations to scan at the level of the main lobar fissure and right portal vein to find the gallbladder. The size of gallbladder is variable, although the normal ranges are said to be 8 to 10 cm in length and no more than 4 to 5 cm in diameter. Most authors agree that a gallbladder that measures over 4 cm in transverse should evoke special scrutiny of the biliary tract for signs of obstruction. The gallbladder should be evaluated in the supine, left lateral decubitus, prone, upright, and any other position needed to demonstrate the mobility—or lack of mobility—of any apparent intraluminal objects like gallstones or polyps (Fig. 3-3). Intercostal imaging should be employed, especially if midline visualization is obstructed by overlying bowel gas.

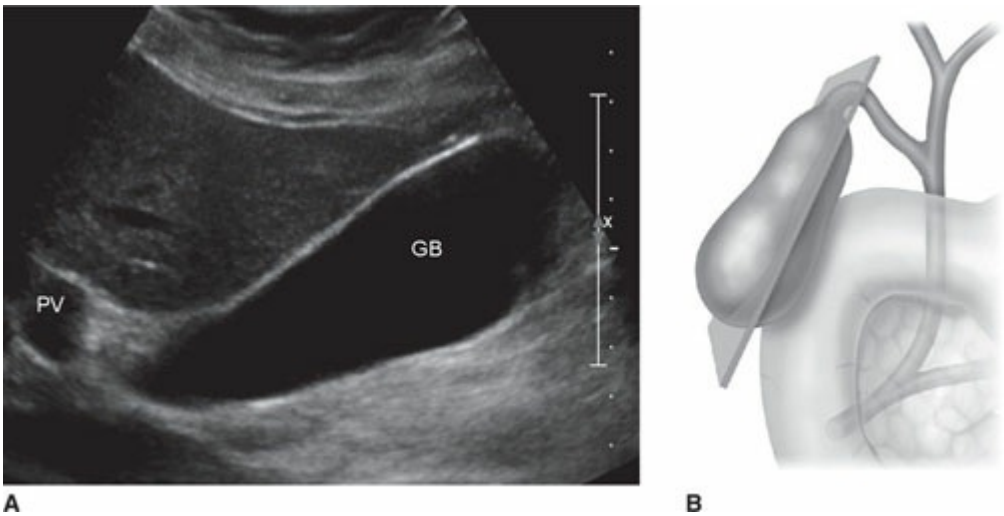


Figure 3-1 Sagittal gallbladder. Sonogram (**A**) of the normal gallbladder (*GB*) and portal vein (*PV*) in the sagittal plane (**B**).

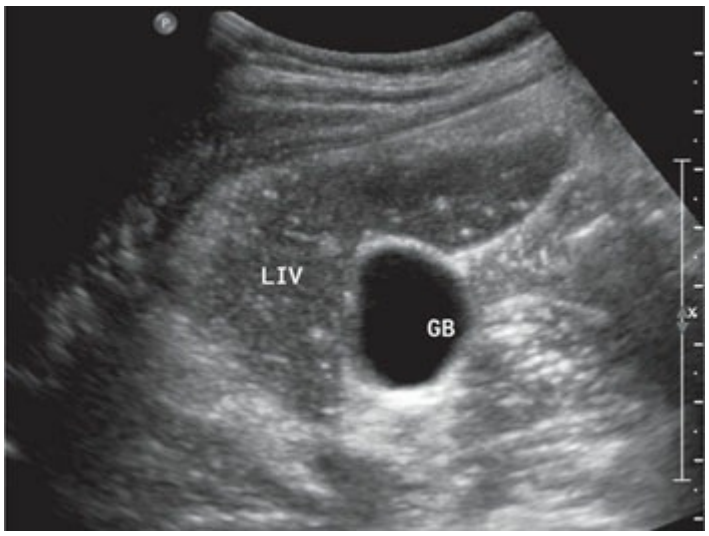


Figure 3-2 Transverse gallbladder. Transverse image of the liver (*LIV*) gallbladder (*GB*) fundus.

The gallbladder neck and fundus should be examined closely because these locations are common sites for gallstones to become lodged or to accumulate. The gallbladder wall, which can be focally or diffusely thickened, should measure no more than 3 mm (Tables 3-2 and 3-2). There are several causes of nonvisualization of the gallbladder, with the most obvious being a previous cholecystectomy (Table 3-4). It is important to note that patients who have had a recent cholecystectomy may have some residual fluid located within the gallbladder fossa. Right upper quadrant sonography may be needed to further assess these patients for residual choledocholithiasis or postoperative complications.

When clinical findings and sonographic findings found in this chapter are consistent with gallbladder disease, the sonographer should closely evaluate the liver, other parts of the biliary tree, and pancreas for additional complications such as intrahepatic and extrahepatic biliary tree obstruction and pancreatitis. Helpful labs to evaluate in the presence of suspected gallbladder disease include alkaline phosphatase (ALP), alanine aminotransferase (ALT), bilirubin, gamma-glutamyltransferase (GGT), and white blood cell count (WBC).

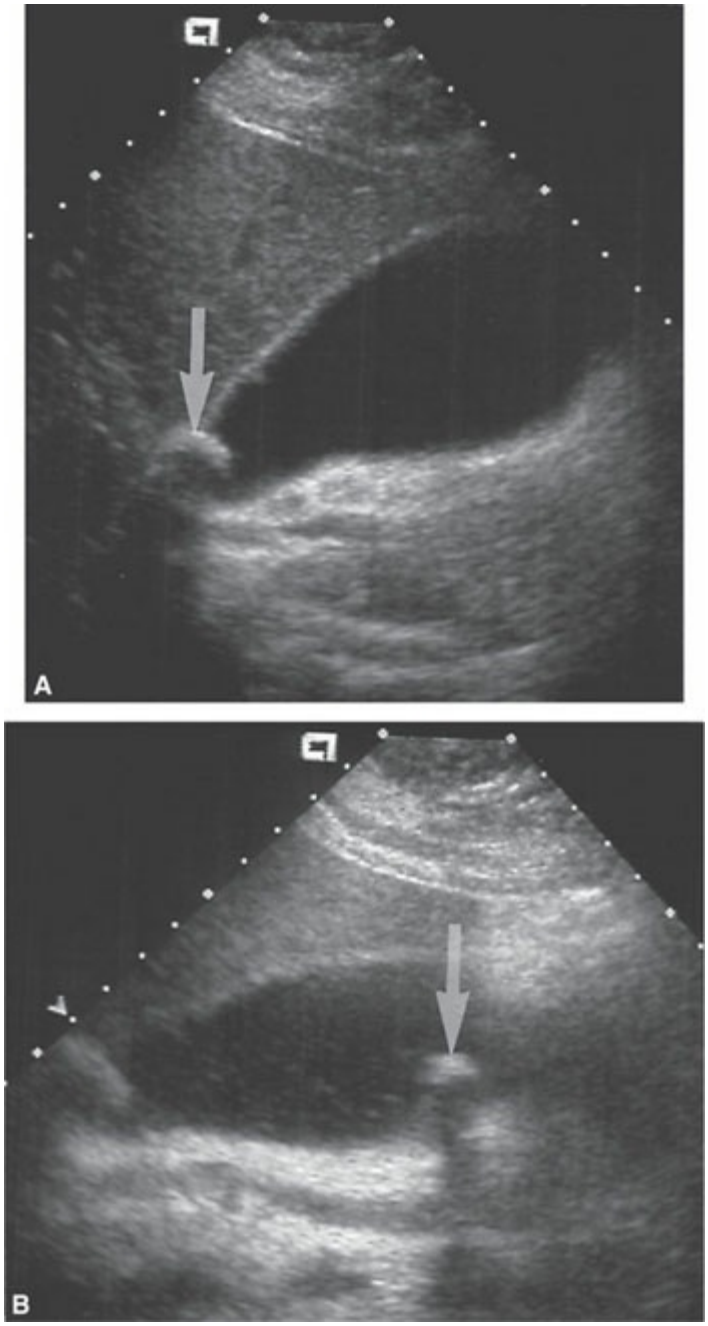


Figure 3-3 Rolling gallstone. **A.** The patient is in the supine position, and the gallstone (*arrow*) is located within the neck of the gallbladder. **B.** The patient has been rolled into the left lateral decubitus position, and the gallstone (*arrow*) moves into the fundus of the gallbladder.

SOUND OFF
When gallbladder disease is suspected, look for an elevation in ALP, ALT, bilirubin, GGT, and WBC.

TABLE 3-2 Sources of diffuse gallbladder wall thickening

Postprandial

Acute cholecystitis
Chronic cholecystitis
Adenomyomatosis
Hepatic dysfunction (e.g., hepatitis, cirrhosis)
Benign ascites
Hypoalbuminemia
AIDS cholangiopathy
Congestive heart failure
Gallbladder carcinoma

TABLE 3-3 Sources of focal gallbladder wall thickening

Gallbladder polyp
Adenomyomatosis
Gallbladder carcinoma
Adhered gallstone

TABLE 3-4 Causes of nonvisualization of the gallbladder

Cholecystectomy
Gallbladder completely filled with stones (**Wall-echo-shadow sign** or WES sign)
Postprandial
Chronic cholecystitis (collapse and fibrosis of the gallbladder)
Ectopic location
Agenesis
Hepatization of the gallbladder (caused by **tumefactive sludge**)
Air-filled gallbladder or **emphysematous** cholecystitis

GALLBLADDER PATHOLOGY

Cholelithiasis

Biliary stones that form within the gallbladder are called gallstones, or cholelithiasis. Gallstones typically consist of a mixture of cholesterol, calcium bilirubinate, and calcium carbonate. Cholelithiasis formation has been associated with many risk factors and predisposing conditions (Table 3-5). Gallstones are more commonly seen in female patients. Moreover, patients who are fat, female, fertile, flatulent, fair, and forty—the six Fs—

have been shown to have higher incidence of gallstones. Gallstones have been found in children, in newborns, and in the fetus. Pediatric patients who have hemolytic anemia, such as sickle cell disease, and patients with Crohn disease have an increased risk for developing gallstones.

TABLE 3-5 Risk factors and predisposing conditions for cholelithiasis

Obesity
Pregnancy
Increased **parity**
Gestational diabetes
Estrogen therapy
Oral contraceptive use
Rapid weight loss programs
Hemolytic disorder
Crohn disease
Total parenteral nutrition

Clinically, patients who have gallstones may be asymptomatic. But biliary colic is often present. Other findings include abdominal pain after fatty meals, epigastric pain, nausea and vomiting, and pain that radiates to the shoulders. Sonographically, a cholelithiasis appears as a mobile, echogenic structure within the gallbladder lumen that produces an acoustic shadow (Fig. 3-4). A gallbladder that is completely filled with gallstones may exhibit the wall-echo-shadow (WES) sign. In this situation, only the gallbladder wall and shadowing from the gallbladder fossa are observable (Fig. 3-5). It is important to note that tiny folds within the cystic duct, the spiral valves of Heister, can also produce a posterior shadow, and therefore small gallstones may be suspected. Changing the patient position and altering scanning planes can often resolve this dilemma. Small gallstones may become adhered to the gallbladder wall and may also not produce a well-defined acoustic shadow. The twinkle artifact—which occurs posterior to a strong, granular, and irregular surface like crystals, calculi, or calcifications—may be used to differentiate an adhered, small gallstone from a gallbladder polyp (Fig. 3-6).



Figure 3-4 Cholelithiasis. Multiple shadowing, echogenic gallstones are noted within this gallbladder.



Figure 3-5 WES sign. Sonogram of the liver and gallbladder fossa reveals the WES sign which denotes a gallbladder that is completely filled with gallstones. WES, wall-echo-shadow.

CLINICAL FINDINGS OF CHOLELITHIASIS

1. Asymptomatic
2. Biliary colic
3. Abdominal pain after fatty meals
4. Epigastric pain
5. Nausea and vomiting
6. Pain that radiates to the shoulders

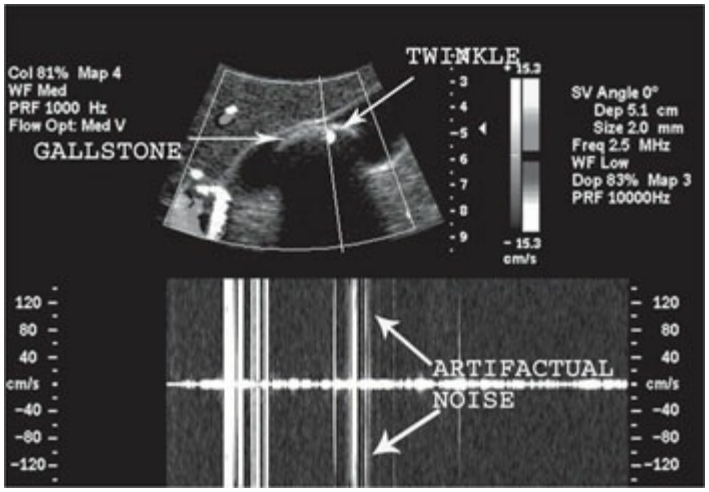


Figure 3-6 Twinkle sign. Color and pulsed Doppler demonstrate a gallstone, the twinkle artifact, and the artifactual noise that results. Color image provided online.

SONOGRAPHIC FINDINGS OF CHOLELITHIASIS

1. Echogenic, mobile, shadowing structure(s) within the lumen of the gallbladder
2. Stones that lodge within the cystic duct or neck of the gallbladder may not move
3. WES sign may be present (gallbladder completely filled with stones)

SOUND OFF
The twinkle artifact can be used to identify small gallstones.

Gallbladder Sludge

Sludge, or viscid bile, within the gallbladder is most often associated with biliary stasis. Sludge may be found in patients who have coexisting gallstones or gallbladder carcinoma and in those suffering from jaundice, liver disease, hyperalimentation, or sepsis. In addition, patients who have undergone an extended period of fasting or are on total parenteral nutrition may have gallbladder sludge. Sludge is typically asymptomatic.

Sonographically, sludge appears as a collection of low-level, nonshadowing, dependent echoes within the gallbladder lumen (Fig. 3-7). When sludge is visualized, the sonographer should closely evaluate the gallbladder for signs of small gallstones and other possible sonographic markers of cholecystitis (Fig. 3-8). Occasionally, sludge can be thick and mimic an intraluminal gallbladder mass. This is referred to as tumefactive sludge. The mobility of this type of sludge should be observed vigilantly. If sludge does not move with patient positioning, suspicion of a solid gallbladder mass may arise, and thus color Doppler should be used to evaluate for signs of vascularity. Tumefactive sludge may also form into sludge balls, which are typically mobile and will not produce an acoustic

shadow. The gallbladder can also completely fill with tumefactive sludge, causing the gallbladder to appear isoechoic to the liver tissue, a condition referred to as hepatization of the gallbladder (Fig. 3-9).

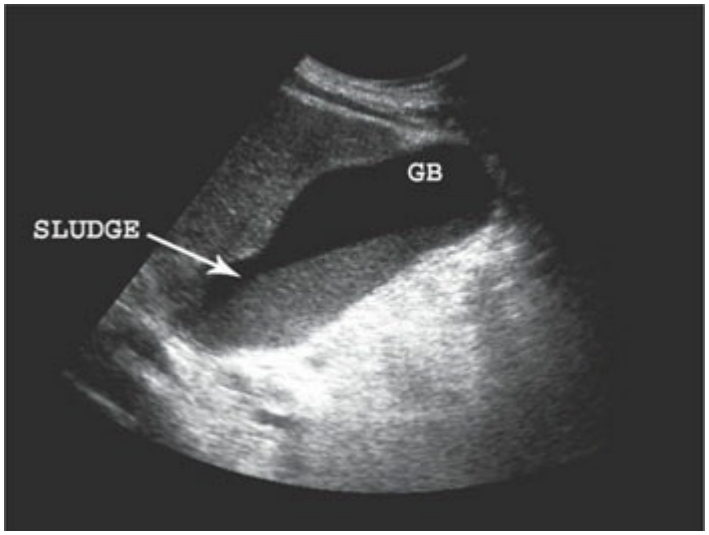


Figure 3-7 Sludge. Sagittal image of the gallbladder (*GB*) demonstrates layering sludge.

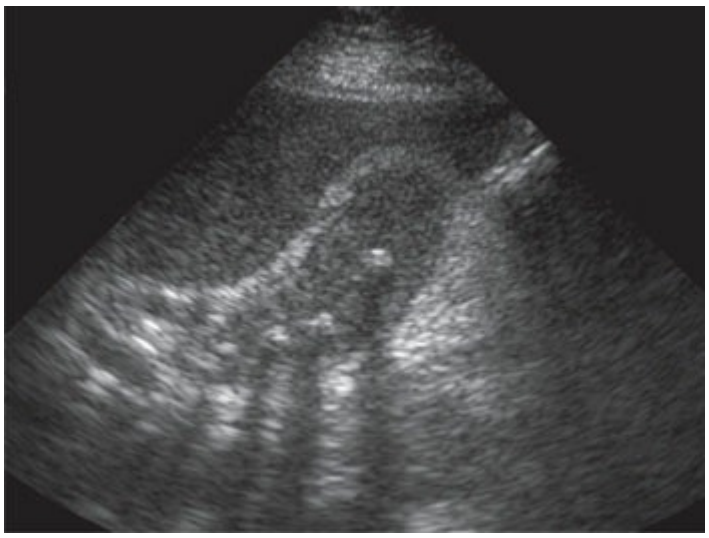


Figure 3-8 Sludge and stones. Sagittal image of the gallbladder that contains both sludge, and small, shadowing stones.

CLINICAL FINDINGS OF GALLBLADDER SLUDGE

1. Asymptomatic
2. Any reason for biliary stasis (e.g., total parenteral nutrition, extended period of fasting)

SONOGRAPHIC FINDINGS OF GALLBLADDER SLUDGE

1. A collection of low-level, nonshadowing, dependent echoes within the

gallbladder lumen

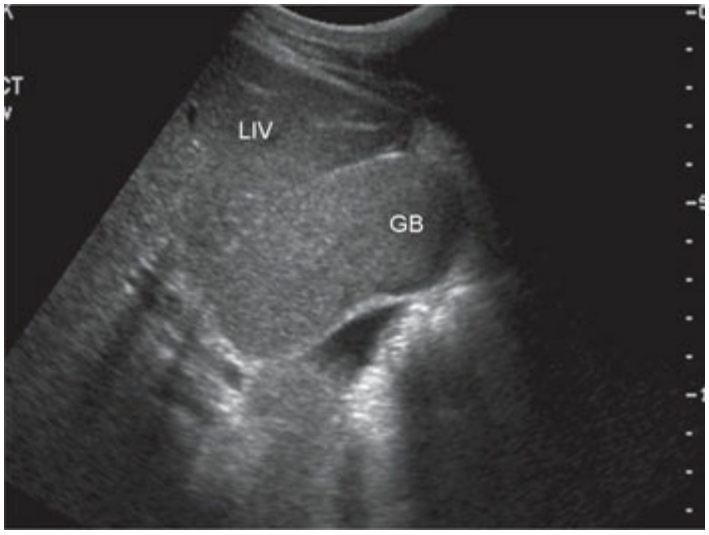


Figure 3-9 Sagittal image of a gallbladder demonstrating hepatization, in which the gallbladder (*GB*) is filled with sludge and is consequently isoechoic to the liver (*LIV*).

Gallbladder Polyps

A gallbladder polyp or cholesterol polyp is a projection of tissue from the gallbladder wall that protrudes into the lumen of the gallbladder. Cholesterol polyps are the most common type of polyps. They tend to be small, measure less than 10 mm, and are the result of an accumulation of cholesterol and triglycerides within the gallbladder wall, thus causing an elevation in the gallbladder mucosal layer. Polyps may be solitary or multiple and will appear sonographically as hyperechoic, nonshadowing, and nonmobile projections of tissue. Although most polyps have a stalk, the stalk may not always be seen, and thus they typically yield the "ball-on-the-wall" sign because the polyp appears to be a round object, like a ball, that is stuck to the gallbladder wall. On varying the patient's position, polyps will neither shadow nor move (Fig. 3-10). Most polyps are benign and incidentally discovered. However, a rapidly growing polyp or large polyp is worrisome for gallbladder carcinoma (see "Gallbladder Carcinoma" section in this chapter).

Gallbladder polyps are often seen with cholesterolosis that results from the disturbance in cholesterol metabolism and accumulation of cholesterol typically within a focal region of gallbladder wall. Cholesterolosis is considered a subset of hyperplastic cholecystosis, and it may also cause a diffuse polypoid appearance of the gallbladder referred to as a strawberry gallbladder, although this is not distinct on imaging. Hyperplastic cholecystosis also includes adenomyomatosis.

CLINICAL FINDINGS OF POLYPS

1. Asymptomatic

SONOGRAPHIC FINDINGS OF POLYPS

1. Hyperechoic, nonshadowing, and nonmobile mass that projects from the gallbladder wall into the gallbladder lumen

SOUND OFF

Hyperplastic cholecystosis, which is a group of proliferative and degenerative gallbladder disorders, includes both adenomyomatosis and cholesterolosis.

Adenomyomatosis

Adenomyomatosis is literally interpreted as "the condition of glands within the muscle" of the gallbladder. Like cholesterolosis, it is a form of hyperplastic cholecystosis of the gallbladder. With adenomyomatosis, the luminal epithelium is hyperplastic, and the muscular layer becomes thickened producing diverticuli or tiny pockets called Rokitansky–Aschoff sinuses. These sinuses may contain cholesterol crystals that produce comet tail artifact that is most often seen protruding into the gallbladder lumen from the anterior wall (Fig. 3-11). Adenomyomatosis can be focal or diffuse and is clinically silent and most often insignificant.

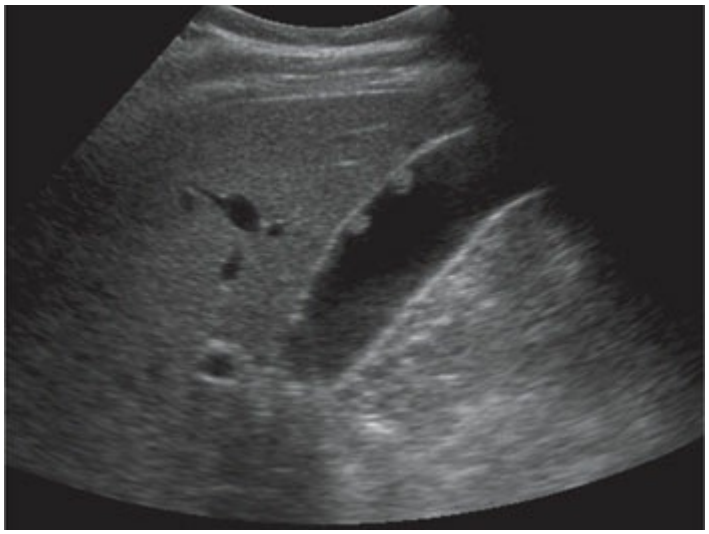


Figure 3-10 Gallbladder polyps. Two polyps are noted attached to the anterior wall of this gallbladder.

CLINICAL FINDINGS OF ADENOMYOMATOSIS

1. Asymptomatic

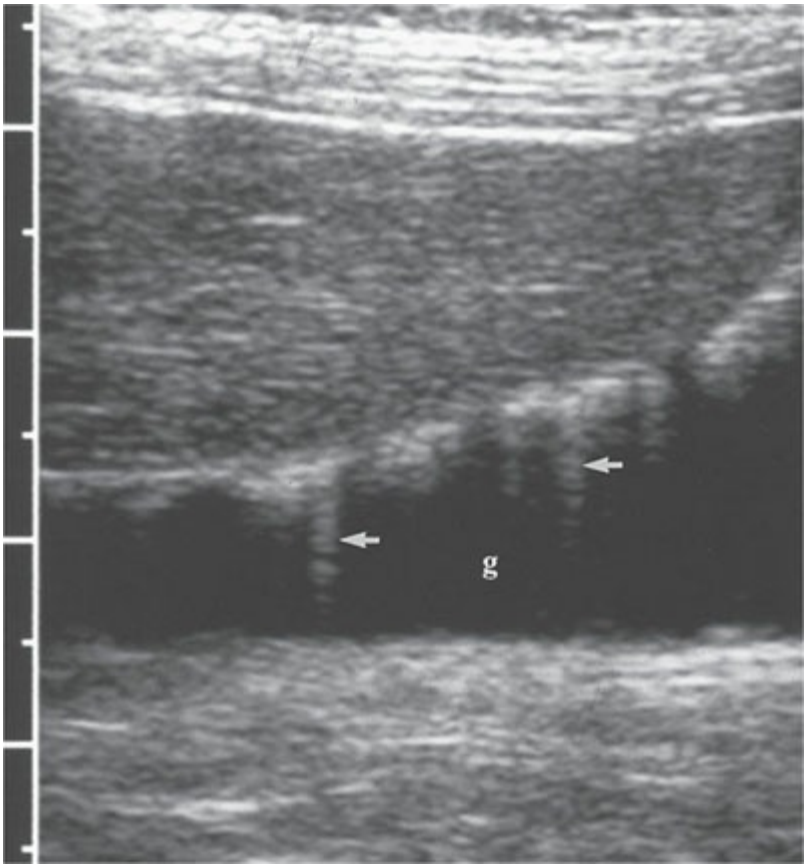


Figure 3-11 Adenomyomatosis of the gallbladder. Characteristic comet tail artifact (*arrows*) is produced by cholesterol crystals located in the Rokitansky–Aschoff sinuses of the anterior gallbladder (*g*) wall.

SONOGRAPHIC FINDINGS OF ADENOMYOMATOSIS

1. Focal or diffuse thickening of the gallbladder wall
2. Comet tail artifact that projects from the gallbladder wall into the lumen of the gallbladder

SOUND OFF
Adenomyomatosis is associated with comet tail artifact.

Acute Cholecystitis

The sudden onset of gallbladder inflammation is referred to as acute cholecystitis. The most common cause of acute cholecystitis is a gallstone that has become lodged in the cystic duct or neck of the gallbladder. Leukocytosis is often associated with acute cholecystitis. Other laboratory findings may include an elevation in ALP and ALT. Bilirubin may also be elevated if obstruction to the ducts occurs. Besides right upper quadrant or epigatric pain, patients often complain of focal tenderness over the gallbladder with transducer pressure when the gallbladder is inflamed. This

is termed a positive sonographic Murphy sign. Other sonographic findings include gallstones, pericholecystic fluid, sludge, and thickening of the gallbladder wall, which may contained pockets of edematous fluid creating a striated appearance (Fig. 3-12).When acute cholecystitis is suspected, the sonographer should closely evaluate the gallbladder for the progression of the disease to gangrenous cholecystitis, gallbladder perforation, and other sequela mentioned in this chapter.

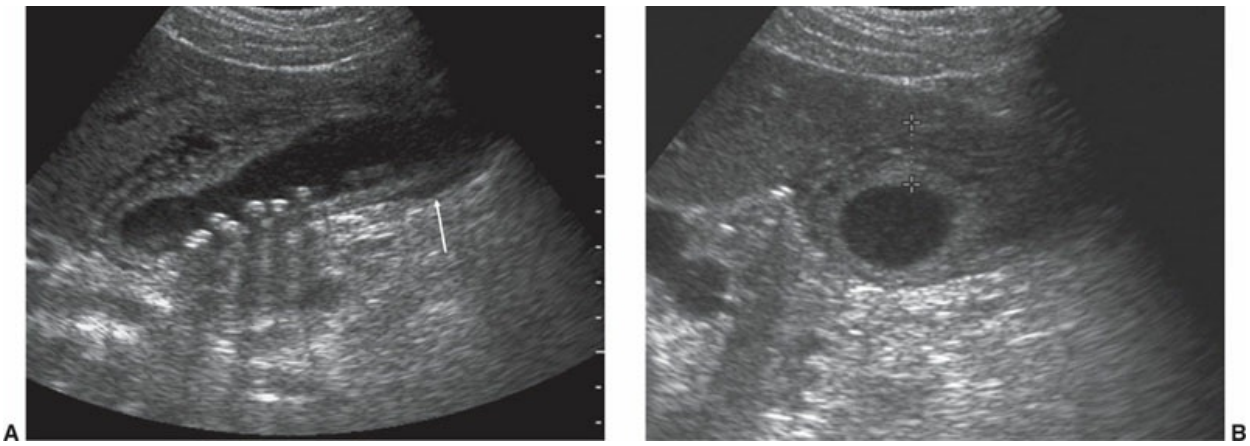


Figure 3-12 Acute cholecystitis. Sagittal **(A)** and transverse **(B)** images of a patient with a positive Murphy sign reveals an inflamed gallbladder containing gallstones and sludge, a thickened gallbladder wall (*calipers*), and pericholechystis fluid (*arrow*).

CLINICAL FINDINGS OF ACUTE CHOLECYSTITIS

1. Right upper quadrant tenderness
2. Epigastric or abdominal pain
3. Leukocytosis
4. Possible elevation in ALP, ALT, GGT, and bilirubin (with obstruction)
5. Fever
6. Pain that radiates to the shoulders
7. Nausea and vomiting

SONOGRAPHIC FINDINGS OF ACUTE CHOLECYSTITIS

1. Gallstones (evaluate the neck and cystic duct for a possible lodged stone)
2. Positive sonographic Murphy sign
3. Gallbladder wall thickening
4. Gallbladder enlargement
5. Pericholecystic fluid
6. Sludge

SOUND OFF

The presence of gallstones and a positive sonographic Murphy sign is a strong indicator of acute cholecystitis.

Gangrenous Cholecystitis and Gallbladder Perforation

Gangrenous cholecystitis can be a direct evolution of acute cholecystitis. In addition to the sonographic findings of acute cholecystitis, gangrenous cholecystitis includes focal wall necrosis, bulges of the gallbladder wall, sloughed membranes, and ulcerative craters. Perforation, or rupture, of the gallbladder has a high mortality and morbidity rate secondary to peritonitis. A distinct gallbladder wall tear may be noted with sonography, and the gallbladder may appear irregular in shape (Fig. 3-13). Clinically, the patient does not always demonstrate the sonographic Murphy sign. One differential diagnosis of gangrenous cholecystitis is empyema of the gallbladder, also referred to as suppurative cholecystitis, in which the gallbladder is filled with purulent material, commonly referred to as pus. Although it may be difficult to diagnose sonographically, chronic infection of the gallbladder may also result in xanthogranulomatous cholecystitis that is characterized by asymmetrical gallbladder wall thickening and the other common sonographic findings of acute cholecystitis.

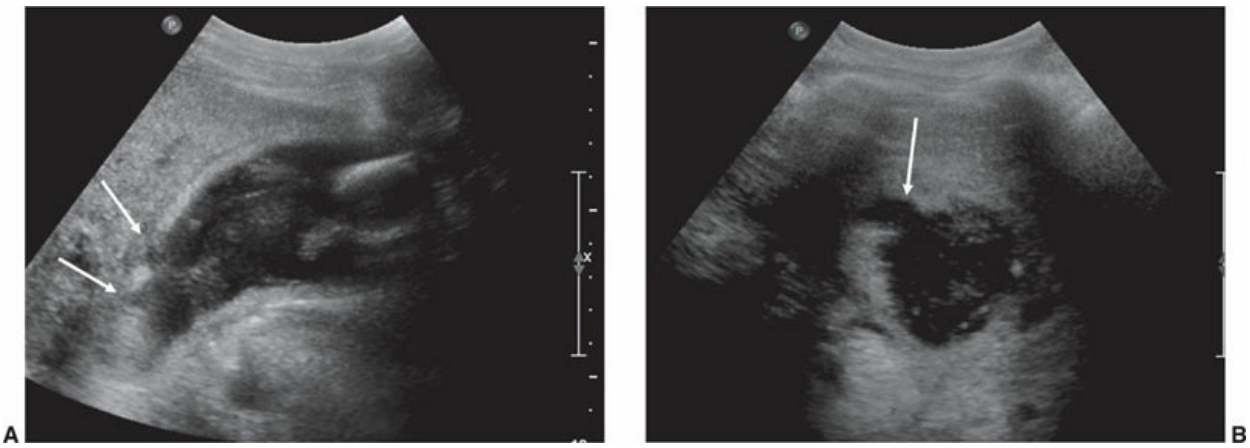


Figure 3-13 Gallbladder perforation. Longitudinal **(A)** and transverse **(B)** images in a patient with gallbladder perforation. The defect seen on the anterior wall (*arrows*) is better demonstrated in the transverse section. Debris is also located within the gallbladder lumen.

CLINICAL FINDINGS OF GANGRENOUS CHOLECYSTITIS AND GALLBLADDER PERFORATION

1. Right upper quadrant pain
2. Epigastric or abdominal pain
3. Leukocytosis
4. Possible elevation in ALP, ALT, GGT, and bilirubin (with obstruction)

5. Fever
6. Pain that radiates to the shoulders
7. Nausea and vomiting

SONOGRAPHIC FINDINGS OF GANGRENOUS CHOLECYSTITIS AND GALLBLADDER PERFORATION

1. Gallstones (evaluate the neck and cystic duct for a possible lodged stone)
2. Loss of the sonographic Murphy sign
3. Gallbladder wall thickening with a possible perceptible wall tear
4. Focal wall necrosis, bulges of the gallbladder wall, sloughed membranes, and ulcerative craters
5. Gallbladder loses its typically shape
6. Pericholecystic fluid
7. Sludge

Emphysematous Cholecystitis

Emphysematous cholecystitis, most often discovered in diabetic patients, is a form of acute cholecystitis that is caused by gas-forming infection invading the gallbladder lumen, wall, or both. The gas or gas bubbles produced by the bacteria within the gallbladder wall will lead to the manifestation of dirty shadowing , reverberation, or ring down artifact, and these gas bubbles may rise to the nondependent wall of the gallbladder, producing a sonographic sign referred to as the “champagne” sign (Fig. 3-14). Although patients with emphysematous cholecystitis may not have a positive Murphy sign and other clinical symptoms associated with acute cholecystitis, this form of the disease can lead to gallbladder perforation, sepsis, and become fatal quickly.

CLINICAL FINDINGS OF EMPHYSEMATOUS CHOLECYSTITIS

1. Diabetic patient
2. Right upper quadrant pain, possibly without Murphy sign
3. Fever
4. Can progress to **sepsis**

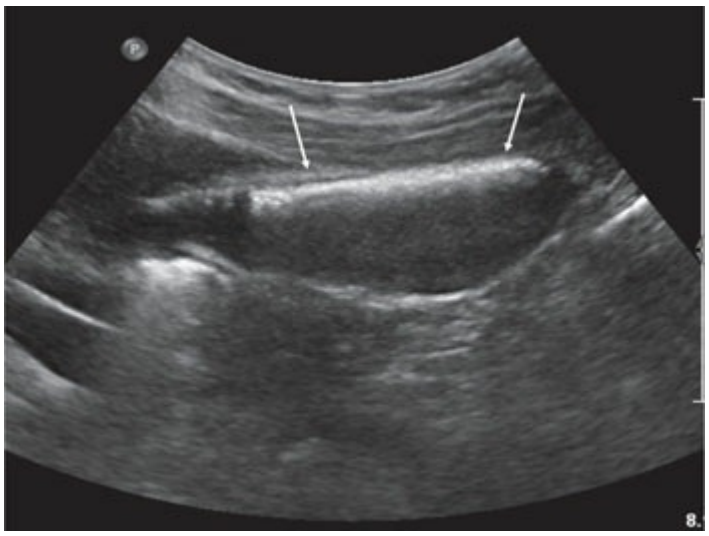


Figure 3-14 Emphysematous cholecystitis. Longitudinal sonogram of a gallbladder that contains air (*arrows*) within its anterior wall secondary to emphysematous cholecystitis.

SONOGRAPHIC FINDINGS OF EMPHYSEMATOUS CHOLECYSTITIS

1. Dirty shadowing reverberation, or ring down artifact emanating from the gallbladder wall or gallbladder lumen
2. Champagne sign (gas bubbles within the gallbladder wall—like the bubbles in champagne—may rise to the nondependent wall of the gallbladder)

SOUND OFF

Emphysematous cholecystitis is most often discovered in diabetic patients.

Chronic Cholecystitis

Chronic cholecystitis results from the intermittent obstruction of the cystic duct by gallstones, resulting in multiple bouts of acute cholecystitis. Clinical findings for chronic cholecystitis include intolerance to fatty foods and a nontender gallbladder. Sonographically, the gallbladder wall will appear thickened, and there may be evidence of WES sign.

CLINICAL FINDINGS OF CHRONIC CHOLECYSTITIS

1. Intolerance to fatty foods because of subsequent abdominal pain
2. Nontender gallbladder

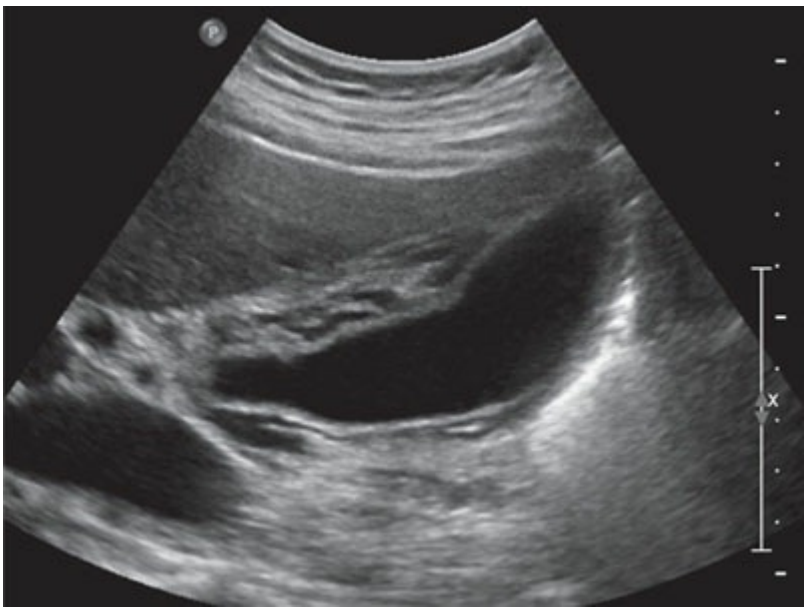


Figure 3-15 Acalculous cholecystitis. Longitudinal image of a gallbladder demonstrating a striated, thickened wall. Although the patient complained of a positive Murphy sign and fever, no gallstones were identified within the gallbladder.

SONOGRAPHIC FINDINGS OF CHRONIC CHOLECYSTITIS

1. Contracted gallbladder
2. WES sign
3. Gallstones
4. Wall thickening

Acalculous Cholecystitis

Acalculous cholecystitis presents with all of the symptoms and sonographic findings of cholecystitis except no gallstones are present (Fig. 3-15). This form of acute cholecystitis is more commonly found in children, recently hospitalized patients, or those who are immunocompromised.

CLINICAL FINDINGS OF ACALCULOUS CHOLECYSTITIS

1. Right upper quadrant tenderness
2. Epigastric or abdominal pain
3. Leukocytosis

SONOGRAPHIC FINDINGS OF ACALCULOUS CHOLECYSTITIS

1. Positive sonographic Murphy sign
2. Gallbladder wall thickening
3. Pericholecystic fluid
4. Sludge

Gallbladder Enlargement

The gallbladder should not exceed 4 to 5 cm in width and 8 to 10 cm in length. The transverse measurement is more indicative of gallbladder enlargement. And again, if the gallbladder transverse measurement exceeds 4 cm, especially in those with clinical indicators of obstruction, then careful analysis of the biliary tract should ensue. An enlarged gallbladder can be caused by a blockage of the cystic duct or other parts of the biliary tree. This may be referred to as a hydropic gallbladder. Patients with a hydropic gallbladder may be asymptomatic or may complain of epigastric pain, nausea, and/or vomiting. An enlarged gallbladder is often palpable on physical examination. Courvoisier gallbladder describes the clinical detection of an enlarged, palpable gallbladder caused by a pancreatic head mass. Patients with Courvoisier gallbladder also typically have painless jaundice. Gallbladder hydrops in older infants and children may be associated with Kawasaki disease, which is a condition associated with vasculitis and can affect the lymph node, skin, and mucous membranes.

CLINICAL FINDINGS OF GALLBLADDER ENLARGEMENT

1. Palpable gallbladder
2. Could suffer from painless jaundice (Courvoisier gallbladder)
3. Possible elevation in ALP, ALT, GGT, and bilirubin (with obstruction)

SONOGRAPHIC FINDINGS OF GALLBLADDER ENLARGEMENT

1. Gallbladder measures >4 to 5 cm in diameter or >8–10 cm in length
2. Search for obstructive entities such as choledocholithiasis or pancreatic mass

Porcelain Gallbladder

A porcelain gallbladder, which is classically clinically silent, results from the calcification of the gallbladder wall. It is sonographically recognized by the presence of an echogenic curvilinear structure within the gallbladder fossa with shadowing. Dense calcification of the gallbladder wall may appear sonographically similar to WES sign or the air seen with emphysematous cholecystitis. Thus, clinical findings should be closely evaluated. With WES sign, the posterior wall of the gallbladder is typically obscured by extensive shadowing. Therefore, the identification of the calcified posterior wall of the gallbladder is helpful to differentiate porcelain gallbladder from WES sign, although often radiography or computed tomography are often utilized to confirm the diagnosis. Gallstones and chronic inflammation are linked with porcelain gallbladder, and although current research studies reject the connection, there was once a suspected increased risk for those with a

porcelain gallbladder to development gallbladder carcinoma.

CLINICAL FINDINGS OF PORCELAIN GALLBLADDER

1. Asymptomatic

SONOGRAPHIC FINDINGS OF PORCELAIN GALLBLADDER

1. Calcification of the gallbladder wall recognized by a echogenic curvilinear structure within the gallbladder fossa with shadowing
2. The identification of the calcified posterior wall of the gallbladder is helpful to differentiate porcelain gallbladder from WES sign
3. Signs of chronic cholecystitis and gallstones may be present

SOUND OFF

The identification of the calcified posterior wall of the gallbladder is helpful to differentiate porcelain gallbladder from WES sign. With WES sign, the posterior wall is typically obscured by the shadowing gallstones within the gallbladder, although many times the posterior wall will be seen with porcelain gallbladder.

Gallbladder Carcinoma

Although it is the most common cancer of the biliary tract, gallbladder carcinoma is rare. It is thought to be caused by chronic irritation of the gallbladder wall by gallstones. Therefore, gallbladder carcinoma is almost always associated with gallstones, and the mass may actually contain gallstones. Furthermore, there appears to be an increased risk for developing gallbladder carcinoma in patients who suffer from chronic cholecystitis. Patients may be asymptomatic at the time of detection, or they may suffer from nausea, vomiting, unexplained weight loss, right upper quadrant pain, jaundice, or hepatomegaly.

Gallbladder carcinoma may appear sonographically as a distinct, nonmobile, hypoechoic mass within the lumen of gallbladder or as diffuse gallbladder wall thickening. It may also appear as an irregular polypoid mass that completely fills the gallbladder fossa, and it may have invaded the adjacent liver tissue at the time of diagnosis. Whenever a mass is visualized within the gallbladder lumen, it should be measured. Gallbladder carcinoma is suspected if a polyp or mass within the gallbladder measures greater than 1 cm. When confused with tumefactive sludge, color Doppler can reveal vessels within the malignancy (Fig. 3-16). The most common metastatic disease of the gallbladder is malignant melanoma. It is difficult to

sonographically differentiate metastasis from primary gallbladder cancer.

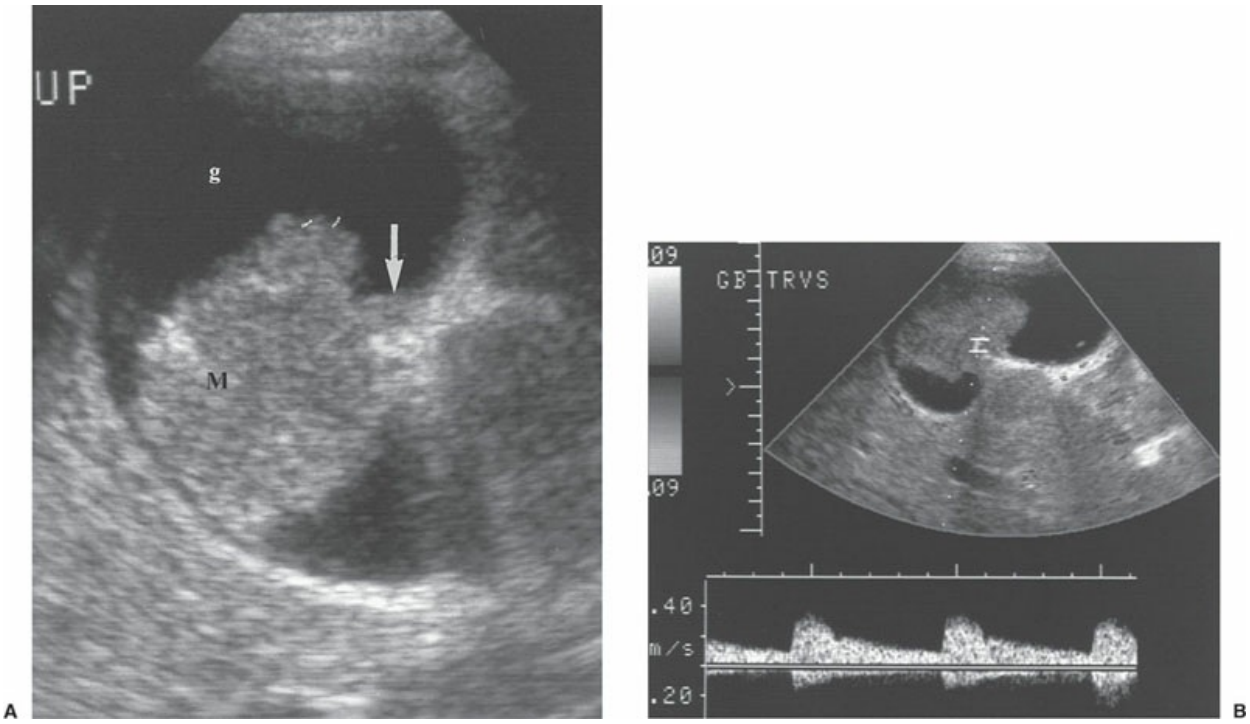


Figure 3-16 Gallbladder carcinoma. **A.** An irregular mass (*M*) projects into the gallbladder (*g*) lumen from a stalk (*arrow*). **B.** Spectral Doppler shows arterial flow within the mass. Color image provided online.

CLINICAL FINDINGS OF GALLBLADDER CARCINOMA

1. Weight loss
2. Right upper quadrant pain
3. Jaundice
4. Nausea and vomiting
5. Hepatomegaly
6. Possible elevation in ALP, ALT, GGT, and bilirubin (with obstruction)

SONOGRAPHIC FINDINGS OF GALLBLADDER CARCINOMA

1. Nonmobile mass within the gallbladder lumen that measures >1 cm
2. Diffuse or focal gallbladder wall thickening
3. Irregular mass that may completely fill the gallbladder fossa
4. Invasion of the mass into surrounding liver tissue

REVIEW QUESTIONS

1. Hepatization of the gallbladder occurs when the gallbladder:
   a. Perforates

b. Becomes hydropic
c. Fills with sludge
d. Undergoes torsion

2. A 71-year-old patient presents to the emergency department with painless jaundice and an enlarged, palpable gallbladder. These findings are highly suspicious for:
   a. Acute cholecystitis
   b. Chronic cholecystitis
   c. Courvoisier gallbladder
   d. Porcelain gallbladder

3. The innermost layer of the gallbladder wall is the:
   a. Fibromuscular layer
   b. Mucosal layer
   c. Serosal layer
   d. Muscularis layer

4. Which of the following would not be a laboratory finding typically analyzed with suspected gallbladder disease?
   a. ALP
   b. ALT
   c. Bilirubin
   d. Alpha-Fetoprotein

5. The cystic artery is most often a direct branch of the:
   a. Main pancreatic artery
   b. Celiac artery
   c. Right hepatic artery
   d. Left hepatic artery

6. The middle layer of the gallbladder wall is the:
   a. Fibromuscular layer
   b. Mucosal layer
   c. Serosal layer
   d. Muscularis layer

7. Which structure is a useful landmark for identifying the gallbladder?
   a. Main lobar fissure
   b. Hepatoduodenal ligament
   c. Falciform ligament
   d. Ligamentum venosum

8. Which of the following would be least likely to cause focal gallbladder wall thickening?
   a. Gallbladder polyp
   b. Adenomyomatosis
   c. Ascites
   d. Adhered gallstone

9. What hormone causes the gallbladder to contract?
   a. Estrogen
   b. Cholecystokinin
   c. Bilirubin
   d. Biliverdin

10. The gallbladder wall should measure not more than:
   a. 5 mm
   b. 6 mm
   c. 4 mm
   d. 3 mm

11. Which of the following is associated with cholelithiasis and is characteristically found in Africans or people of African descent?
   a. Sickle cell disease
   b. Gallbladder torsion
   c. Cholesterolosis
   d. Arland–Berlin syndrome

12. The direct blood supply to the gallbladder is the:
   a. Cholecystic artery
   b. Common hepatic artery
   c. Main portal vein
   d. Cystic artery

13. The outermost layer of the gallbladder wall is the:
   a. Fibromuscular layer
   b. Mucosal layer
   c. Serosal layer
   d. Muscularis layer

14. Which part of the gallbladder is involved in Hartmann pouch?
   a. Neck
   b. Fundus
   c. Body
   d. Phrygian cap

15. The gallbladder is connected to the biliary tree by the:
    a. Common hepatic duct
    b. Common bile duct
    c. Cystic duct
    d. Right hepatic duct

16. At which level of the gallbladder is the junctional fold found?
    a. Neck
    b. Fundus
    c. Body
    d. Phrygian cap

17. Empyema of the gallbladder denotes:
    a. Gallbladder hydrops
    b. Gallbladder filled with pus
    c. Gallbladder completely filled with air
    d. Gallbladder completely filled with polyps

18. What is/are cholelithiasis?
    a. Inflammation of the gallbladder
    b. Gallstones
    c. Hyperplasia of the gallbladder wall
    d. Polyps within the biliary tree

19. The diffuse polypoid appearance of the gallbladder referred to as strawberry gallbladder is seen with:
    a. Cholesterolosis
    b. Adenomyomatosis
    c. Cholangitis
    d. Kawasaki disease

20. The most common variant of gallbladder shape is the:
    a. Phrygian cap
    b. Hartmann pouch
    c. Septated gallbladder
    d. Junctional fold

21. The diameter of the gallbladder should not exceed:
    a. 8 cm
    b. 5 cm
    c. 7 mm
    d. 3 cm

22. Acute cholecystitis that leads to necrosis and abscess development within the gallbladder wall describes:
    a. Emphysematous cholecystitis
    b. Gangrenous cholecystitis
    c. Chronic cholecystitis
    d. Gallbladder perforation

23. All of the following are sources of diffuse gallbladder wall thickening except:
    a. Acute cholecystitis
    b. AIDS
    c. Hepatitis
    d. Gallbladder polyp

24. Which statement is not true of cholelithiasis?
    a. Men have an increased likelihood of developing cholelithiasis.
    b. Patients who have been or are pregnant have an increased occurrence of cholelithiasis.
    c. A rapid weight loss may increase the likelihood of developing cholelithiasis.
    d. Patients who have hemolytic disorders have an increased occurrence of cholelithiasis.

25. WES sign denotes:
    a. The presence of a gallstone lodged in the cystic duct
    b. Multiple biliary stones and biliary dilatation
    c. A gallbladder filled with cholelithiasis
    d. The sonographic sign of a porcelain gallbladder

26. Which of the following is the most likely clinical finding of adenomyomatosis?
    a. Murphy sign
    b. Hepatitis
    c. Congestive heart failure
    d. Asymptomatic

27. Tumefactive sludge can resemble the sonographic appearance of:
    a. Cholelithiasis
    b. Gallbladder carcinoma
    c. Cholecystitis
    d. Adenomyomatosis

28. The champagne sign is associated with:

a. Adenomyomatosis
b. Cholangiocarcinoma
c. Emphysematous cholecystitis
d. Acalculous cholecystitis

29. The sequela of acute cholecystitis that is complicated by gas within the gallbladder wall is:
a. Emphysematous cholecystitis
b. Membranous cholecystitis
c. Chronic cholecystitis
d. Gallbladder perforation

30. A 32-year-old female patient presents to the sonography department with vague abdominal pain. The sonographic investigation of the gallbladder reveals a focal area of gallbladder wall thickening that produces comet tail artifact. These findings are consistent with:
a. Gangrenous cholecystitis
b. Gallbladder perforation
c. Acalculous cholecystitis
d. Adenomyomatosis

31. Which of the following would not be the least likely finding of acalculous cholecystitis?
a. Gallbladder wall thickening
b. Pericholecystitic fluid
c. Cholelithiasis
d. Positive Murphy sign

32. Intermittent obstruction of the cystic duct by a gallstone results in:
a. Emphysematous cholecystitis
b. Gangrenous cholecystitis
c. Chronic cholecystitis
d. Acute cholecystitis

33. Which of the following is not a risk factor for the development of gallstones?
a. Phrygian cap
b. Pregnancy
c. Total parenteral nutrition
d. Oral contraceptive use

34. A nonmobile, nonshadowing focus is seen within the gallbladder lumen. This most likely represents a:

a. Gallstone
b. Gallbladder carcinoma
c. Gallbladder polyp
d. Sludge ball

35. Focal tenderness over the gallbladder with probe pressure describes:
a. Murphy sign
b. Strawberry sign
c. Courvoisier sign
d. Hydrops sign

36. Diabetic patients suffering from acute cholecystitis have an increased risk for developing:
a. Emphysematous cholecystitis
b. Gangrenous cholecystitis
c. Chronic cholecystitis
d. Gallbladder torsion

37. Cholesterol crystals within the Rokitansky–Aschoff sinuses are found with:
a. Acute cholecystitis
b. Acalculous cholecystitis
c. Adenomyomatosis
d. Gallbladder perforation

38. The spiral valves of Heister are found within the:
a. Gallbladder neck
b. Cystic duct
c. Gallbladder fundus
d. Gallbladder wall

39. With which of the following is Courvoisier gallbladder associated?
a. A pancreatic head mass
b. A stone in the cystic duct
c. Cholecystitis
d. Chronic diverticulitis

40. Calcification of the gallbladder wall is termed:
a. Concrete gallbladder
b. Heister syndrome
c. Porcelain gallbladder
d. Hyperplastic cholecystosis

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4

The Bile Ducts

Introduction

Sonography has become the modality of choice in the evaluation of the bile ducts for suspected disease. This chapter provides normal anatomy and pathology of the biliary tree.

Key Terms

acute pancreatitis—inflammation of the pancreas secondary to the leakage of pancreatic enzymes from the acinar cells into the parenchyma of the organ

ampulla of Vater—the merging point of the pancreatic duct and common bile duct just before the sphincter of Oddi; also referred to as the hepatopancreatic ampulla

ascariasis—an infection of the small intestine that is caused by *Ascaris lumbricoides*, a parasitic roundworm

biliary atresia—a congenital disease described as the narrowing or obliteration of all or a portion of the biliary tree

biliary colic—pain secondary to a blockage of the biliary tree

biliary stasis—a condition in which bile is stagnant and allowed to develop into sludge or stones

bilirubin—a yellowish pigment found in bile that is produced by the breakdown of old red blood cells by the liver

biliverdin—a green pigment found in the bile

Caroli disease—a congenital disorder characterized by segmental dilatation of the intrahepatic ducts

central dot sign—the presence of echogenic dots in the nondependent part of the dilated duct representing small fibrovascular bundles; seen with Caroli disease

Charcot triad—fever, right upper quadrant pain, and jaundice associated with cholangitis

cholangiocarcinoma—primary bile duct cancer

cholangiography—a radiographic procedure in which contrast is injected into the bile ducts to assess for the presence of disease

cholangitis—inflammation of the bile ducts

chronic pancreatitis—the recurring destruction of the pancreatic tissue that results in atrophy, fibrosis, scarring, and the development of calcifications within the gland

double-duct sign—coexisting dilation of the common bile duct and pancreatic duct

endoscopic retrograde cholangiopancreatography—endoscopic procedure that utilizes fluoroscopy to evaluate the biliary tree and pancreas

hepatopancreatic ampulla—the level of the biliary tree where the common bile duct and the main pancreatic duct meet; may also be referred to as the ampulla of Vater

hepatopancreatic sphincter—the muscle that controls the emptying of bile and pancreatic juices into the duodenum; may also be referred to as the sphincter of Oddi

inflammatory bowel disease—chronic inflammation of all or parts of the bowel

Klatskin tumor—a malignant biliary tumor located at the junction of the right and left hepatic ducts

Mirizzi syndrome—a clinical condition when the patient presents with jaundice, pain, and fever secondary to a lodged stone in the cystic duct causing compression of the common duct

parallel tube sign—the enlargement of the common duct to the size of the adjacent portal vein within the porta hepatis

pneumobilia—air within the biliary tree

pruritus—severe itchiness of the skin

shotgun sign—the enlargement of the common duct to the size of the adjacent portal vein within the porta hepatis; also referred to as the parallel tube sign

sphincter of Oddi—the muscle that controls the emptying of bile and

pancreatic juices into the duodenum; also referred to as the hepatopancreatic sphincter

ulcerative colitis—an inflammatory bowel disease that leads to the development of ulcers within the bowel

ANATOMY AND PHYSIOLOGY OF THE BILE DUCTS

Bile, a vital digestive fluid, is produced by the liver. Cholesterol is a major component of bile, although it includes other key elements that aid in digestion such as bilirubin, biliverdin, and bile acids. The function of the biliary tree is to provide a conduit for bile to drain from the liver into the small intestine (Fig. 4-1). Bile first accumulates in the small intrahepatic biliary radicles that are located throughout the liver. These tiny ducts are scattered throughout the liver parenchyma and are part of the portal triads. Each portal triad contains a small branch of the hepatic artery, portal vein, and intrahepatic ducts (biliary radicles). From these small biliary radicles, bile flows into either the right or left hepatic duct. The right and left hepatic ducts eventually unite to form the common hepatic duct. Bile then travels only a short distance to the gallbladder, where it is concentrated and stored.

The gallbladder is attached to the biliary tree by the cystic duct. The point of attachment of the cystic duct to the gallbladder marks the proximal margin of the common bile duct. The cystic duct contains tiny structures called the spiral valves of Heister. These small projections of tissue prevent the cystic duct from collapsing or distending. When stimulated by cholecystokinin—produced by the duodenum—the gallbladder contracts and empties bile into the biliary tree at the level of the proximal common bile duct. Bile travels from the common bile duct toward the duodenum, where it meets the main pancreatic duct at the ampulla of Vater or hepatopancreatic ampulla. There, pancreatic juices and bile are mixed together. The sphincter of Oddi, also referred to as the hepatopancreatic sphincter, is the opening that allows bile and pancreatic juices to flow into the duodenum. The fluid is mixed with chyme in the duodenum and appropriate chemical reactions ensue.

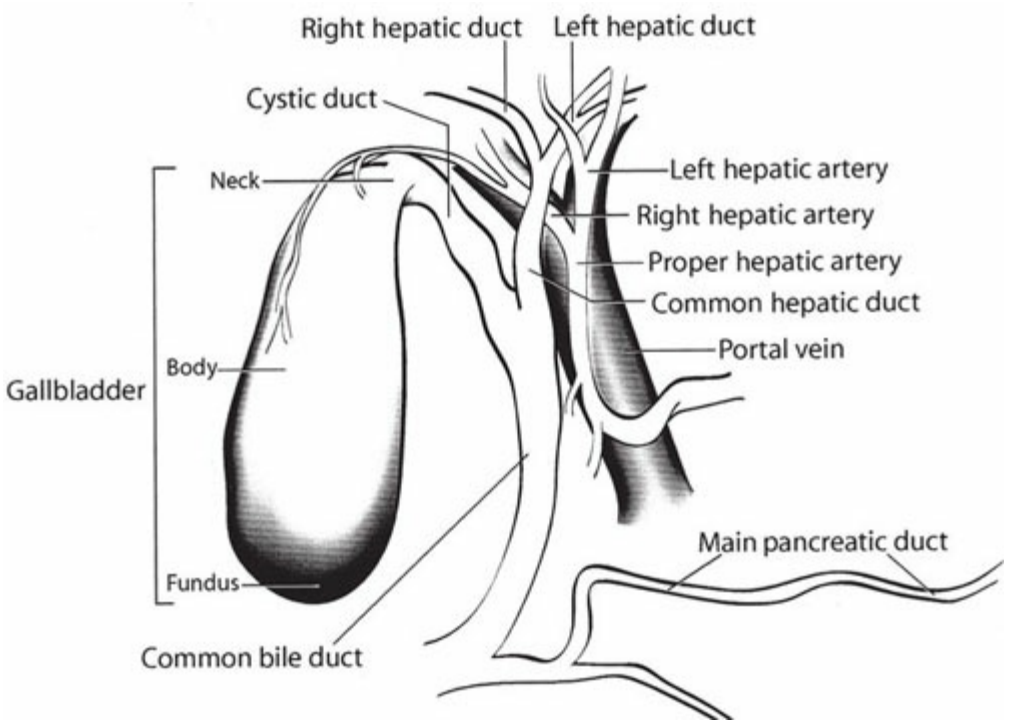


Figure 4-1 Normal anatomy of the biliary tree, gallbladder, and adjacent vasculature.

SOUND OFF

Bile flow = liver → biliary radicles → right or left hepatic duct → common hepatic duct → cystic duct → gallbladder → common bile duct → ampulla of Vater → sphincter of Oddi → duodenum

SONOGRAPHY OF THE BILE DUCTS

Although a period of 8 hours is optimal, patients should have nothing to eat or drink for at least 4 hours before a sonogram of the biliary tree is performed. The entire biliary tree should be examined. Although the common bile duct can often be differentiated from the common hepatic duct if it recognized posterior to the head of the pancreas or inferior to the gallbladder neck, delineation may be difficult at times. For this reason, many sonographers and interpreting physicians may describe the portion of the biliary tree that is located at the porta hepatis as the common duct.

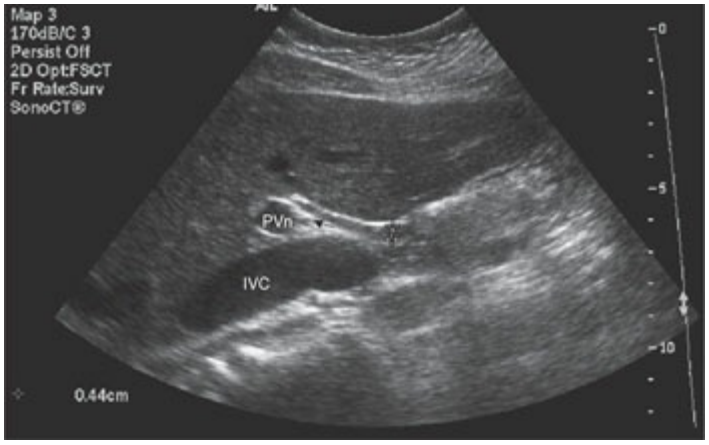


Figure 4-2 Common bile duct. Longitudinal image of the common bile duct (*calipers*), hepatic artery (*arrow*), portal vein (*PVn*), and inferior vena cava (*IVC*).

In general, a common bile duct diameter that exceeds 6 mm is typically considered abnormal, and thus the cause of dilatation should systematically be investigated through diligent scanning of the entire right upper quadrant, including the complete biliary tree, liver, gallbladder, and pancreas (Fig. 4-2). For the sonographer, when an enlarged portion of the biliary tree is identified, a more thorough inquiry of the patient's clinical history should also ensue, for the obtained measurement of the biliary tree is only part of the overall patient assessment, and thus the entire clinical picture must be appreciated in order to assist the interpreting physician in making the correct diagnosis. For example, some authors claim that the normal anteroposterior diameter of the common duct in adults at the level of the porta hepatis is between 1 and 7 mm. For patients older than age 60 or who have had a cholecystectomy, a maximum diameter of 10 mm may be considered normal if the patient is asymptomatic. Thus, clinical history is vital. Laboratory results, such alanine aminotransferase (ALT), alkaline phosphatase (ALP), serum bilirubin, gamma-glutamyltransferase (GGT), and urobilirubin, are often elevated in the presence of biliary obstruction or disease. Also, liver function and pancreatic laboratory results—specifically amylase and lipase—should be closely evaluated when biliary abnormalities are suspected. The intrahepatic ducts are considered dilated if they exceed 2 mm (Fig. 4-3).

Caliper placement when measuring the duct should be from inner to inner wall. The "shotgun sign" or "parallel tube sign" describes the enlargement of the common duct to the size of the adjacent portal vein within the porta hepatis. Also, coexisting dilation of the common bile duct and pancreatic duct has been referred to as the "double-duct sign." When these finding are present, color Doppler is helpful for delineating the vasculature from bile ducts.

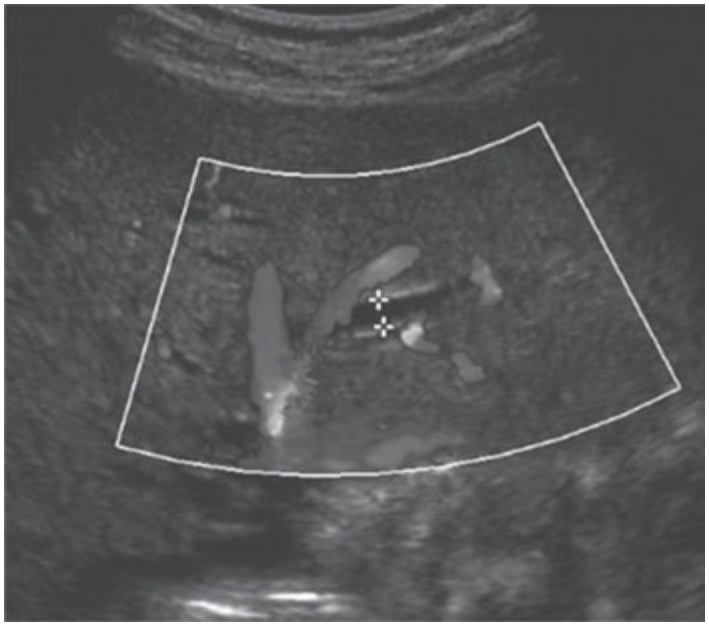


Figure 4-3 Dilated intrahepatic duct. Color Doppler image of a dilated intrahepatic duct (*between calipers*). Color image provided online.

SOUND OFF
When biliary tree obstruction or disease is suspected, look for an elevation in ALP, ALT, serum bilirubin, GGT, and urobilirubin.

PATHOLOGY OF THE BILE DUCTS

Biliary Obstruction and Jaundice

Understanding the origin and flow of bile from the liver to the duodenum is imperative to determine the level of biliary obstruction. The origin of bile is within the liver, which is considered the proximal portion of the biliary tree. Conversely, the common bile duct segment closest to the pancreatic head is considered the most distal segment of the biliary tree. As a rule, biliary dilatation will occur proximal to the level of obstruction. The common bile duct, the cystic duct, and part of the common hepatic duct are considered extrahepatic in location. All other portions of the biliary tree are considered intrahepatic. The most common level for an obstruction to occur is the distal common bile duct. In most instances, the extrahepatic ducts will dilate first. Therefore, with obstruction of the distal common bile duct, there will be eventual dilatation of the common bile duct, gallbladder, common hepatic duct, and intrahepatic ducts. The most common causes of common bile duct obstruction are choledocholithiasis, chronic pancreatitis, acute pancreatitis, and pancreatic carcinoma.

As a result of an obstruction within the biliary tree, the patient will eventually suffer from jaundice. Jaundice occurs as a consequence of

bilirubin accumulation within the tissues of the body. Bilirubin, which is a yellowish pigment found in bile, can turn the skin and the whites of the eyes —the sclerae—yellow if allowed to accumulate. Accordingly, excessive bilirubin in the body leads to elevated serum bilirubin. Although biliary obstruction is a common cause of jaundice, it can also occur with other conditions, including hepatitis, cirrhosis, liver carcinoma, pancreatic carcinoma, and hemolytic disorders. And while other causes exist, infant jaundice is typically caused by the inability of the newborn liver to eliminate bilirubin from the bloodstream. It is often treated successfully with phototherapy.

SOUND OFF
The most common level for an obstruction to occur is the distal common bile duct.

Choledocholithiasis

Whenever biliary stasis occurs, gallstone formation is probable. Choledocholithiasis describes the presence of gallstones within the bile ducts (Fig. 4-4). Stones typically form in the gallbladder and pass into the biliary tree. Rarely, they can form in the ducts themselves, although some conditions increase the incidence of primary biliary tree stones. Gallstones located within the common bile duct are considered the most common cause of obstructive jaundice. Most stones will be located near the ampulla of Vater and can be difficult to image secondary to neighboring bowel gas shadows. It is important to note that patients presenting with biliary symptoms who have recently undergone a cholecystectomy should be closely evaluated for retained gallstones located within the biliary tree.

Patients with choledocholithiasis may be asymptomatic, and the biliary ducts may actually be normal in caliber. However, if biliary obstruction has occurred as a result of choledocholithiasis, the patient will have jaundice, elevated bilirubin, ALP, and ALT, and right upper quadrant pain. Stones located within the duct will typically appear as echogenic, shadowing foci; however, about 20% of the time these stones may not shadow.

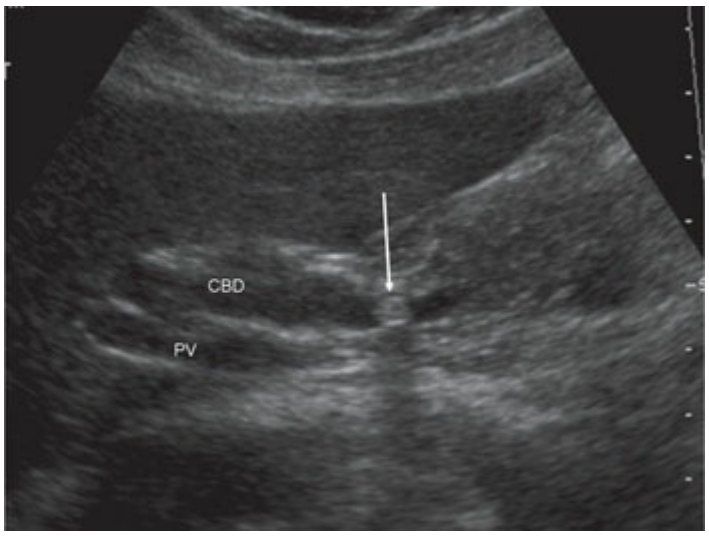


Figure 4-4 Choledocholithiasis. A gallstone (*arrow*) is noted within the distal common bile duct (*CBD*). The portal vein (*PV*) is also seen.

An uncommon manifestation of choledocholithiasis is Mirizzi syndrome. It is a clinical condition in which the patient presents with jaundice, pain, and fever secondary to a lodged stone in the cystic duct with subsequent compression of the common duct (Fig. 4-5). The sonographic findings and symptoms may appear much like those found with cholecystitis. Mirizzi syndrome may be suspected with sonography, but typically it is diagnosed by cholangiography or endoscopic retrograde cholangiopancreatography.

CLINICAL FINDINGS OF CHOLEDOCHOLITHIASIS

1. Jaundice
2. Elevated ALP, ALT, and GGT, and bilirubin (with obstruction)
3. Right upper quadrant pain

SONOGRAPHIC FINDINGS OF CHOLEDOCHOLITHIASIS

1. Echogenic foci within the bile duct that may or may not shadow
2. May have biliary dilatation but not always

Cholangitis

Inflammation of the biliary ducts is termed cholangitis. When the bile duct walls thicken greater than 5 mm, one should suspect some form of cholangitis. Indeed, if the biliary duct wall appears visible thickened at any time, cholangitis should be suspected (Fig. 4-6). The most common cause of cholangitis is often some type of obstructive disease, as in the case of choledocholithiasis. There are several types of cholangitis, including acute bacterial, AIDS, Oriental (recurrent pyogenic cholangitis), and sclerosing (Table 4-1). Acute bacterial cholangitis is typically preceded by a biliary

obstruction, and patients often present with fever, right upper quadrant pain, and jaundice, a condition referred to a Charcot triad. Patients with bacterial cholangitis also suffer from leukocytosis, and elevated ALP and bilirubin. All of the variants of cholangitis have similar sonographic findings that include some degree of biliary dilatation, biliary sludge, and bile duct wall thickening. Cholangitis can lead to cirrhosis and portal hypertension.

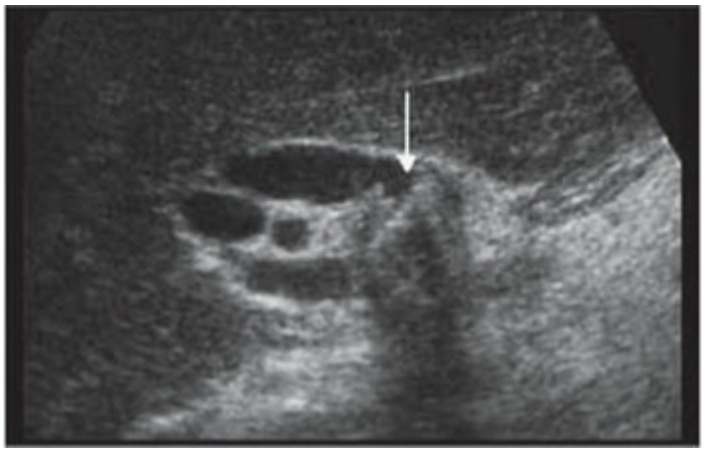


Figure 4-5 Mirizzi syndrome. A stone (*arrow*) is noted lodged in the cystic duct, compressing the common bile duct and leading to obstruction and dilation of the extrahepatic biliary tree.

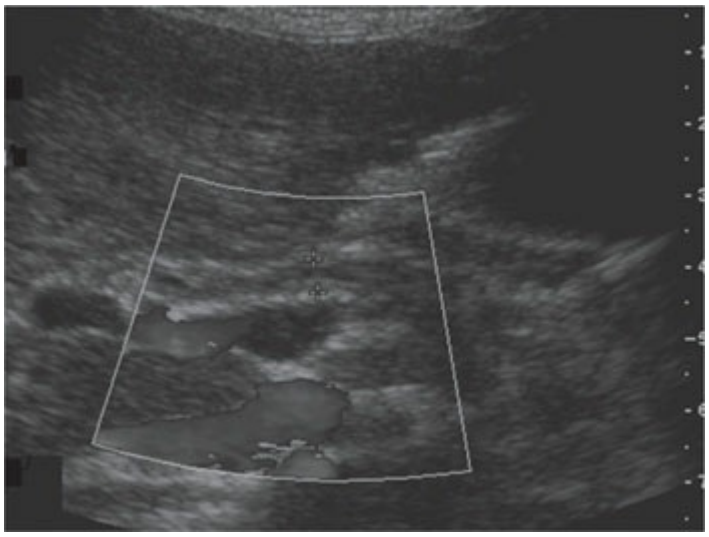


Figure 4-6 Cholangitis. The internal walls of this duct (*calipers*) can be clearly noted, indicating inflammation and evidence of cholangitis. Color image provided online.

CLINICAL FINDINGS OF CHOLANGITIS

1. Charcot triad: fever, right upper quadrant pain, and jaundice
2. Leukocytosis
3. Elevated ALP, ALT, GGT, and bilirubin (with obstruction)

SONOGRAPHIC FINDINGS OF CHOLANGITIS

1. Biliary dilatation
2. Biliary sludge or pus
3. Choledocholithiasis
4. Bile duct wall thickening

SOUND OFF
Charcot triad is fever, right upper quadrant pain, and jaundice

TABLE 4-1 Types of Cholangitis

Type of Cholangitis	Important Points
Acute bacterial cholangitis	• Caused by bacterial accumulation secondary to obstruction • Bacteria can be introduced during an ERCP for choledocholithiasis • Pus may be noted within the bile ducts as low-level echoes
AIDS cholangitis	• Associated with advance HIV and AIDS • Most often results from infection with *Cryptosporidium* or cytomegalovirus
Oriental cholangitis	• Endemic to Asia • Seen in America because of immigration
Sclerosing cholangitis	• Characterized by fibrotic thickening of the bile ducts • Most often affects young men • Associated with **inflammatory bowel disease** or **ulcerative colitis** • Increased risk for cholangiocarcinoma

ERCP, endoscopic retrograde cholangiopancreatography.

Pneumobilia

Pneumobilia is defined as air within the biliary tree. Pneumobilia may be associated with recent biliary or gastric surgery, emphysematous or prolonged acute cholecystitis, or fistula formation. Pneumobilia is diagnosed sonographically when echogenic linear structures are seen within the ducts (Fig. 4-7). It may be difficult to differentiate pneumobilia from intrahepatic stones. However, air within the bile ducts may be linear in appearance and

will most often produce ring-down artifact and have dirty shadowing, while intrahepatic stones will produce an acoustic shadow if large enough.

CLINICAL FINDINGS OF PNEUMOBILIA

1. Recent biliary or gastric surgery, emphysematous or acute cholecystitis, or fistula formation
2. Symptoms of acute cholecystitis

SONOGRAPHIC FINDINGS OF PNEUMOBILIA

1. Echogenic linear structures within the ducts that produce ring-down artifacts and dirty shadowing

Ascariasis

Ascariasis is an infection of the small intestine that is caused by Ascaris lumbricoides, a parasitic roundworm. The roundworm, which is transmitted the fecal–oral route, develops in the small intestine and makes its way to the biliary tree via the ampulla of Vater. Some patients may be asymptomatic, whereas others may complain of biliary colic, or have symptoms of inflammation of the biliary tree, gallbladder, or pancreas. Sonographically, the worm will be noted within the biliary duct as an echogenic linear structure, and its movement with real-time imaging confirms diagnosis.

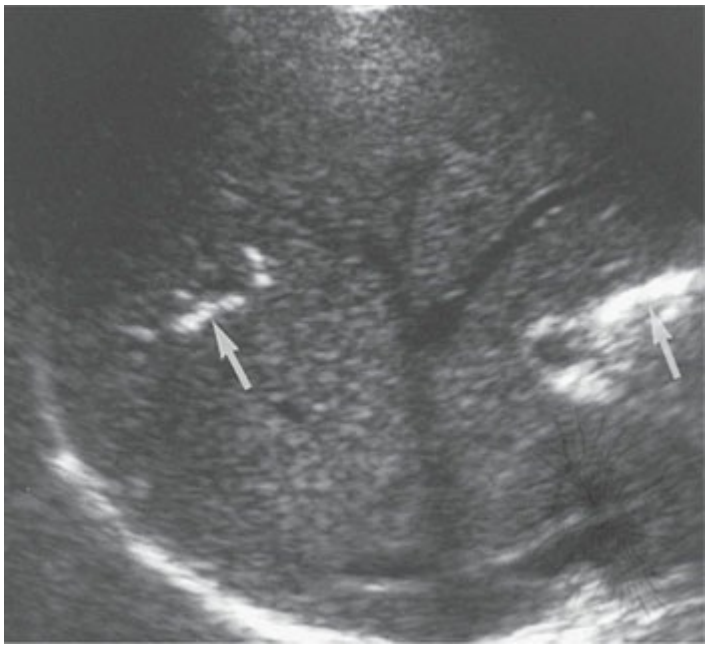


Figure 4-7 Pneumobilia. Air within the biliary tree is seen as bright echogenic structures that produce ring-down artifact (*arrows*).

CLINICAL FINDINGS OF ASCARIASIS

1. Asymptomatic
2. May have symptoms of inflammation of the biliary tree, gallbladder, or pancreas

SONOGRAPHIC FINDINGS OF ASCARIASIS

1. The worm will be noted within the biliary duct as an echogenic linear structure in the sagittal plane
2. Movement of the worm within the duct confirms diagnosis

Cholangiocarcinoma and Klatskin Tumors

Primary biliary tree cancer is referred to as cholangiocarcinoma. Primary sclerosing cholangitis is the most common risk factor for cholangiocarcinoma, while recurrent biliary infections and stone disease also increase the risk. It can have an intrahepatic or extrahepatic location, both of which carry a poor prognosis. Klatskin tumors are the most common manifestation of cholangiocarcinoma. These tumors are located at the junction of the right and left hepatic ducts and cause dilatation of the intrahepatic ducts. Patients will present with jaundice, pruritus, unexplained weight loss, and abdominal pain. Laboratory findings include an elevated serum bilirubin and ALP. Sonographically, dilated intrahepatic ducts that abruptly terminate at the level of the tumor are suggestive of cholangiocarcinoma (Fig. 4-8). Occasionally, a solid mass may be noted within the liver or ducts. Cholangiocarcinoma is most often adenocarcinoma, but other forms of biliary cancer can occur, such as squamous cell carcinoma and cystadenocarcinoma.

CLINICAL FINDINGS OF CHOLANGIOCARCINOMA

1. Jaundice
2. Pruritus
3. Unexplained weight loss
4. Abdominal pain
5. Elevated bilirubin
6. Elevated ALP

SONOGRAPHIC FINDINGS OF CHOLANGIOCARCINOMA

1. Dilated intrahepatic ducts that abruptly terminate at the level of the tumor
2. A solid mass may be noted within the liver or ducts



Figure 4-8 Cholangiocarcinoma. The dilated common bile duct (*d*) abruptly ends at a small tissue mass (*arrow*) that fills the duct. The hepatic artery (*a*) is also noted in this image.

SOUND OFF
Klatskin tumors are located at the junction of the right and left hepatic ducts and cause dilatation of the intrahepatic ducts.

PEDIATRIC PATHOLOGY OF THE BILE DUCTS

Biliary Atresia

Biliary atresia is a congenital disease that is thought to be caused by a viral infection at birth, although some think it may be an inherited disorder. It is a disease with a poor prognosis that is described as the narrowing or obliteration of all or a portion of the biliary tree. Eventually, infants suffer from cirrhosis and portal hypertension. Sonographically, biliary atresia will appear as absent ducts. The gallbladder may be absent or small as well. There may be evidence of the "triangular cord sign," which is an avascular, echogenic, triangular or tubular structure anterior to the portal vein, representing the replacement of the extrahepatic duct with fibrous tissue in the porta hepatis (Fig. 4-9). Eventually, sonographic features of cirrhosis and portal hypertension will be seen if the disorder is not treated. Clinical findings can be confused with neonatal hepatitis. Both atresia and hepatitis include elevated AST, ALT, and bilirubin. However, unlike neonatal hepatitis, which can be treated medically, biliary atresia is often fatal without surgical intervention.

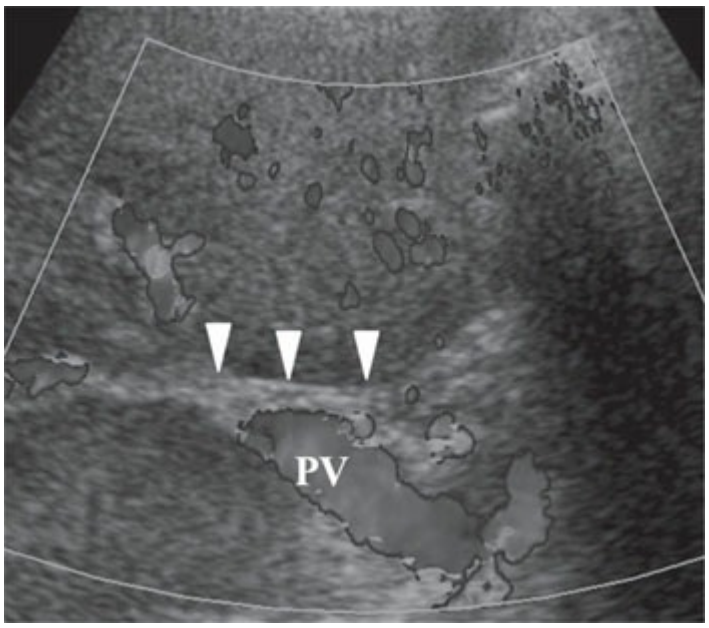


Figure 4-9 Triangular cord sign. Color Doppler image shows an avascular fibrous cord (*arrowheads*) anterior to the main portal vein (*PV*). Color image provided online.

CLINICAL FINDINGS OF BILIARY ATRESIA

1. Neonatal jaundice
2. Elevated AST, ALT, and bilirubin

SONOGRAPHIC FINDINGS OF BILIARY ATRESIA

1. Absent biliary ducts
2. Triangular cord sign (avascular, echogenic, triangular or tubular structure anterior to the portal vein)
3. Sonographic signs of cirrhosis and portal hypertension (see Chapter 2)

Choledochal Cyst

There are four different types of choledochal cysts, with the most common being described as the cystic dilatation of the common bile duct. They are usually discovered in infancy or in the first decade of life. Patients with a choledochal cyst present with an abdominal mass, jaundice, pain, and fever. Choledochal cysts can lead to cholangitis, portal hypertension, pancreatitis, and liver failure. Sonographic findings of a choledochal cyst include a fusiform cystic mass in the area of the porta hepatis and biliary dilatation (Fig. 4-10).

CLINICAL FINDINGS OF A CHOLEDOCHAL CYST

1. Jaundice

2. Pain
3. Fever

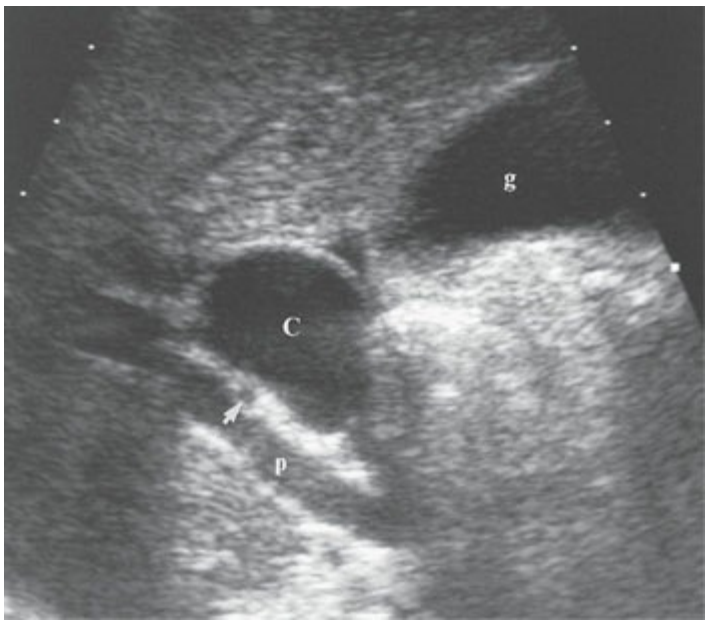


Figure 4-10 Choledochal cyst. Marked focal dilation of the common bile duct (*C*) is evident. The portal vein (*p*), hepatic artery (*arrow*), and gallbladder (*g*) all appear normal.

SONOGRAPHIC FINDINGS OF A CHOLEDOCHAL CYST

1. Cystic mass in the area of the porta hepatis (separate from the gallbladder)
2. Biliary dilatation

Caroli Disease

Caroli disease, or Caroli syndrome, is a congenital disorder characterized by segmental dilatation of the intrahepatic ducts. It is often seen in association with cystic renal disease and may precede the development of cholangiocarcinoma, a hepatic abscess, cholangitis, and sepsis. Patients may present with pain, fever, jaundice, or signs of portal hypertension. Sonographic findings include segmental dilatation of the intrahepatic ducts. The “central dot sign” may also be noted, which is described as the presence of echogenic dots in the nondependent part of the dilated duct representing small fibrovascular bundles (Fig. 4-11).

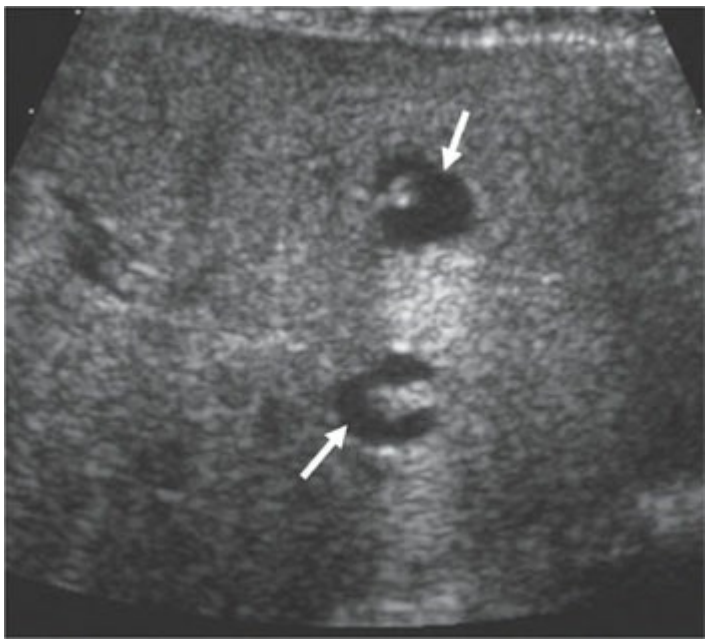


Figure 4-11 Caroli disease. Image of the liver with dilated ducts (*arrows*) demonstrating the "central dot" sign associated with Caroli disease that are representing small fibrovascular bundles.

CLINICAL FINDINGS OF CAROLI DISEASE

1. Pain
2. Fever
3. Jaundice
4. Signs of portal hypertension (see Chapter 2)

SONOGRAPHIC FINDINGS OF CAROLI DISEASE

1. Segmental dilatation of the intrahepatic ducts
2. The patient may also have cystic renal disease
3. Central dot sign (echogenic dots in the nondependent part of the dilated duct)

REVIEW QUESTIONS

1. A congenital disease in which there is narrowing or obliteration of the bile ducts is referred to as:
   a. Caroli disease
   b. Mirizzi disease
   c. Choledochal cysts
   d. Biliary atresia

2. Ascariasis is:
   a. A form of biliary tree carcinoma

b. A congenital disorder characterized by segmental dilatation of the intrahepatic ducts
c. Caused by a parasitic roundworm
d. A type of ringworm that invades the liver

3. Primary biliary tree cancer is referred to as:
a. Gallbladder carcinoma
b. Biloma
c. Cholangiocarcinoma
d. Lymphangioma

4. Which of the following is associated with Charcot triad?
a. Cholangitis
b. Cholesterolosis
c. Klatskin tumor
d. Choledochal cyst

5. The merging point of the pancreatic duct and common bile duct at the level of duodenum is referred to as the:
a. Sphincter of Oddi
b. Ampulla of Vater
c. Common bile duct
d. Cystic duct

6. Which of the following would be the least helpful laboratory value to analyze in patients with suspected biliary tract disease?
a. ALT
b. ALP
c. GGT
d. Creatinine

7. A gallstone located within the biliary tree is referred to as:
a. Cholecystitis
b. Choledocholithiasis
c. Cholangitis
d. Cholangiocarcinoma

8. Which of the following disorders is associated with the sonographic triangular cord sign?
a. Cholangitis
b. Choledocholithiasis
c. Biliary atresia
d. Ascariasis

9. The yellowish staining of the whites of the eyes and the skin secondary to a liver disorder or biliary obstruction is referred to as:
   a. AIDS cholangitis
   b. Pruritus
   c. Jaundice
   d. Bilirubinemia

10. The Klatskin tumor is located:
   a. At the junction of the right and left hepatic ducts
   b. At the junction of the cystic and common bile duct
   c. At the junction of the common bile duct and common hepatic duct
   d. Between the pancreatic head and the duodenum

11. Inflammation of the bile ducts is referred to as:
   a. Pneumobilia
   b. Choledocholithiasis
   c. Cholelithiasis
   d. Cholangitis

12. A patient presents with jaundice, pain, and fever secondary to an impacted stone in the cystic duct. This is referred to as:
   a. Caroli syndrome
   b. Mirizzi syndrome
   c. Choledochal cysts
   d. Biliary atresia

13. Air within the biliary tree is referred to as:
   a. Pneumobilia
   b. Cholangitis
   c. Choledocholithiasis
   d. Cholesterolosis

14. The presence of an echogenic dot in the nondependent part of a dilated duct representing small fibrovascular bundles is seen with:
   a. Caroli disease
   b. Choledochal cysts
   c. Biliary atresia
   d. Mirizzi syndrome

15. The spiral valves of Heister are located within the:
   a. Common bile duct
   b. Pancreatic duct

c. Common hepatic duct
d. Cystic duct

16. Which of the following is characterized by fibrotic thickening of the bile ducts, found most often in young males, and is associated with inflammatory bowel disease or ulcerative colitis?
a. Ulcerative biliary atresia
b. Oriental cholangitis
c. Sclerosing cholangitis
d. AIDS biliary atresia

17. If a gallstone, causing obstruction, is located within the distal common hepatic duct, which of the following would become dilated?
a. Main pancreatic duct
b. Gallbladder only
c. Intrahepatic ducts
d. Distal common bile duct

18. Which of the following is considered the most proximal portion of the biliary tree?
a. Intrahepatic radicles
b. Cystic duct
c. Common hepatic duct
d. Common bile duct

19. Pneumobilia will produce:
a. Through transmission
b. Ring-down artifact
c. Acoustic shadowing
d. Edge artifact

20. Which of the following would be the most distal portion of the biliary tree?
a. Common bile duct
b. Common hepatic duct
c. Gallbladder
d. Intrahepatic radicles

21. Which of the following could accidentally introduce bacteria into the biliary tree and thus cause cholangitis?
a. Computed tomography
b. Endoscopic retrograde cholangiopancreatography
c. Magnetic resonance imaging

d. Radiography

22. If an obstructive biliary calculus is located within the distal common duct, which of the following could ultimately dilate?
    a. Common bile duct
    b. Gallbladder
    c. Common hepatic duct
    d. All of the above

23. The muscle that controls the emptying of bile and pancreatic juices into the duodenum is the:
    a. Cystic duct
    b. Ampulla of Vater
    c. Sphincter of Oddi
    d. Common bile duct

24. The most common level for biliary obstruction to occur is the:
    a. Junction of the right and left hepatic ducts
    b. Proximal common hepatic duct
    c. Distal common bile duct
    d. Cystic duct

25. A 32-year-old female patient presents to the sonography department with a history of fever, leukocytosis, and right upper quadrant pain. Sonographically, you visualize dilated bile ducts that have thickened walls and contain sludge. What is the most likely diagnosis?
    a. Choledocholithiasis
    b. Cholangitis
    c. Mirizzi syndrome
    d. Biliary atresia

26. Sonographically, you visualize scattered echogenic linear structures within the liver parenchyma that produce ring-down artifact. What is the most likely diagnosis?
    a. Pneumobilia
    b. Choledocholithiasis
    c. Sludge balls
    d. Cholesterolosis

27. A 64-year-old man presents to the sonography department for a right upper quadrant sonogram. He is complaining of abdominal pain, weight loss, and pruritus. Sonographically, you visualize an area of dilated ducts that abruptly end. What is the most likely diagnosis?

a. Biliary atresia
b. Choledocholithiasis
c. Caroli syndrome
d. Cholangiocarcinoma

28. An abdominal sonogram is ordered for an infant in the intensive care unit who is suffering from jaundice and fever. Sonographically, you visualize a cystic mass within the common bile duct that is causing a focal enlargement. This is most suggestive of:
a. Cholangiocarcinoma
b. Mirizzi syndrome
c. Choledochal cyst
d. Biliary atresia

29. All of the following are clinical findings consistent with cholangiocarcinoma except:
a. Pruritus
b. Weight loss
c. Elevated bilirubin
d. Dilation of the intrahepatic ducts

30. Which of the following is not associated with the development of pneumobilia?
a. Cholangiopneumonia
b. Gastric surgery
c. Acute cholecystitis
d. Fistula formation

31. A Klatskin tumor is a form of:
a. Lymphocytic carcinoma
b. Cholangiocarcinoma
c. Pancreatic carcinoma
d. Gallbladder carcinoma

32. The biliary duct wall should never measure more than:
a. 2 mm
b. 9 mm
c. 4 mm
d. 5 mm

33. Clinical findings of choledocholithiasis include all of the following except:
a. Jaundice

b. Elevated bilirubin
c. Elevated blood urea nitrogen
d. Elevated ALP

34. Which segment of the biliary tree tends to dilate first with obstruction?
a. Intrahepatic
b. Extrahepatic

35. Which of the following is not a plausible cause of common bile duct obstruction in adults?
a. Choledocholithiasis
b. Chronic pancreatitis
c. Choledochal cyst
d. Pancreatic carcinoma

36. All of the following are forms of cholangitis except:
a. Acute bacterial
b. AIDS
c. Oriental
d. Parabolic

37. The yellowish pigment found in bile that is produced by the breakdown of old red blood cells by the liver is:
a. Biliverdin
b. Bilirubin
c. Cholesterol
d. Chyme

38. Which of the following is typically found in pediatric patients and is described as the cystic dilation of the common bile duct?
a. Biliary atresia
b. Mirizzi syndrome
c. Caroli disease
d. Choledochal cyst

39. For patients older than age 60, or those who have had a cholecystectomy, a maximum diameter of _____ may be considered normal.
a. 1 cm
b. 12 mm
c. 14 mm
d. 1.5 cm

40. Which of the following would be the most common cause of obstructive

jaundice?

a. Klatskin tumor
b. Cholangiocarcinoma
c. Biliary atresia
d. Choledocholithiasis

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5 The Pancreas

Introduction

This chapter contains information about normal pancreatic anatomy and pancreatic abnormalities that may be noted during a sonographic examination. The reviewer should be attentive to detailed clinical findings because many of the abnormalities mentioned in this chapter can appear sonographically similar.

Key Terms

acinar cells—the cells of the pancreas that carry out the exocrine function and therefore produce amylase, lipase, sodium bicarbonate, and other digestive enzymes

annular pancreas—congenital anomaly of the pancreas that results in the maldevelopment of the pancreas in which the most ventral part of the pancreas encases the duodenum and may consequently lead to duodenal obstruction

chronic pancreatitis—the recurring destruction of the pancreatic tissue that results in atrophy, fibrosis with scarring, and the development of calcification within the gland

cystic fibrosis—inherited disorder that can affect the lungs, liver, pancreas, and other organs; this disorder changes how the body creates mucus and sweat

double-duct sign—coexisting enlargement of the common bile duct and

pancreatic duct

duct of Santorini—the accessory duct of the pancreas

duct of Wirsung—the main pancreatic duct

duodenum—the first segment of the small intestine

endoscopic retrograde cholangiopancreatography—endoscopic procedure that utilizes fluoroscopy to evaluate the biliary tree and pancreas

gastrinoma—an islet cell tumor found within the pancreas

hyperamylasemia—elevated amylase

hyperparathyroidism—the presence of elevated parathyroid hormone

ileus—bowel obstruction caused by the lack of normal peristalsis

insulinoma—an islet cell tumor found within the pancreas

islets of Langerhans—small islands of tissue found within the pancreas that produce insulin and glucagon

islet cell tumors—tumor found within the islets of Langerhans of the pancreas

lesser sac—a peritoneal cavity located between the stomach and pancreas where fluid can accumulate

pancreatic adenocarcinoma—the most common form of pancreatic malignancy, typically found within the head of the pancreas

pancreatic divisum—congenital anomaly of the pancreas that results in a shortened main pancreatic duct that only works to drain the pancreatic head and not the entire pancreas

pancreaticoduodenectomy—the surgical procedure in which the head of the pancreas, the gallbladder, some of the bile ducts, and the proximal duodenum are removed because of a malignant pancreatic neoplasm; also referred to as the Whipple procedure

pancreatic pseudocyst—a cyst surrounded by fibrous tissue that consists of pancreatic enzymes that have leaked from the pancreas

phlegmon—the peripancreatic fluid collection that results from the inflammation of the pancreas

uncinate process—a posteromedial extension of the pancreatic head

von Hippel–Lindau disease—a hereditary disease that includes the development of cysts within the pancreas and other organs

Whipple procedure—see pancreaticoduodenectomy

Zollinger–Ellison syndrome—the syndrome that includes an excessive secretion of acid by the stomach caused by the presence of a functional gastrinoma within the pancreas

ANATOMY AND PHYSIOLOGY OF THE PANCREAS

The pancreas develops initially in the embryo from two separate parts that eventually fuse together to constitute its typical comma-shaped appearance. It is located within the epigastrium between the C-loop of the duodenum and the splenic hilum (Fig. 5-1). It consists of four main parts: head, neck, body, and tail. In some individuals, there exists a posteromedial extension of the pancreatic head, referred to as the uncinate process. Although some of the pancreatic head may be covered by peritoneum, the pancreas is considered to be a retroperitoneal organ. The organ functions as both an exocrine and an endocrine gland.

SOUND OFF

The pancreas is both an exocrine gland (uses ducts to transport digestive juices) and an endocrine gland (releases hormone directly into the bloodstream).

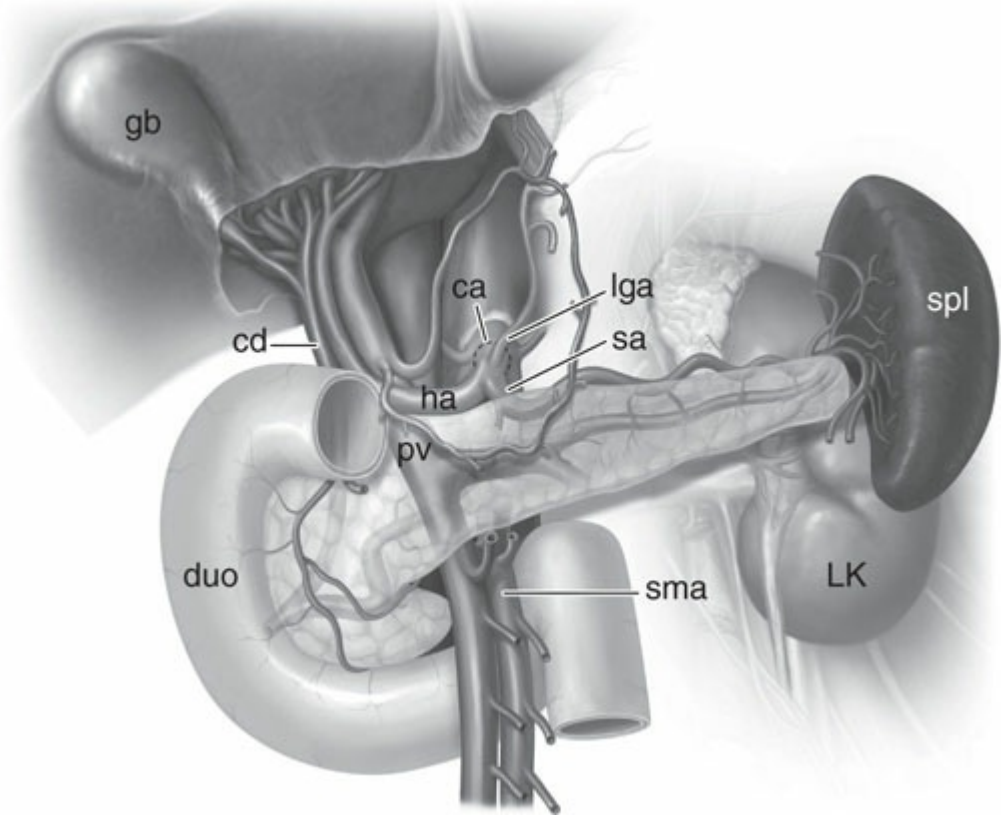


Figure 5-1 Diagram showing the pancreas and surrounding anatomy including the celiac axis (*ca*), duodenum (*duo*), gallbladder (*gb*), proper hepatic artery (*ha*), common bile duct (*cd*), left gastric artery (*lga*), left kidney (*LK*), main portal vein (*pv*), splenic artery (*sa*), superior mesenteric artery (*sma*), and spleen (*spl*).

TABLE 5-1 Exocrine function of the pancreas

1. Amylase: digests carbohydrates and converts starch to sugar
2. Lipase: digests fats and converts fats to fatty acids and glycerol
3. Sodium bicarbonate: neutralizes stomach acid
4. Trypsin, chymotrypsin, and carboxypolypeptidase: digests proteins

Primarily, the pancreas is an exocrine gland that aids in digestion (Table 5-1). The acinar cells of the pancreas carry out the exocrine function because they produce vital digestive enzymes, such as amylase and lipase, and sodium bicarbonate. The pancreas also produces trypsin, chymotrypsin, and carboxypolypeptidase as part of its exocrine function. These pancreatic enzymes drain from the pancreas into the main pancreatic duct, or duct of Wirsung, which travels the length of the pancreas (Fig. 5-2). An accessory duct, the duct of Santorini, which is typically a branch of the main pancreatic duct, has a separate minor sphincter into the duodenum. From the main pancreatic duct, the enzymes collect in the ampulla of Vater. At the ampulla of Vater, the pancreatic digestive enzymes are mixed with bile from the liver and released into the duodenum through the major sphincter, or sphincter of Oddi. The opening of the sphincter of Oddi is triggered by cholecystokinin released by the duodenum as a result of the presence of chyme. Therefore, cholecystokinin causes the simultaneous contraction of the gallbladder and relaxation of the sphincter of Oddi. The breakdown of the various food products into useful derivatives for the body ensues once the pancreatic enzymes and bile mix with chyme in the proximal portion of the duodenum.

The endocrine function of the pancreas is performed by the islets of Langerhans. These clusters of tissue, which are dispersed like islands throughout the pancreas, are composed of alpha, beta, and delta cells (Table 5-2). The islets of Langerhans produce vital hormones, including insulin and glucagon, which are released directly into the bloodstream. Glucagon promotes the release of glucose by the liver, which in turn increases blood sugar levels. Insulin stimulates the body to use up glucagon to produce energy.

VASCULAR ANATOMY OF THE PANCREAS

The arterial blood supply to the head of the pancreas is via the gastroduodenal artery. The body and tail of the pancreas receive their blood supply from the splenic and superior mesenteric arteries. Venous drainage is achieved by means of the splenic vein, superior mesenteric vein, inferior

mesenteric vein, and portal vein.

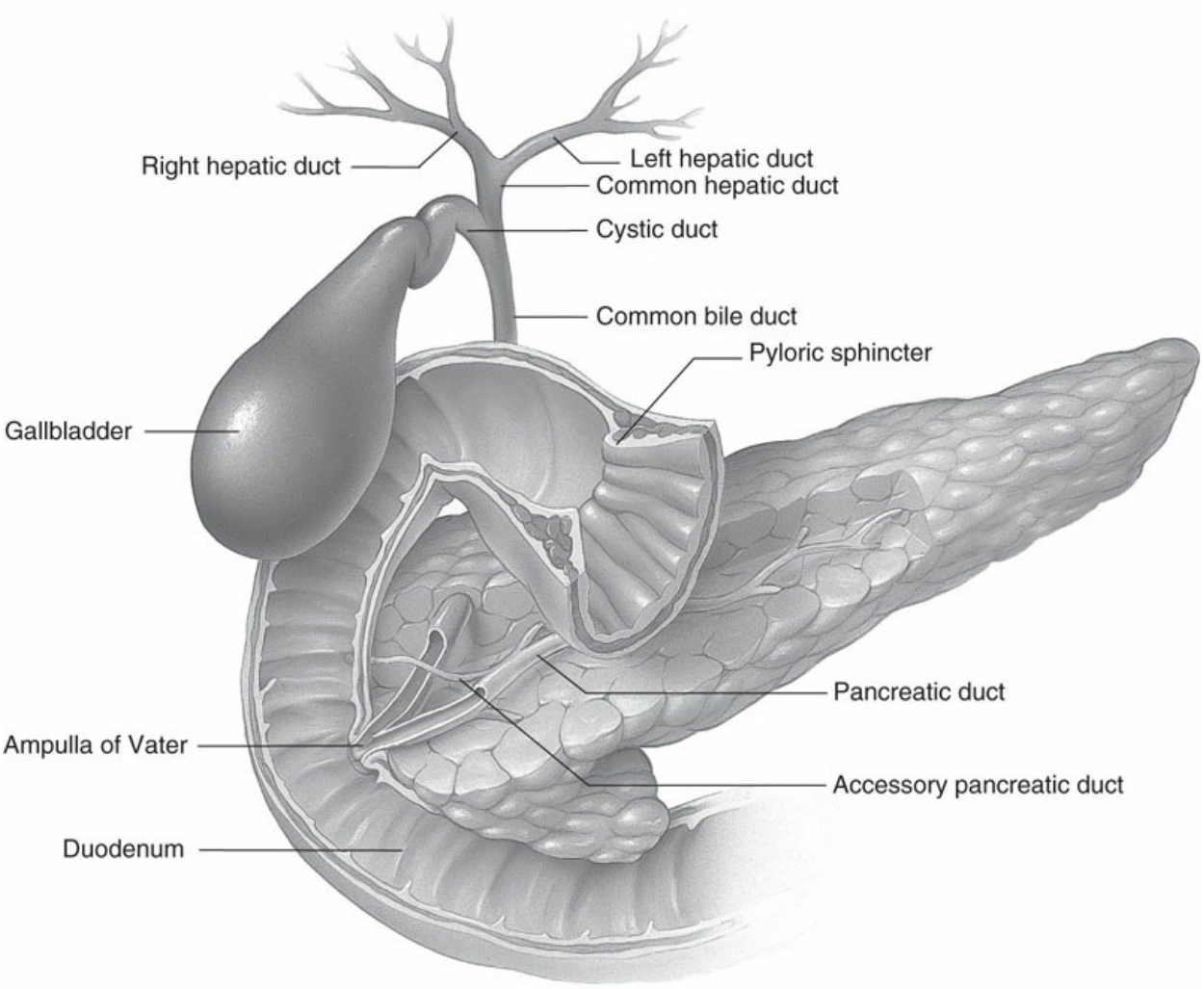


Figure 5-2 Diagram of biliary tree with pancreas.

TABLE 5-2 Endocrine function of the pancreas

Alpha Cells	Glucagon	Promotes the release of glucose by the liver (increases blood sugar level)
Beta Cells	Insulin	Stimulates the body's use of glucagon
Delta Cells	Somatostatin	Restrains insulin and glucose level

SONOGRAPHY OF THE PANCREAS

Rarely, the pancreas is imaged without including the complete right upper quadrant. A thorough evaluation of the bile ducts and gallbladder for associated abnormalities is generally required. The pancreas can frequently be a neglected abdominal organ because of the challenge that it presents for

the sonographer. Adjacent bowel gas and body habitus are two obstacles that the sonographer encounters when attempting to assess the pancreas using sound. To improve visualization of the pancreatic head, the sonographer can ask the patient to drink a small cup of water. The water, once in the C-loop of the duodenum, will provide a delineated view of the pancreatic head in most individuals. Additionally, left lateral decubitus position may help improve visualization of the pancreatic head. To better visualize the pancreatic tail area, the sonographer can scan through the left kidney and spleen while the patient is in the right lateral decubitus position. Upright scanning can furthermore be valuable.

The pancreas is identified sonographically by its neighboring vasculature (Fig. 5-3, Table 5-3). The normal echogenicity of the pancreas is greater than that of the liver, and equal to, or greater than, that of the spleen in the adult. The pediatric pancreas may appear more hypoechoic because of the lack of fat surrounding the pancreas in younger patients. In the transverse plane, two round anechoic structures may be noted within the pancreatic head. The anterior structure is the gastroduodenal artery, and the more posterior structure is the common bile duct (Fig. 5-4).

Depending on the resolution of the ultrasound system, the normal main pancreatic duct may be noted during a routine sonographic examination. It will appear as an anechoic tube, consisting of two parallel lines and an anechoic lumen. The anteroposterior diameter of the main pancreatic duct should not exceed 2 mm. Color-flow Doppler imaging is helpful to differentiate the splenic artery from the main pancreatic duct because these two structures can have parallel paths within the body. The sonographic analysis of the pancreas may include measurements of the various parts of the organ. The pancreas is typically measured in the anteroposterior dimension in the transverse scan plane. The normal measurement of the pancreatic head and body is between 2 and 3 cm, while the tail should measure between 1 and 2 cm.

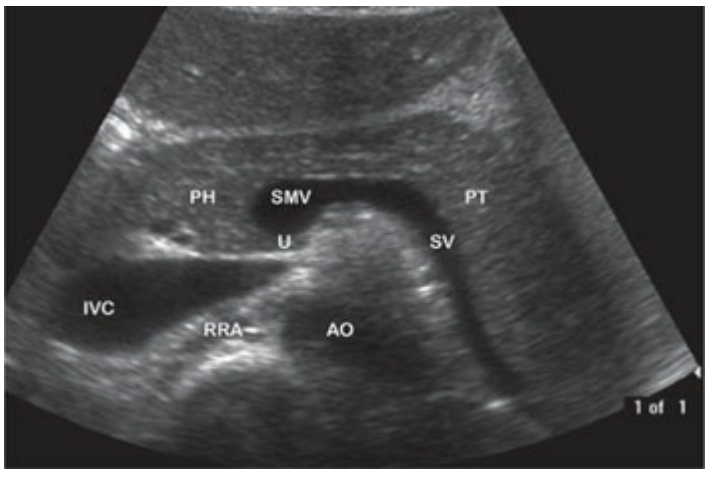


Figure 5-3 Transverse image of the pancreas showing the relationship of the pancreatic head (*PH*), pancreatic body, and pancreatic tail (*PT*) to the aorta (*AO*), inferior vena cava (*IVC*), splenic vein (*SV*), superior messenteric vein (*SMV*), uncinate process (*U*), and right renal artery (*RRA*).

TABLE 5-3 Adjacent vasculature associated with the pancreas

Part of the Pancreas	Adjacent Vasculature
Pancreatic head	Right lateral to superior mesenteric vein Anterior to inferior vena cava and inferior to portal vein
Uncinate process	Posterior to superior mesenteric vein; may completely surround superior mesenteric vein Anterior to aorta
Pancreatic neck	Anterior to portal confluence
Pancreatic body	Anterior to superior mesenteric vein, splenic vein, and superior mesenteric artery
Pancreatic tail	Splenic vein marks posterior border of pancreatic tail

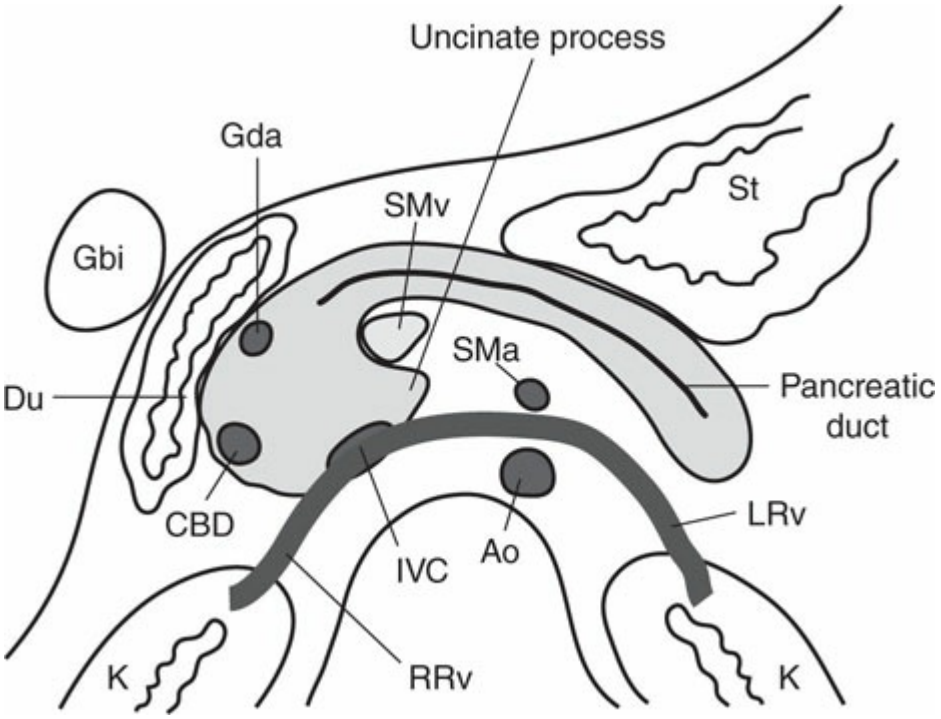


Figure 5-4 Transverse pancreas. Transverse drawing of pancreatic anatomy demonstrating the gallbladder (*Gbi*), duodenum (*Du*), stomach (*St*), kidneys (*K*), inferior vena cava (*IVC*), aorta (*Ao*), superior mesenteric artery (*SMa*), superior mesenteric vein (*SMv*), right renal vein (*RRv*), left renal vein (*LRv*), common bile duct (*CBD*), gastroduodenal artery (*Gda*), uncinate process of the pancreas, and the

pancreatic duct.

CONGENITAL ANOMALIES OF THE PANCREAS

The two most common congenital anomalies of the pancreas are pancreatic divisum and annular pancreas. Pancreatic divisum, which is the most common congenital variant of pancreatic anatomy, results from abnormal fusion of the pancreatic ducts during embryologic development. Pancreatic divisum results in a shortened main pancreatic duct (duct of Wirsung) that works to drain only the pancreatic head and not the entire pancreas. The accessory duct (duct of Santorini), which is much smaller than the main pancreatic duct, is therefore forced to drain the rest of the pancreas and empty a larger than normal amount of pancreatic juices through the minor sphincter. This abnormal duct arrangement causes a functional obstruction, disallowing proper pancreatic drainage and increasing the risk for pancreatic inflammation secondary to the obstruction. Therefore, although these individuals may be asymptomatic, some may be prone to suffer from both chronic and acute pancreatitis. The annular pancreas results from the maldevelopment of the two embryologic elements of the pancreas (Fig. 5-5). With an annular pancreas, the most ventral part of the pancreas encases the duodenum and may consequently lead to duodenal obstruction. This anomaly is typically detected in the neonate with the use of radiography.



SOUND OFF
Pancreatic divisum can lead to both acute and chronic pancreatitis.

PATHOLOGY OF THE PANCREAS

Acute Pancreatitis

Acute pancreatitis is the inflammation of the pancreas secondary to the leakage of pancreatic enzymes from the acinar cells into the parenchyma of the organ. These enzymes can destroy the pancreatic tissue and the tissues surrounding the pancreas. Acute pancreatitis may be classified as mild, moderate, or severe. The most common causes of acute pancreatitis are alcohol abuse and biliary tract disease, such as choledocholithiasis. Other causes of acute pancreatitis include post endoscopic retrograde cholangeopancreatography and trauma.

There are several specific clinical findings that suggest acute pancreatitis. The patient will complain of abdominal pain and back pain and also have an elevation in blood glucose (hyperglycemia), leukocytosis, serum amylase,

and lipase. Amylase levels will rise first, and within 72 hours an accompanying rise in lipase should occur. Lipase appears to be more specific for diagnosing pancreatitis because hyperamylasemia can be associated with other abnormalities. Alanine aminotransferase (ALT) is typically elevated with gallstone pancreatitis. Patients suffering from acute pancreatitis may find reprieve from symptoms in certain positions. For example, the supine position is often most painful, while sitting or leaning forward may temporarily relieve pain.

SOUND OFF

Acute pancreatitis will cause a rise in amylase first and then a rise in lipase, with lipase being the most helpful laboratory finding for the diagnosis of the disease.

Milder cases of pancreatitis can resolve spontaneously. Higher mortality rates are associated with acute pancreatitis when the disease progresses and leads to severe necrosis and hemorrhage of the organ (termed hemorrhagic pancreatitis). In these situations, patients may suffer from shock, ileus, and have a decreased hematocrit secondary to hemorrhage.

Unfortunately, sonography is not always successful at diagnosing cases of acute pancreatitis because the pancreas may appear completely normal with mild disease. But it can provide useful information as to the size and echogenicity of the gland and determine if any peripancreatic fluid collections exist. This peripancreatic fluid collection may be referred to as phlegmon. The involvement of the gland can be focal or diffuse. Focal pancreatitis will lead to an enlargement of the gland in a particular segment, most often in the head, appearing as a hypoechoic region. This manifestation of pancreatitis can resemble a neoplasm, and a close investigation of laboratory findings and other imaging is often required in such cases (Fig. 5-6).

Diffuse enlargement of the gland can also occur with pancreatitis, and with this manifestation the entire pancreas will most likely become enlarged and hypoechoic (Fig. 5-7). The pancreatic margins may appear ill defined with areas of fluid collections noted within and around the pancreas. Both focal and diffuse acute pancreatitis can lead to hemorrhage, peripancreatic fluid collections, and a pancreatic pseudocyst. With moderate and severe pancreatitis, the body will attempt to encapsulate the damaging digestive enzymes that leak from the pancreas and form a pseudocyst. One of the more common sites for a pancreatic pseudocyst is the lesser sac, which is located between the pancreas and the stomach, although pseudocysts may be found as far away as the groin. A pancreatic pseudocyst will appear as an anechoic

mass with posterior enhancement, although it may contain some internal echoes (Fig. 5-8). Vascular complications can also arise secondary to the destructive influence of the pancreatic enzymes on adjacent vascular structures. The more common vascular complications include thrombosis of the splenic vein and pseudoaneurysm of the splenic artery.

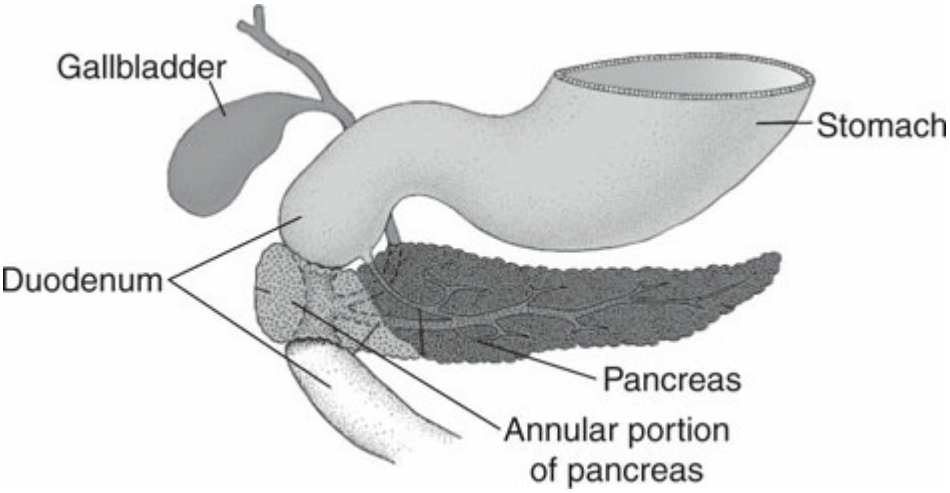


Figure 5-5 Annular pancreas. The most ventral part of the pancreas encases the duodenum and may consequently lead to duodenal obstruction.

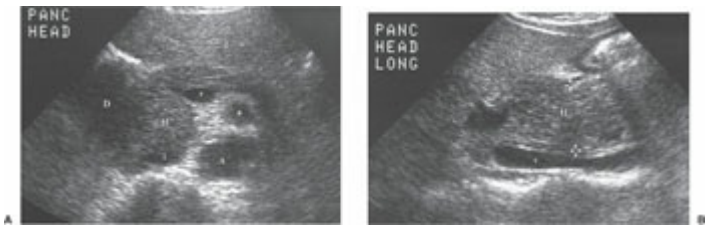


Figure 5-6 Focal acute pancreatitis. **A**. Transverse image of the pancreas reveals the duodenum (*D*), liver (*l*), inferior vena cava (*i*), aorta (*A*), superior mesenteric artery (*a*), superior mesenteric vein (*v*), and an enlarged pancreatic head (*H*). **B**. Longitudinal image of the pancreatic head (*H*) *between calipers*.

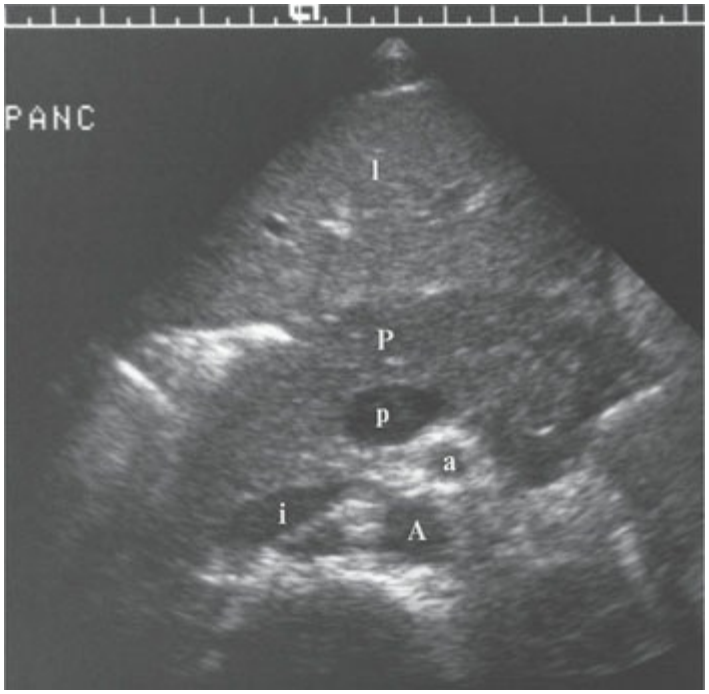


Figure 5-7 Diffuse acute pancreatitis. This transverse image of a diffusely enlarged and hypoechoic pancreas (*P*) demonstrates diffuse acute pancreatitis. Also seen in this image are the portal confluence (*p*), superior mesenteric artery (*a*), aorta (*A*), inferior vena cava (*i*), and liver (*l*).

SOUND OFF
Diffuse acute pancreatitis will result in a diffusely enlarge, hypoechoic gland.

CLINICAL FINDINGS OF ACUTE PANCREATITIS

1. Elevated amylase (within 24 h)
2. Elevated lipase (within 72 h)
3. Leukocytosis
4. Elevated ALT and other liver function labs when biliary obstruction is present
5. Abdominal pain (especially in the supine position)
6. Back pain
7. Fever
8. Nausea and vomiting
9. Severe acute pancreatitis may lead to hemorrhage and a decreased hematocrit



Figure 5-8 Pancreatic pseudocyst. Longitudinal image showing pancreatic pseudocysts arising from the tail of the pancreas (P) in a patient with acute pancreatitis.

SONOGRAPHIC FINDINGS OF ACUTE PANCREATITIS

1. The pancreas may appear normal
2. Diffusely enlarged, hypoechoic pancreas (diffuse manifestation)
3. Focal hypoechoic area within the pancreas (focal manifestation)
4. Unencapsulated anechoic fluid collection surrounding all or part of the pancreas (peripancreatic fluid)
5. Pancreatic pseudocyst
6. Abscess formation can occur and is seen as echogenic fluid containing gas bubbles
7. Biliary obstruction may be present (possibly choledocholithiasis)
8. Vascular complications such as splenic vein thrombosis and pseudoaneurysm of the splenic artery

Chronic Pancreatitis

Repeated bouts of pancreatic inflammation can lead to chronic pancreatitis, but not all patients who have a history of acute pancreatitis will develop chronic pancreatitis. Like acute pancreatitis, chronic pancreatitis is often caused by chronic alcohol abuse. But other causes exist, including hyperparathyroidism, congenital anomalies (pancreatic divisum), genetic disorders, pancreatic duct obstruction, and trauma. When destruction of the pancreatic tissue recurs, it can result in atrophy, fibrosis with scarring, and the development of calcification within the gland.

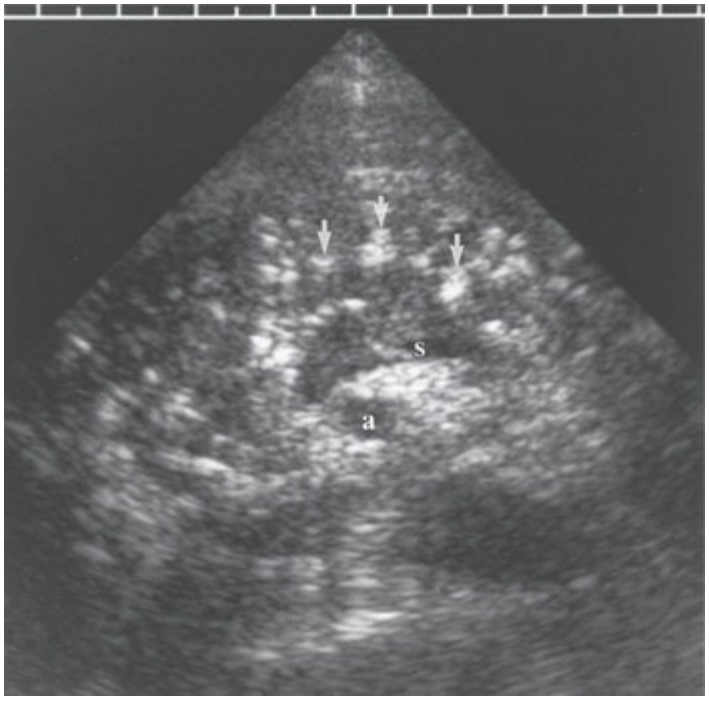


Figure 5-9 Chronic pancreatitis. Transverse image of a pancreas demonstrates multiple parenchymal calcifications (*arrows*), a sonographic sign of chronic pancreatitis. The superior mesenteric artery (*a*) and splenic vein (*s*) are also seen.

Although patients may be completely asymptomatic, they may present with a possible elevation in alkaline phosphatase (ALP), amylase and lipase, persistent epigastric and back pain, and jaundice. Patients may also suffer from weight loss, anorexia, vomiting, and constipation.

Sonographically, the pancreas will appear small, heterogeneous or hyperechoic, and have poor margins. Calcifications are often noted throughout the parenchyma of the organ, although they may be confined to the pancreatic ducts (Fig. 5-9). This, in turn, can lead to pancreatic duct and biliary dilatation. Like acute pancreatitis, chronic pancreatitis can affect only a segment of the pancreas. In addition, up to 40% of the time, there will be pseudocyst formation in association with chronic pancreatitis , and there is the possibility of portosplenic vein thrombosis.

SOUND OFF

Chronic pancreatitis can result in an atrophic, hyperechoic pancreas with calcifications and a prominent pancreatic duct.

CLINICAL FINDINGS OF CHRONIC PANCREATITIS

1. Asymptomatic
2. Persistent epigastric pain
3. Jaundice
4. Back pain

5. Possible elevation in amylase or lipase (but they may remain normal)
6. Possible elevation in ALP
7. Anorexia
8. Vomiting
9. Weight loss
10. Constipation

SONOGRAPHIC FINDINGS OF CHRONIC PANCREATITIS

1. Heterogeneous, or hyperechoic, atrophic gland with poor margins
2. Calcifications within the gland
3. Pancreatic pseudocyst
4. Dilated pancreatic duct
5. Stone(s) within the pancreatic duct that may lead to biliary obstruction
6. Possible portosplenic vein thrombosis

Pancreatic Adenocarcinoma

Pancreatic adenocarcinoma, also referred to as pancreatic ductal adenocarcinoma, is the most common primary pancreatic malignancy, and it is most commonly discovered in men. This disease often presents late and is too advanced to treat when it is discovered. Consequently, pancreatic cancer is the fourth most common cause of cancer-related deaths in men. The most common location of a pancreatic adenocarcinoma is within the pancreatic head, although they may be seen in other parts of the pancreas. If located within the head of the pancreas, this mass will often lead to obstruction of the common bile duct and Courvoisier gallbladder. Recall that Courvoisier gallbladder describes the clinical detection of an enlarged, palpable gallbladder that may be caused by a (potentially malignant) pancreatic head mass (Fig. 5-10). The patient frequently has jaundice secondary to the obstruction of the common bile duct by the mass (Fig. 5-11). Other clinical features include elevated amylase and/or lipase, nausea, persistent back or epigastric pain, weight loss, and loss of appetite.



SOUND OFF

Pancreatic adenocarcinoma is most commonly found in the head of the pancreas.

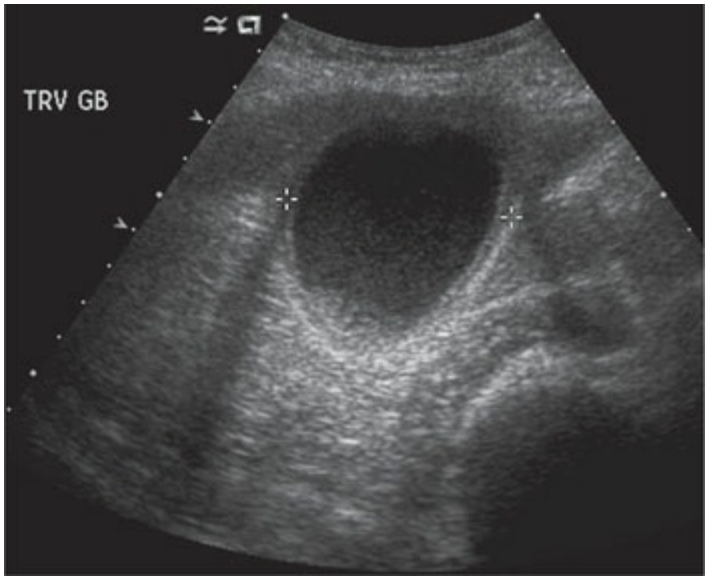


Figure 5-10 Courvoisier gallbladder. This gallbladder (*between calipers*) was enlarged, measuring greater than 5 cm in width, contained sludge, and was associated with a malignant pancreatic head mass.



Figure 5-11 Dilated common bile duct. This dilated common bile duct (*between calipers*) measured more than 2 cm in diameter. It was associated with a malignant pancreatic head mass.

Sonographically, the most common appearance of pancreatic adenocarcinoma is a hypoechoic mass in the head of the pancreas (Fig. 5-12). Obstruction of both the common bile duct and pancreatic duct may be present, a condition known as the double-duct sign. The liver and other abdominal organs should be evaluated for possible metastasis. The surgical procedure that is performed on patients with pancreatic adenocarcinoma is referred to as the Whipple procedure. The Whipple procedure may also be called a pancreaticoduodenectomy. This procedure is the removal of the head

of the pancreas, the gallbladder, some of the bile ducts, and the proximal duodenum.

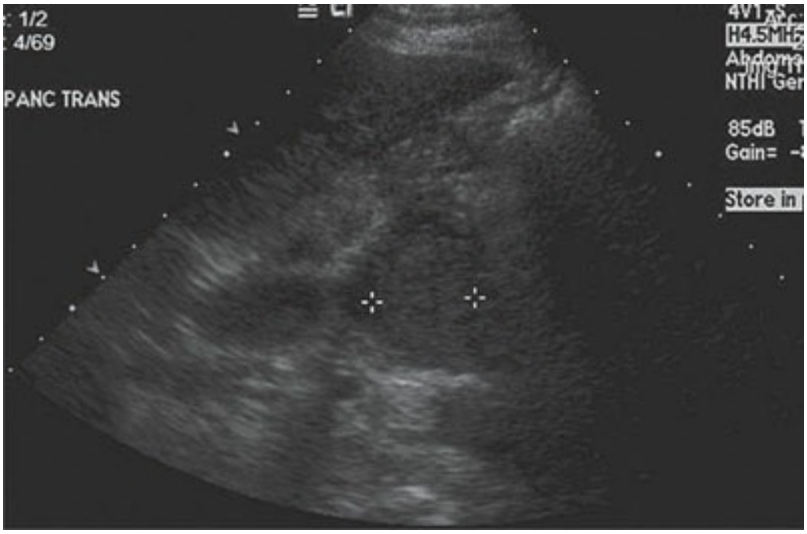


Figure 5-12 Pancreatic carcinoma. A solid hypoechoic mass (*between calipers*) representing pancreatic carcinoma is noted in the head of the pancreas.

CLINICAL FINDINGS OF PANCREATIC ADENOCARCINOMA

1. Elevated amylase and/or lipase
2. Loss of appetite
3. Weight loss
4. Jaundice
5. Courvoisier gallbladder (enlarged palpable gallbladder)
6. Epigastric pain
7. Elevated ALP and possibly other liver function labs associated with biliary obstruction

SONOGRAPHIC FINDINGS OF PANCREATIC ADENOCARCINOMA

1. Hypoechoic mass in the head of the pancreas
2. Dilated common bile duct and pancreatic duct (double-duct sign)
3. Liver and other abdominal organs should be evaluated for possible metastasis
4. Enlarged (hydropic) gallbladder

Pancreatic Cystadenomas and Cystadenocarcinoma

A cystadenoma within the pancreas may be referred to as either a (microcystic) serous cystadenoma or (macrocystic) mucinous cystadenoma. Serous tumors are small and always benign, while mucinous tumors are larger and have malignant potential. When malignant, the mucinous tumors are referred to as mucinous cystadenocarcinomas. They are most often found within the body and tail of the pancreas. Patients with these masses present

later than those with pancreatic head masses and may be asymptomatic initially. When symptomatic, patients often complain of epigastric pain, weight loss, palpable mass, and jaundice. The sonographic appearance of a benign serous cystadenoma is that of a small cystic mass, that sonographically may actually appear solid and echogenic secondary to the small size of the cysts. A mucinous cystadenoma or cystadenocarcinoma most often appears as a multilocular cystic masses that may contain mural nodules and calcifications. There may be associated dilation of the pancreatic duct as well.

SOUND OFF

Pancreatic cystadenocarcinoma is most often found in the body or tail of the pancreas.

CLINICAL FINDINGS OF CYSTADENOMAS AND CYSTADENOCARCINOMAS

1. May be asymptomatic initially
2. Epigastric pain
3. Weight loss
4. Palpable mass
5. Jaundice

SONOGRAPHIC FINDINGS OF SEROUS CYSTADENOMA

1. Cystic mass
2. May actually appear solid and echogenic secondary to the small size of the cysts

SONOGRAPHIC FINDINGS OF MUCINOUS CYSTADENOMA AND CYSTADENOCARCINOMA

1. Multilocular cystic masses that may contain mural nodules and calcifications
2. There may be associated dilation of the pancreatic duct

Islet Cell Tumors

Endocrine tumors can be found within the islets of Langerhans. There are two types of islet cell tumors: the insulinoma and the gastrinoma. These slow-growing tumors can be either functional or nonfunctional. Among the two, insulinomas are more common. Insulinomas are usually solitary, while gastrinomas are often multiple and difficult to image (Fig. 5-13). The functional gastrinomas can produce Zollinger–Ellison syndrome, which is described as the excessive secretion of acid by the stomach that leads to

peptic ulcers. Functional insulinomas can cause hypoglycemia. When seen, the most common sonographic appearance of an islet cell tumor is that of a small, hypoechoic mass that may contain calcifications. Islet cell tumors can be malignant or benign, with the functioning tumors most often appearing hypervascular with color Doppler interrogation.

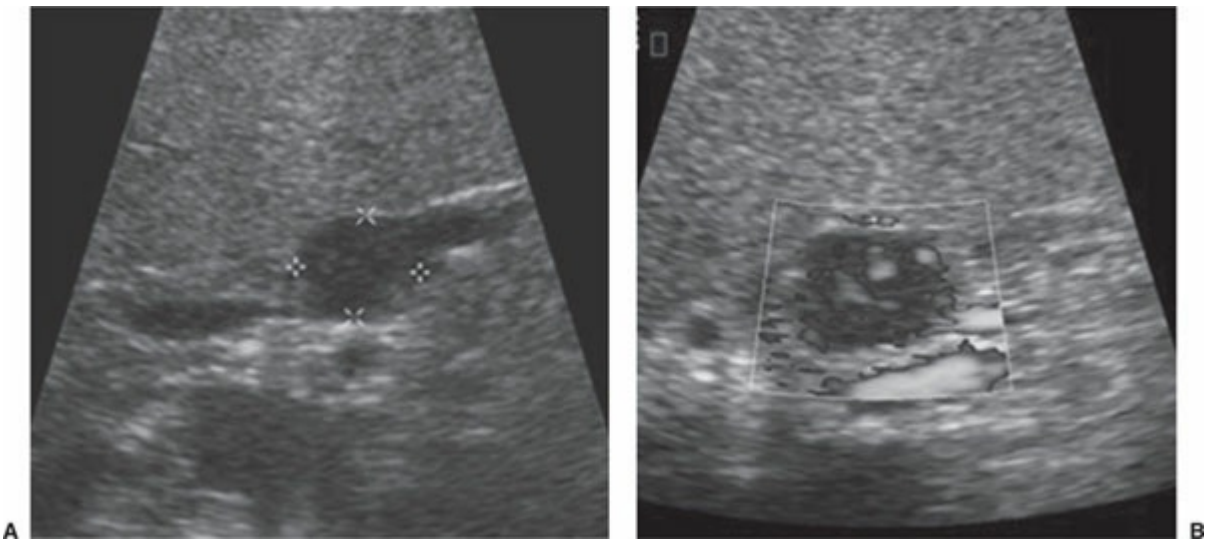


Figure 5-13 Insulinoma. A. A hypoechoic mass is noted within the pancreas (*between calipers*). B. The mass appears to be highly vascular. (Color image provided online.)

CLINICAL FINDINGS OF ISLET CELL TUMORS

1. Insulinoma: low blood sugar symptoms
2. Gastrinoma: Zollinger–Ellison syndrome

SONOGRAPHIC FINDINGS OF ISLET CELL TUMORS

1. Hypoechoic mass that may contain calcifications
2. Visualization is hard because of their small size

True Pancreatic Cysts

Cysts noted within the pancreas may be seen with von Hippel–Lindau disease, cystic fibrosis, or autosomal dominant polycystic kidney disease (ADPKD), the latter of which is associated with the development of cysts in many organs. Caution should be taken to ensure that the patient does not have a pancreatic pseudocyst , which is most often associated with a history of acute or chronic pancreatitis.

CLINICAL FINDINGS OF TRUE PANCREATIC CYSTS

1. Possible history of von Hippel–Lindau disease or cystic fibrosis
2. Possible history of ADPKD

SONOGRAPHIC FINDINGS OF TRUE PANCREATIC CYSTS

1. Well-defined, anechoic mass with posterior enhancement

Pancreatic Transplant Assessment

Transplantation of the pancreas can occur for several reasons, including treating severe type 1 diabetes. Transplantation techniques can vary, however; and in up to 80% of the time, patients undergo a renal transplant at the same time. If this occurs, the pancreas is placed within the right side of the abdomen and the renal transplant is placed on the left. There are two common types of transplantation techniques—exocrine bladder drainage and exocrine enteric drainage.

With exocrine bladder drainage, the vasculature of the donor pancreas is anastomosed to the recipient's common iliac vessels and the donor duodenum is anastomosed to the urinary bladder. Thus, the recipient's urinary bladder is used to expel the pancreatic secretions. This procedure has been associated with many drawbacks, including dehydration and bladder irritation.

The other type of pancreatic transplantation, which is more common, is referred to as exocrine enteric drainage, in which case the donor's duodenum is anastomosed to a loop of jejunum (Fig. 5-14). With this technique, the splenic and superior mesenteric arteries are connected with the donor iliac arteries in what is referred to as a "Y" graft. The donor common iliac portion is anastomosed to the recipient's common iliac artery and external iliac artery. These transplants may be located in the right upper quadrant or on the right side and have a vertical orientation within the body.

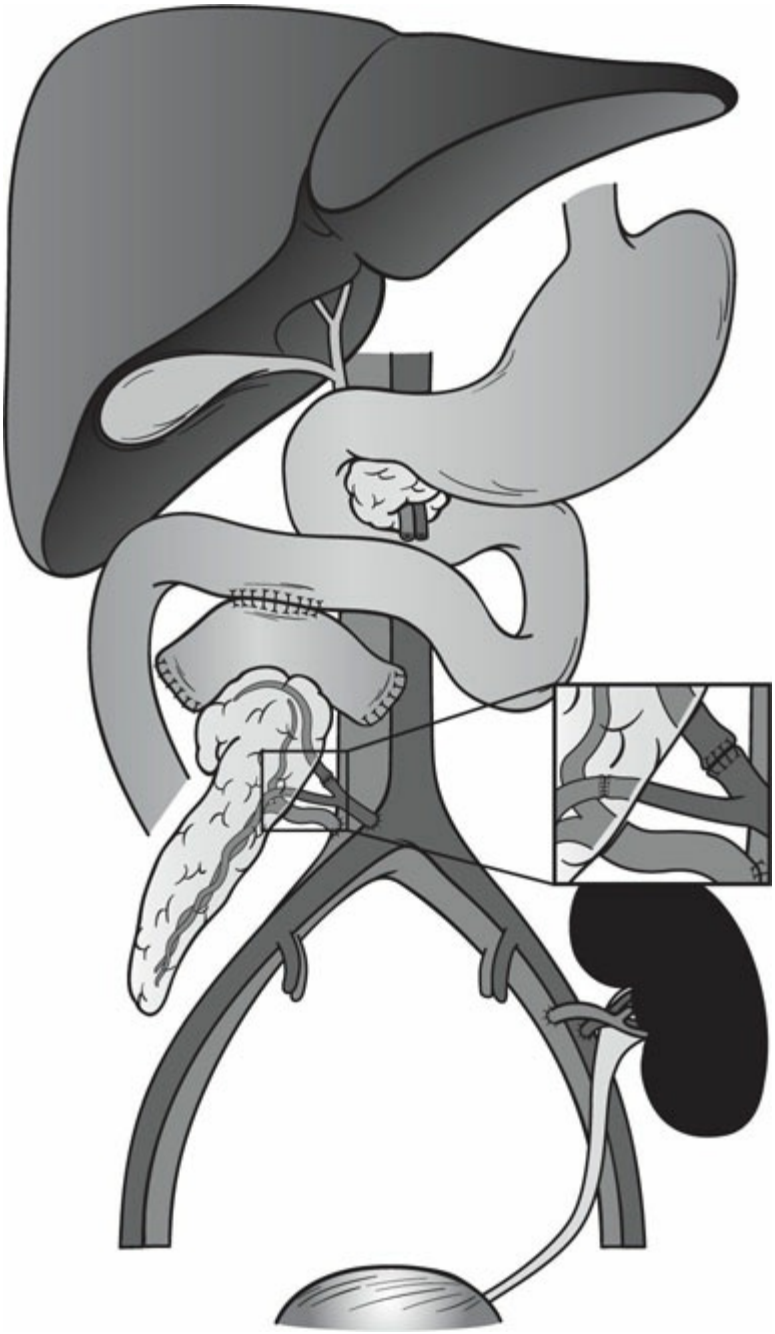


Figure 5-14 Pancreatic transplant of the most common exocrine enteric drainage arrangement.

The sonographic assessment of a pancreatic transplant includes a general evaluation of vascularity, the pancreatic parenchyma, and a search for fluid collections (Table 5-4). The pancreatic parenchyma should be homogenous and may be hypoechoic just after transplantation, but a hypoechoic transplant may also be a sign of pancreatitis or acute rejection, so close clinical evaluation is warranted. With rejection, the pancreas may also appear heterogeneous. Elevated resistive indices are often indicative of acute rejection as well. With chronic rejection, the pancreas can appear more hyperechoic, atrophic, and contain calcifications.

TABLE 5-4 Pancreatic transplant fluid collections

- Abscess
- Ascites
- Hematoma
- Urinoma (secondary to anastomosis problems at urinary bladder)
- Pseudocysts

An appreciation of the surgical transplant technique will help guide the sonographer in the analysis of the various vascular anastomoses because there can be several vascular complications (Table 5-5). Color Doppler, pulsed Doppler, and power Doppler can all be used to evaluate the vasculature of the transplant. Thrombosis of the graft, whether arterial or venous, is a common complication, and it typically occurs shortly after surgery. Graft thrombosis must be suspected if no flow can be detected within the gland. Other complications include pancreatitis, arterial stenosis, pseudoaneurysms, and fluid collections, such as hematomas and urinomas (with exocrine bladder drainage). An ultrasound-guided transplant biopsy may be performed to differentiate rejection from other complications if needed.

SONOGRAPHIC FINDINGS OF ACUTE PANCREATIC TRANSPLANT REJECTION

1. Hypoechoic or heterogeneous gland
2. Elevated resistive indices

TABLE 5-5 Pancreatic transplant vascular complications

- Arterial stenosis: focal areas of increased velocities
- Arterial thrombosis
- Graft thrombosis
- Pseudoaneurysms
- Splenic vein thrombosis: elevated pulsed-wave Doppler resistive index in the arterial inflow Doppler waveform, often greater than 1.0; absent splenic inflow
- Strictures: evident with turbulent flow

SONOGRAPHIC FINDINGS OF CHRONIC PANCREATIC

TRANSPLANT REJECTION

1. Hyperechoic echotexture
2. Atrophy
3. Pancreas may contain calcifications

REVIEW QUESTIONS

1. What results in a shortened main pancreatic duct that works to drain only the pancreatic head and not the entire pancreas?
   a. Pancreatic divisum
   b. Annular pancreas
   c. Acute pancreatitis
   d. Zollinger–Ellison syndrome

2. All of the following are part of the exocrine function of the pancreas except for the:
   a. Production of lipase
   b. Production of glucagon
   c. Production of amylase
   d. Production of sodium bicarbonate

3. What is another name for the accessory duct of the pancreas?
   a. Duct of Santorini
   b. Duct of Langerhans
   c. Duct of Oddi
   d. Duct of Wirsung

4. Which of the following results from the maldevelopment of the two embryologic elements of the pancreas and consequent obstruction of the duodenum?
   a. Pancreatic divisum
   b. Annular pancreas
   c. Whipple syndrome
   d. Zollinger–Ellison syndrome

5. Which of the following is associated with development of cysts within the pancreas?
   a. Autosomal recessive polycystic kidney disease
   b. von Hippel–Lindau disease
   c. Zollinger–Ellison syndrome
   d. Endoscopic retrograde cholangiopancreatography

6. The most common form of malignancy of the pancreas is:
   a. Cystadenocarcinoma
   b. Islet cell tumors
   c. Cystadenoma
   d. Adenocarcinoma

7. The Whipple procedure is performed on patients who have:
   a. Chronic pancreatitis
   b. Acute pancreatitis
   c. Pancreatic carcinoma
   d. Pancreatic transplants

8. Which of the following is the enzyme released by the pancreas that neutralizes stomach acid?
   a. Insulin
   b. Somatostatin
   c. Glycogen
   d. Sodium bicarbonate

9. The most common location of adenocarcinoma of the pancreas is within the:
   a. Head of the pancreas
   b. Neck of the pancreas
   c. Body of the pancreas
   d. Tail of the pancreas

10. Which of the following is a peripancreatic fluid collection that results from the inflammation of the pancreas?
   a. Pus
   b. Trypsin
   c. Phlegmon
   d. Chyme

11. The most common location of focal pancreatitis is within the:
   a. Head of the pancreas
   b. Neck of the pancreas
   c. Body of the pancreas
   d. Tail of the pancreas

12. All of the following are sonographic features of chronic pancreatitis except:
   a. Dilated pancreatic duct
   b. Calcifications within the pancreas

c. Pancreatic pseudocyst
d. Diffusely hypoechoic pancreas

13. Which of the following would be the least likely complication of a pancreatic transplant?
    a. Hematoma
    b. Biloma
    c. Ascites
    d. Urinoma

14. All of the following are classic clinical features of acute pancreatitis except:
    a. Leukocytosis
    b. Back pain
    c. Weight gain
    d. Fever

15. Which of the following laboratory values appears to be more specific for acute pancreatitis?
    a. Amylase
    b. Lipase
    c. Aspartate aminotransferase
    d. Serum glutamic oxaloacetic transaminase

16. Which type of pancreatic transplantation is more common?
    a. Exocrine enteric drainage
    b. Exocrine bladder drainage
    c. Endocrine bladder drainage
    d. Endocrine enteric drainage

17. One of the most common locations for a pancreatic pseudocyst is within the:
    a. Paracolic gutters
    b. Groin
    c. Spleen
    d. Lesser sac

18. Which of the following would be the least likely cause of acute pancreatitis?
    a. Alcohol abuse
    b. Hepatitis
    c. Trauma
    d. Gallstones

19. Which of the following is the most common islet cell tumor?
    a. Granuloma
    b. Gastrinoma
    c. Insulinoma
    d. Cystadenoma

20. Which of the following laboratory findings elevates first in the presence of acute pancreatitis?
    a. Amylase
    b. ALP
    c. ALT
    d. Lipase

21. Courvoisier gallbladder is found in the presence of:
    a. Hepatitis
    b. Cholecystitis and chronic pancreatitis
    c. Adenocarcinoma in the head of the pancreas
    d. Islet cell tumor in the tail of the pancreas

22. A gastrinoma of the pancreas can produce:
    a. Autosomal recessive polycystic kidney disease
    b. Von Hippel–Lindau disease
    c. Zollinger–Ellison syndrome
    d. Hyperinsulinemia

23. The muscle that controls the emptying of bile and pancreatic juices into the duodenum is the:
    a. Sphincter of Vater
    b. Sphincter of Oddi
    c. Ampulla of Vater
    d. Ampulla of Oddi

24. What is the name of the main pancreatic duct?
    a. Duct of Santorini
    b. Duct of Langerhans
    c. Duct of Oddi
    d. Duct of Wirsung

25. All of the following are clinical findings associated with pancreatic adenocarcinoma except:
    a. Epigastric pain
    b. Weight loss

c. Jaundice
d. Decrease amylase and lipase

26. The portion of the bowel that encompasses the head of the pancreas is the:
a. Duodenum
b. Jejunum
c. Ileum
d. Cecum

27. Which cells perform the exocrine function of the pancreas?
a. Whipple cells
b. Islets of Langerhans
c. Delta cells
d. Acinar cells

28. The most common echogenicity of an acutely inflamed pancreas is:
a. Anechoic
b. Hyperechoic
c. Hypoechoic
d. Calcified

29. Which of the following would be the most likely vascular complication of acute pancreatitis?
a. Thrombosis in the splenic vein
b. Pseudoaneurysm of the superior mesenteric artery
c. Thrombosis of the main portal vein
d. Stenosis of the superior mesenteric artery

30. The arterial blood supply to the head of the pancreas is via the:
a. Superior mesenteric artery
b. Splenic artery
c. Gastroduodenal artery
d. Hepatic artery

31. One clinical sign of an insulinoma is the presence of:
a. Hypoglycemia
b. Elevated alpha-fetoprotein
c. Hepatitis
d. Zollinger–Ellison syndrome

32. What is the early sonographic appearance of acute pancreatitis?
a. Calcifications within the gland

b. Pancreatic pseudocyst
c. Normal
d. Hyperechoic glandular echotexture

33. Within which parts of the pancreas are mucinous cystadenocarcinomas most often located?
a. Uncinate process and neck
b. Head and neck
c. Body and tail
d. Fundus and neck

34. Coexisting obstruction of the common bile duct and pancreatic duct may be referred to as the:
a. Double-barrel shotgun sign
b. Courvoisier sign
c. Mirizzi sign
d. Double-duct sign

35. Courvoisier gallbladder is the:
a. Enlargement of the pancreatic duct secondary to coexisting masses within the pancreatic body and gallbladder
b. Palpable gallbladder caused by a biliary obstruction in the area of the pancreatic head
c. Gallbladder disorder associated with the buildup of cholesterol crystals within the gallbladder wall
d. Type of gallbladder carcinoma that is the result of chronic cholecystitis

36. The pancreas is an:
a. Intraperitoneal organ
b. Retroperitoneal organ

37. Which part of the pancreas is located right lateral to superior mesenteric vein, anterior to inferior vena cava, and inferior to portal vein?
a. Head
b. Neck
c. Body
d. Tail

38. What vascular structure outlines the pancreatic tail posteriorly?
a. Superior mesenteric artery
b. Inferior mesenteric vein
c. Portal confluence

d. Splenic vein

39. Which part of the pancreas is located anterior to portal confluence?
    a. Uncinate process
    b. Pancreatic body
    c. Pancreatic neck
    d. Pancreatic tail

40. Which of the following is the hormone released by the pancreas that encourages the body's use of glucagon?
    a. Insulin
    b. Somatostatin
    c. Glycogen
    d. Sodium bicarbonate

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6 The Spleen

Introduction

Sonography is often used in conjunction with other imaging modalities to follow up pathologic processes affecting the spleen. This chapter will provide an overview of splenic anatomy, function, and pathology.

Key Terms

accessory spleen—a small, round island of splenic tissue often located near the splenic hilum or near the tail of the pancreas; also referred to as a splenule, a splenunculus, or a supernumerary spleen

angiosarcoma—a rare malignant tumor of the spleen that is derived from blood vessels

asplenia—the congenital absence of the spleen

autosplenectomy—the gradual fibrosis and dysfunction of the spleen secondary to a disease

bacterial endocarditis—an infection of the surface of the heart that can spread to other organs

Beckwith–Weidemann syndrome—a growth disorder syndrome synonymous with enlargement of several organs including the skull, tongue, and liver

blunt trauma—non-penetrating injury to the body

culling—the splenic process of removing irregular red blood cells from the

bloodstream

Epstein–Barr infection—a herpesvirus that can lead to infectious mononucleosis

erythropoiesis—the process of making red blood cells

extramedullary hematopoiesis—the spleen's hematopoietic function which can return in cases of severe anemia

granulomas—small echogenic calcifications that result from inflammation of the tissue in that area

granulomatous disease—an inherited disease that disrupts the normal immune system and causes it to malfunction resulting in immunodeficiency; chronic inflammation can lead to the development of granulomas in several organs

hemangioma—a benign tumor composed of blood vessels

heterotaxia syndromes—a situation in which the organs of the chest and abdomen are abnormally arranged

histoplasmosis—a disease that results from the inhalation of an airborne fungus that can affect the lungs and may spread to other organs

Hodgkin lymphoma—carcinoma of the lymphocytes that has a relatively high recovery rate; cancer of the lymphatic system

hydatid cyst—a cyst that results from the parasitic infestation of an organ by a tapeworm

lysis—breaking down of a cellular membrane

mononucleosis—an infectious disease caused by the Epstein–Barr virus

non-Hodgkin lymphoma—carcinoma of the lymphocytes; cancer of the lymphatic system

pitting—the splenic process of cleaning red blood cells of unwanted material

polysplenia—having many small islands of splenic tissue

portal hypertension—the elevation of blood pressure within the portal venous system

red pulp—specialized tissue within the spleen that performs its phagocytic function

Reed–Sternberg cells—the cells that indicate the presence of Hodgkin lymphoma

sarcoidosis—a systemic disease that result in the development of granulomas throughout the body

sickle cell anemia—an inherited disease in which the body produces abnormally shaped red blood cells

splenic cleft—a congenital anomaly in which the spleen is divided into two

portions by a band of tissue

splenic hamartoma—benign splenic mass that has been associated with Beckwith–Weidemann syndrome and tuberous sclerosis

splenic infarct—an area within the spleen that has become necrotic because of a lack of oxygen

splenic lymphangioma—benign tumor composed of lymph spaces

splenic torsion—the twisting of the splenic vasculature causing a disruption in the blood supply to the spleen and subsequent ischemia

splenomegaly—enlargement of the spleen

splenosis—the implantation of ectopic splenic tissue possibly secondary to splenic rupture

splenule—an accessory spleen

tuberous sclerosis—a systemic disorder that leads to the development of tumors within various organs

wandering spleen—a highly mobile spleen

white pulp—specialized lymphatic tissue within the spleen

ANATOMY AND PHYSIOLOGY OF THE SPLEEN

The spleen, the largest structure of the reticuloendothelial system, is an intraperitoneal organ located within the left upper quadrant of the abdomen whose primary objective is to filter the peripheral blood (Tables 6-1 and 6-1). The gastrosplenic ligament attaches the spleen to the stomach, placing the spleen inferior to the diaphragm and posterolateral to the stomach. The spleen, which has a concave inferior surface and a convex superior surface, is also considered the largest lymphatic organ of the body. It begins to develop around the fifth week of gestation. In the fetus, it is responsible for erythropoiesis. In childhood, it plays an important role in the defense against infection, while in adults it produces lymphocytes and monocytes. Although red blood cell production in the adult is primarily performed by the bone marrow, the spleen's hematopoietic function can return in cases of severe anemia. This is referred to as extramedullary hematopoiesis.

TABLE 6-1 Anatomy bordering the spleen

Inferior to the diaphragm
Posterolateral to the stomach
Superior to the left kidney
Lateral to the adrenal gland and pancreatic tail

TABLE 6-2 Functions of the spleen

1. Defense against disease
2. Hematopoiesis/erythropoiesis
3. Destruction and removal of flawed red blood cells and platelets
4. Blood reservoir
5. Storage of iron

The spleen is composed of specialized tissues called white pulp and red pulp. The lymphatic function of the spleen is performed by the white pulp, which produces lymphocytes to aid in the immune response. The red pulp, which contains red blood cells and macrophages, performs the phagocytic function of the spleen. Phagocytes engulf and destroy pathogens. The spleen also removes irregular red blood cells from the bloodstream through a process called culling. It can also clean red blood cells of unwanted material, a process called pitting.

VASCULAR ANATOMY OF THE SPLEEN

The splenic artery is a branch of the celiac trunk, which may also be referred to as the celiac artery or celiac axis. From the trunk, the splenic artery courses laterally toward the spleen. It marks the superior border of the pancreatic body and tail. This is why the splenic artery can be confused for the main pancreatic duct in some patients. The splenic artery enters the spleen at the splenic hilum superior and anterior to the splenic vein. The splenic vein exits the spleen and travels along the posterior border of the pancreatic tail and body. It joins with the superior mesenteric vein posterior to the pancreatic neck to form the portal vein (Fig. 6-1).



SOUND OFF

The splenic artery can be confused for the main pancreatic duct in some patients because it takes a similar course in the body.

SONOGRAPHY OF THE SPLEEN

Most often, the spleen is best visualized with deep inspiration, with the patient lying on his or her right side. The sonographic appearance of the normal spleen is frequently isoechoic to the liver, although it may be slightly more echogenic. As stated earlier, the adult spleen has a concave, pointed

inferior margin and a convex superior border, offering the typical crescent moon shape on sonography. The size of the spleen in the adult varies with age and sex. The spleen decreases in size with advancing age and may enlarge—which is termed splenomegaly—when pathology is present. The splenic hilum, located along the medial surface of the spleen, is the location of the splenic vessels.

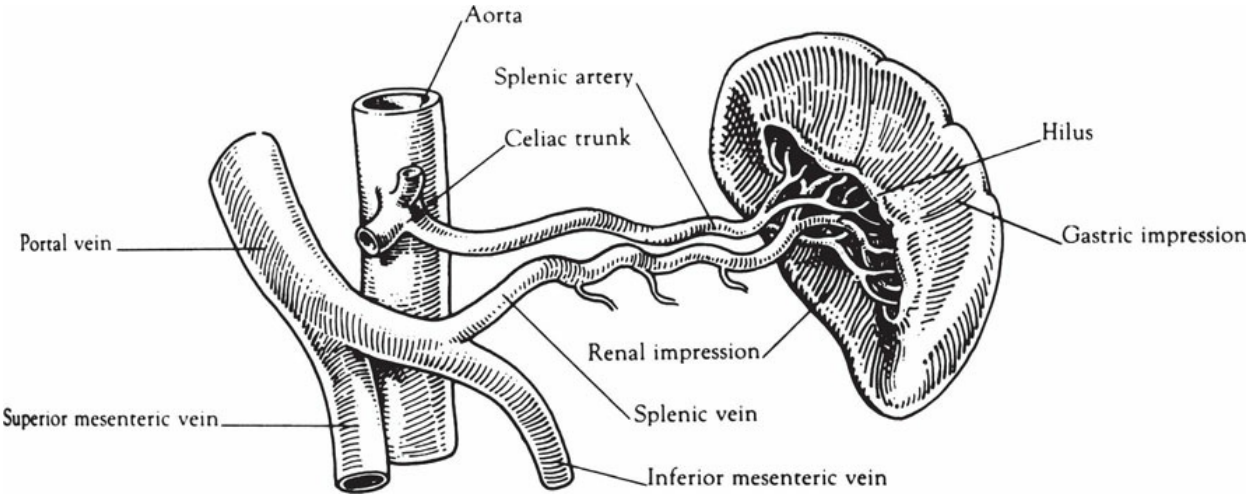


Figure 6-1 The circulation of the spleen, including the splenic vein and splenic artery. (Images reprinted with permission from Kawamura D. Abdomen and Superficial Structures. 2nd Ed. Philadelphia: Lippincott Williams & Wilkins, 1997:267.)

SOUND OFF
The spleen is typically either isoechoic or more hyperechoic to the liver.

CONGENITAL ANOMALIES AND VARIANTS

Some persons may have an accessory spleen, also referred to as a splenule, a splenunculus, or a supernumerary spleen. This small, round island of splenic tissue is typically located near the splenic hilum or possibly near the tail of the pancreas. An accessory spleen will appear isoechoic to the spleen (Fig. 6-2). The spleen may also appear to be divided by a hyperechoic line in some individuals, which is a common anomaly termed splenic cleft. Conversely, two uncommon congenital anomalies are asplenia and polysplenia. Whereas asplenia is the congenital absence of the spleen, polysplenia leads to the development of multiple small masses of splenic tissue. Both asplenia and polysplenia have been associated with some complex cardiac malformations and the abnormal location of other organs—termed heterotaxia syndromes.

The implantation of ectopic splenic tissue, also referred to as splenosis,

can occur following splenic rupture. In this situation, the ectopic tissue can resemble a mass. Though exceedingly rare, the spleen may also be identified as a wandering spleen, in which case the splenic ligaments are absent or underdeveloped, thus allowing the opportunity for the spleen to be highly mobile and often positioned well into the lower abdomen. Unfortunately, an individual with a wandering spleen could suffer from splenic torsion because the vessels of the spleen may twist secondary to the hypermobility of the organ. The resulting vascular torsion can lead to a splenic infarction (see section “Splenic Infarct” in this chapter).

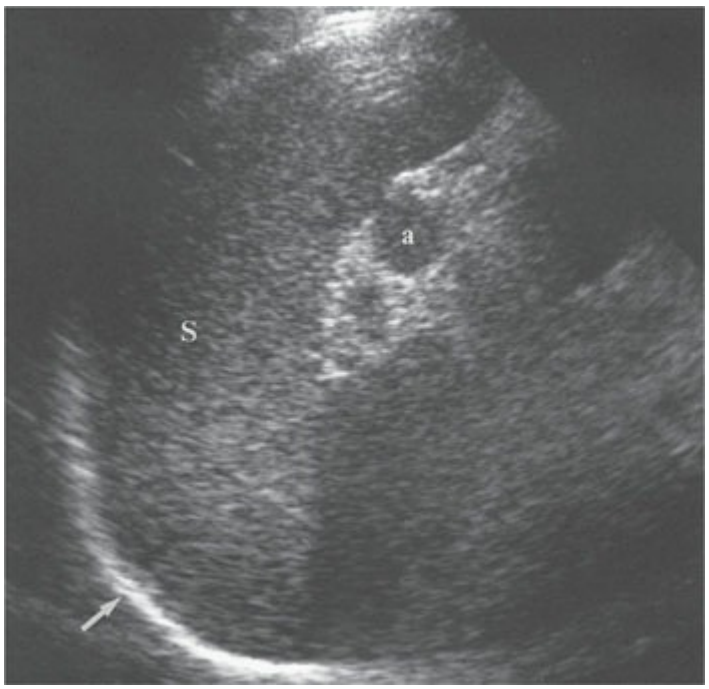


Figure 6-2 Accessory spleen. An isoechoic mass is seen adjacent to the spleen (S) at the level of the splenic hilum. This is the most common location and appearance of an accessory spleen (a). The diaphragm is also clearly identified in this image (*arrow*).

PATHOLOGY OF THE SPLEEN

Splenomegaly

The most common abnormality of the spleen is splenomegaly. Enlargement of the spleen can be manually suspected on physical examination and subsequently confirmed using sonography. Although the splenic size varies with age, gender, and body sizes, the spleen should never measure more than 12 to 13 cm in length and 6 cm in thickness in adults. Suspicion of splenomegaly should arise however when the spleen extends beyond the inferior pole of the left kidney. As the spleen enlarges, it tends to become more hypoechoic.

The most common cause of splenomegaly is portal hypertension. And

when portal hypertension is suspected as the cause of splenomegaly, the sonographer should closely evaluate the splenic hilum for evidence of abdominal varices seen in this condition (Fig. 6-3). Other causes of splenomegaly include trauma, leukemia, lymphoma, a pediatric sickle cell anemia crisis, granulomatous disease, and infections, such as endocarditis, acquired immunodeficiency syndrome (AIDS), and hepatitis. Epstein–Barr infection, which is associated with infectious mononucleosis, will typically result in splenomegaly in both adults and children. It is important to note that massive splenomegaly can lead to spontaneous splenic rupture.

SOUND OFF
The most common cause of splenomegaly is portal hypertension.

CLINICAL FINDINGS OF SPLENOMEGALY

1. Palpable, enlarged spleen
2. Hemolytic abnormalities (sickle cell)
3. Trauma
4. Infection
5. History of cirrhosis, trauma, leukemia, or lymphoma
6. Possible elevated white blood cell and/or red blood cell count

SONOGRAPHIC FINDINGS OF SPLENOMEGALY

1. Enlargement of the spleen to greater than 12 to 13 cm in length or 6 cm in thickness
2. Spleen extends beyond the inferior pole of the left kidney

Splenic Cysts

Most often, true splenic cysts will have thin walls, an anechoic center, and posterior enhancement (Fig. 6-4). However, cysts found in the spleen can appear complex, particularly those associated with trauma (see section "Splenic Trauma" in this chapter). Other complex appearing cysts could be displaced pancreatic pseudocysts, an abscess, congenital cysts, hydatid cysts, cystic metastasis, or even cystic manifestation of primary cancers. The hydatid cyst will have a similar sonographic appearance and clinical findings to those found in the liver (see section "Hydatid Liver Cyst" in Chapter 2).



Figure 6-3 Splenomegaly. Transverse image of an enlarged spleen (SP) in a patient with cirrhosis and portal hypertension. Note that there are multiple prominent blood vessels adjacent to the splenic hilum (*arrows*).

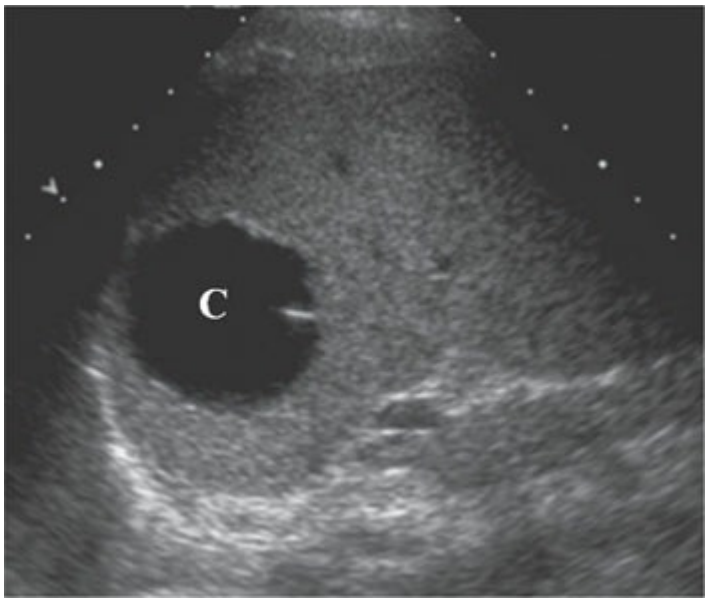


Figure 6-4 Splenic cyst. A simple splenic cyst (*C*) is noted in this patient.

SOUND OFF

The splenic infarct is typically seen sonographically as a hypoechoic, wedge-shaped mass.

CLINICAL FINDINGS OF SIMPLE SPLENIC CYSTS

1. Asymptomatic
2. Pain can occur with hemorrhage

SONOGRAPHIC FINDINGS OF SIMPLE SPLENIC CYSTS

1. Round

2. Smooth-walled mass
3. Anechoic mass
4. Posterior enhancement

Splenic Abscess

Though uncommon, an abscess can develop in the spleen. Clinical findings of a splenic abscess may include fever, leukocytosis, left upper quadrant tenderness, left flank pain, and splenomegaly. A splenic abscess will most likely have a complex appearance, but can be completely hypoechoic, and possibly contain debris or gas. As with any abscess, the air and gas produced by the bacteria within a splenic abscess can produce dirty shadowing.

CLINICAL FINDINGS OF SPLENIC ABSCESS

1. Fever
2. Leukocytosis
3. Left upper quadrant tenderness
4. Left flank pain
5. Splenomegaly

SONOGRAPHIC FINDINGS OF SPLENIC ABSCESS

1. Complex appearance
2. May contain debris or gas (that produces dirty shadowing)
3. Can be completely hypoechoic

Splenic Infarct

Tissue that has been deprived of oxygen will eventually die. This is referred to as an infarct. Clinically, patients often suffer from the sudden onset of left upper quadrant pain. A splenic infarct may be caused by sickle cell disease, bacterial endocarditis, tumor embolization, vasculitis, and lymphoma. It will appear as a hypoechoic, wedge-shaped mass within the spleen in the acute stage (Fig. 6-5). In the chronic stage, splenic infarcts tend to appear more echogenic compared to adjacent normal splenic tissue.

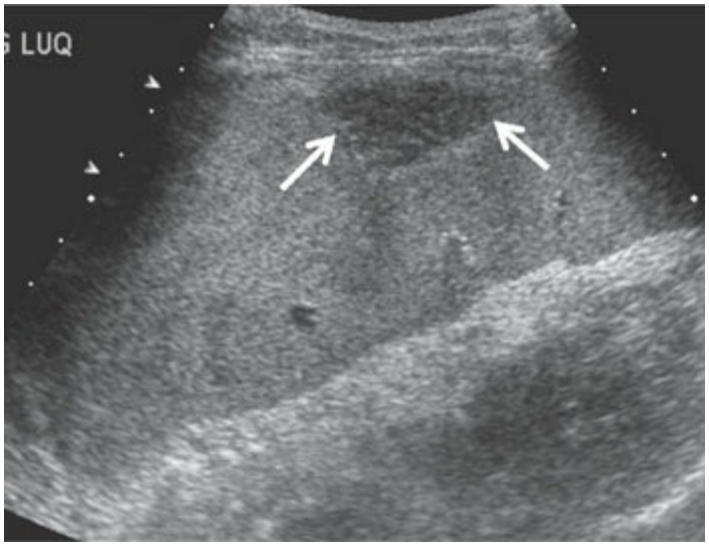


Figure 6-5 Splenic infarct. Infarcts often appear as wedge-shaped hypoechoic areas (*arrows*) within the spleen.

CLINICAL FINDINGS OF A SPLENIC INFARCT

1. Sudden onset of left upper quadrant pain

SONOGRAPHIC FINDINGS OF A SPLENIC INFARCT

1. Acute infarct—hypoechoic, wedge-shaped mass within the spleen
2. Chronic infarct—hyperechoic, wedge-shaped mass within the spleen

Splenic Trauma

The spleen is often injured in cases of blunt trauma. And though sonography may not be the initial modality of choice immediately following trauma, it is often utilized to evaluate the spleen once the initial diagnosis of splenic trauma is established. Patients who suffer from splenic trauma complain of left upper quadrant pain and will have decreased hematocrit. A hematoma within the spleen can be difficult to identify with sonography, as it may appear isoechoic to the splenic tissue and can be located either subcapsular or within the splenic parenchyma. The evolution of a splenic hematoma as it undergoes lysis may range from complex or hypoechoic (early in the event) to echogenic or isoechoic, and then back to hypoechoic or anechoic as the hematoma resolves (Fig. 6-6). Occasionally, a laceration may be noted as an echogenic line within the spleen immediately following trauma. In time, hemorrhagic cysts that result from trauma may eventually have calcified walls. Also, as mentioned earlier in this chapter, splenic rupture can lead to implants of ectopic splenic tissue referred to as splenosis. These masses of splenic tissue have a similar sonographic appearance to normal splenic tissue, and when found in unusual locations, can be mistaken for more

worrisome neoplasms.

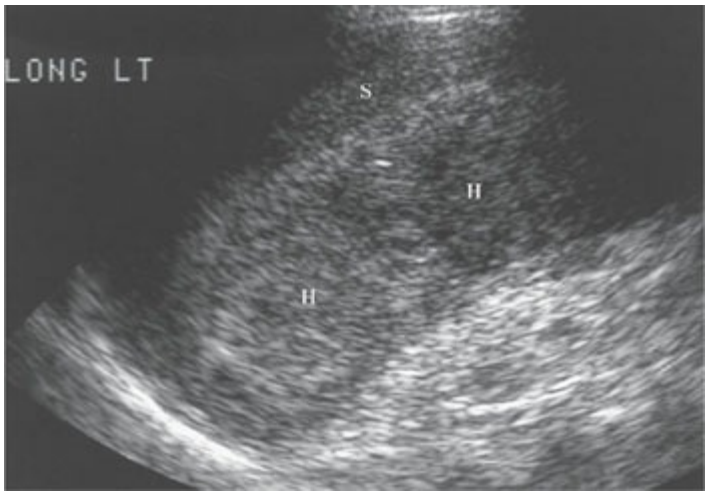


Figure 6-6 Splenic hematoma. An intraparenchymal hematoma (*H*) is seen as a solid-appearing mass within the spleen (*S*).

CLINICAL FINDINGS OF SPLENIC TRAUMA

1. Blunt trauma to the left upper quadrant
2. Severe left upper quadrant pain
3. Decreased hematocrit level indicating active bleeding

SONOGRAPHIC FINDINGS OF SPLENIC TRAUMA

1. Acute hemorrhage—complex or hypoechoic
2. Middle stage—echogenic (with clot formation) or isoechoic
3. Later stages of hemorrhage—anechoic or hypoechoic
4. Chronic hematomas may have a complex appearance or calcified walls

Splenic Hemangioma

The hemangioma is the most common benign tumor of the spleen. A splenic hemangioma will most often appear as a well-defined, hyperechoic mass (Fig. 6-7). The patient with a hemangioma will be asymptomatic, although pain may occur with hemorrhage.

SOUND OFF
The most common mass of the spleen is the benign hemangioma.

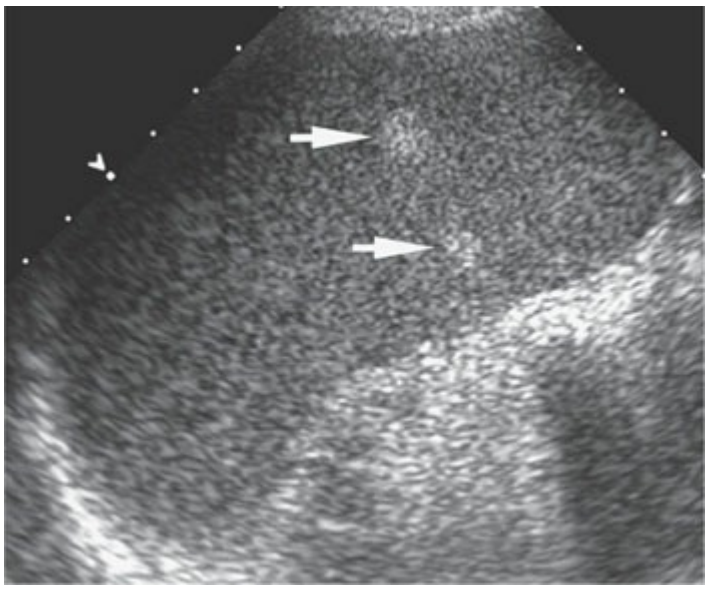


Figure 6-7 Splenic hemangioma. Two small, echogenic masses representing hemangiomas (*arrows*) are noted in this asymptomatic patient.

CLINICAL FINDINGS OF A SPLENIC HEMANGIOMA

1. Asymptomatic
2. Pain occurs with hemorrhage

SONOGRAPHIC FINDINGS OF A SPLENIC HEMANGIOMA

1. Well-defined, hyperechoic mass

Granulomatous Disease in the Spleen

Occasionally, small echogenic foci may be seen throughout the spleen. These small foci most often represent granulomas. They can be individual or multiple and may produce an acoustic shadow. Granulomas can be found in patients who have a history of histoplasmosis, tuberculosis, or sarcoidosis. While granulomas tend to be small, larger calcifications may result from the resolution of splenic hematomas, infarctions, abscesses, neoplasms, or infection.

CLINICAL FINDINGS OF GRANULOMATOUS DISEASE OF THE SPLEEN

1. Asymptomatic
2. May have a history of histoplasmosis, tuberculosis, or sarcoidosis

SONOGRAPHIC FINDINGS OF GRANULOMATOUS DISEASE OF THE SPLEEN

1. Small, echogenic foci that may shadow

Splenic Hamartoma

The splenic hamartoma is benign and typically appears as a hypoechoic mass, though the sonographic appearance can be variable. These tumors have been associated with Beckwith–Weidemann syndrome and tuberous sclerosis. They are typically asymptomatic. Color Doppler may yield hypervascularity.

CLINICAL FINDINGS OF SPLENIC HAMARTOMA

1. Asymptomatic
2. Pain can occur with rupture
3. Patient may have a history of Beckwith–Weidemann syndrome or tuberous sclerosis

SONOGRAPHIC FINDINGS OF SPLENIC HAMARTOMA

1. Hypoechoic mass or masses (echotexture can vary however)
2. Color Doppler may reveal hypervascularity

Malignant Diseases of the Spleen

Patients with splenic malignancy may suffer from LUQ pain, fever, weight loss, and malaise. Although exceedingly rare, the primary malignant tumor of the spleen is an angiosarcoma. Angiosarcomas will appear sonographically as a complex or solid mass. More often, lymphoma and leukemia rather than angiosarcoma will involve the spleen, with lymphoma being cited as the most common malignancy of the spleen. Diffuse involvement of lymphoma or leukemia will often produce splenomegaly. These malignant processes can also manifest as a focal disease and be recognized as a hypoechoic mass or masses scattered throughout spleen (Fig. 6-8). However, focal masses are less commonly seen with leukemia.

Lymphoma can be classified as Hodgkin lymphoma or non-Hodgkin lymphoma. Both are malignant disorders affecting the lymphocytes, with subsequent immune system compromise. The differentiation between these two types of cancers is performed microscopically. The presence of Reed–Sternberg cells indicates Hodgkin lymphoma. Hodgkin lymphoma can be treated and carries a high recovery rate. The other form of lymphoma, non-Hodgkin lymphoma, is not as easily managed but is more common. Metastatic disease to the spleen is rare and occurs late in the disease process. The most common primary locations are the breast, lung, skin (melanoma), and ovary.

CLINICAL FINDINGS OF SPLENIC MALIGNANCY

1. LUQ pain
2. Fever
3. Weight loss
4. Malaise



Figure 6-8 Lymphoma. Transverse image of the spleen in a patient with Hodgkin lymphoma reveals a hypoechoic mass (*between calipers*).

SONOGRAPHIC FINDINGS OF SPLENIC MALIGNANCY

1. Diffuse—splenomegaly
2. Focal—hypoechoic masses

PEDIATRIC PATHOLOGY OF THE SPLEEN

Splenic Lymphangioma

The splenic lymphangioma is a benign lesion that is a congenital malformation of the lymphatic system. Sonographically, lymphangiomas appear as multicystic masses that contain hypoechoic or anechoic locules and hyperechoic septations. Patients often suffer from splenomegaly as well. Lymphangiomas are most commonly identified in children. Clinically, a child with a splenic lymphangioma would most likely complain of nausea, LUQ pain, and abdominal distention.

CLINICAL FINDINGS OF SPLENIC LYMPHANGIOMA

1. Nausea

2. LUQ pain
3. Abdominal distention

SONOGRAPHIC FINDINGS OF SPLENIC LYMPHANGIOMA

1. Multicystic masses
2. Masses may contain hypoechoic or anechoic locules and hyperechoic septations

Sickle Cell Anemia

Sickle cell disease is a group of inherited blood disorders that includes sickle cell anemia. Those with sickle cell anemia have abnormally, crescent-shaped red blood cells that have a tendency to attach to each other and obstruct normal vascular channels. Sickle cell anemia is found more frequently in African-American, Middle East, Mediterranean, and Hispanic children of Caribbean descent in the United States. As mentioned earlier, a child suffering from sickle cell disease often has an enlarged spleen during a sickle cell crisis. However, with time and with recurrent sickle cell crises, the spleen will eventually become fibrotic and atrophy. The wasting-away of the spleen in this manner is caused by multiple infarctions and is termed autosplenectomy. Patients undergoing a sickle cell crisis may have decreased hematocrit and complain of bone pain. These patients are at increased risk for multiple organ damage, blindness, gallstones, and strokes.

REVIEW QUESTIONS

1. A 15-year-old male patient presents to the sonography department with a history of left sided trauma 5 years earlier. He currently has no LUQ discomfort. The sonographic findings of the spleen include a mass that contains calcification producing distinct posterior shadowing. What is the most likely diagnosis?
   a. Splenic hemangioma
   b. Splenic hamartoma
   c. Splenic lymphangioma
   d. Splenic hematoma

2. A 25-year-old female patient presents to the sonography department for a complete abdominal sonogram. She complains of right lower quadrant pain and nausea. The right upper abdomen appears normal. A small mass is noted in the area of the splenic hilum. This mass appears isoechoic to the spleen. What does this most likely represent?
   a. Pancreatic cystadenocarcinoma

b. Splenic hemangioma
c. Accessory spleen
d. Neuroblastoma

3. A rare malignant tumor of the spleen that consists of blood vessels is a/an:
   a. Lymphoma
   b. Angiosarcoma
   c. Hemangioma
   d. Granuloma

4. A 48-year-old male patient with a history of severe, sudden onset of left upper quadrant pain without trauma presents to the sonography department for a sonogram of the spleen. You visualize a wedge-shaped, hypoechoic area within the spleen. This most likely represents a:
   a. Splenic infarct
   b. Splenic hematoma
   c. Splenic hemangioma
   d. Splenic metastasis

5. A patient with a wandering spleen would have an increased risk for:
   a. Splenic infection
   b. Splenosis
   c. Splenic carcinoma
   d. Splenic torsion

6. What is the most common sonographic appearance of a splenic hemangioma?
   a. Echogenic
   b. Hypoechoic
   c. Anechoic
   d. Complex

7. The process of making red blood cells is termed:
   a. Erythropoiesis
   b. Leukopoiesis
   c. Histopoiesis
   d. Anemia

8. Multiple, small echogenic foci scattered throughout the spleen in a patient with a history of toxoplasmosis most likely represent:
   a. Sarcoidosis
   b. Granulomas

c. Lymphangiomas
d. Hemangiomas

9. The splenic artery marks the:
   a. Posterior aspect of the pancreatic body and tail
   b. Superior aspect of the pancreatic body and tail
   c. Medial surface of the pancreatic body and tail
   d. Lateral aspect of the pancreatic body and tail

10. The most common cause of splenomegaly is:
   a. Hepatitis
   b. Portal hypertension
   c. Lymphoma
   d. Trauma

11. The splenic hamartoma may be discovered more often in individuals with a history of:
   a. HIV
   b. Splenic carcinoma
   c. Tuberous sclerosis
   d. Meckel–Gruber syndrome

12. The type of tissue within the spleen that is responsible for its phagocytic function is the:
   a. Red pulp
   b. White pulp
   c. Culling pulp
   d. Pitting pulp

13. A 32-year-old female patient presents to the sonography department for an abdominal sonogram. An evaluation of the spleen reveals a 1-cm, rounded, echogenic mass that does not produce acoustic shadowing. What is the most likely diagnosis?
   a. Pheochromocytoma
   b. Lipoma
   c. Splenic metastasis
   d. Hemangioma

14. Which of the following is a benign lesion that is a congenital malformation of the lymphatic system:
   a. Lymphangioma
   b. Hemangioma
   c. Angiosarcoma

d. Myeloma

15. The spleen is a/an:
    a. Intraperitoneal organ
    b. Retroperitoneal organ

16. The type of tissue within the spleen that is responsible for its lymphatic function is the:
    a. Red pulp
    b. White pulp
    c. Culling segment
    d. Pitting segment

17. Which of the following children would least likely suffer from sickle cell anemia?
    a. African-American
    b. Caucasian
    c. Middle Eastern
    d. Mediterranean

18. The splenic vein marks the:
    a. Posterior aspect of the pancreatic body and tail
    b. Anterior aspect of the pancreatic body and tail
    c. Medial surface of the pancreatic body and tail
    d. Lateral aspect of the pancreatic body and tail

19. All of the following are functions of the spleen except:
    a. Storage of iron
    b. Defense against disease
    c. Blood reservoir
    d. Destruction of phagocytic cells

20. A 26-year-old patient with a long-standing history of multiple sickle cell crises and subsequent splenic infarctions presents to the sonography department for an abdominal sonogram. After thoroughly evaluating the left upper quadrant, only a fraction of splenic tissue can be identified. This describes the process of:
    a. Splenomicroly
    b. Asplenia
    c. Splenosis
    d. Autosplenectomy

21. Where is the most common location of an accessory spleen?

a. Superior to the spleen
b. Medial to the diaphragm and left kidney
c. Splenic hilum
d. Anterior to the pancreatic body

22. All of the following can be associated with splenomegaly except:
a. Trauma
b. Hemolytic abnormalities
c. Mononucleosis
d. Pancreatitis

23. What is the splenic process of cleaning red blood cells of unwanted material:
a. Pitting
b. Plucking
c. Culling
d. Coring

24. Diffuse involvement of lymphoma or leukemia of the spleen will often lead to:
a. Splenomegaly
b. Splenic atrophy
c. Epstein–Barr infection
d. Splenic torsion

25. The splenic artery originates at the:
a. Superior mesenteric artery
b. Inferior phrenic artery
c. Celiac trunk
d. Gastroduodenal artery

26. Which of the following is a congenital anomaly in which the spleen is divided into two portions by a band of tissue?
a. Splenic infarct
b. Splenic cleft
c. Splenosis
d. Splenic impertecta

27. A 35-year-old male patient presents to the sonography department for an abdominal sonogram with a history of abdominal pain and histoplasmosis. What are you more likely to identify within the spleen?
a. Multiple histomas
b. Multiple hemangiomas

c. Multiple metastatic lesions
d. Multiple granulomas

28. A 14-year-old male patient presents to the sonography department after falling from his bicycle. An abdominal sonogram reveals a complex-appearing mass within the spleen. This most likely represents a:
    a. Splenic hemangioma
    b. Splenic granuloma
    c. Splenic hematoma
    d. Splenic infarct

29. A sickle cell crisis will often lead to:
    a. Splenic metastasis
    b. Sarcoidosis
    c. Splenomegaly
    d. Wandering spleen

30. Epstein–Barr infection is best described as:
    a. A herpesvirus that can lead to infectious mononucleosis
    b. A herpesvirus that is often associated with splenic granulomatous disease
    c. An infection that results in sickle cell anemia in children
    d. An infection within a splenic hematoma following blunt trauma

31. The spleen removes irregular cells from the bloodstream through a process called:
    a. Pitting
    b. Culling
    c. Crimping
    d. Amassing

32. An area within the spleen that has become necrotic because of a lack of oxygen is referred to as a:
    a. Splenic hemangioma
    b. Splenic hematoma
    c. Splenic infarct
    d. Granuloma

33. What systemic disease results in the development of granulomas within the spleen and throughout the body?
    a. Granulomatosis
    b. Sarcoidosis
    c. Sickle cell anemia

d. Beckwith–Weidemann syndrome

34. A complex cyst that results from the parasitic infestation of the spleen by a tapeworm is the:
    a. Bacterial endocarditic cyst
    b. Choledochal cyst
    c. Hydatid cyst
    d. Candidiasis

35. From the list below, what is the most likely clinical finding of a patient who has a splenic hemangioma?
    a. Fever
    b. Decreased hematocrit
    c. Elevated white blood cell count
    d. Asymptomatic

36. In a patient with suspected lymphoma, the presence of Reed–Sternberg cells indicates:
    a. Hodgkin lymphoma
    b. Non-Hodgkin lymphoma
    c. Metastatic liver disease
    d. Splenic infarction

37. Which of the following describe the implantation of ectopic splenic tissue possibly secondary to splenic rupture?
    a. Splenosis
    b. Polysplenia
    c. Asplenia
    d. Wandering spleen

38. All of the following are true of the spleen except:
    a. It is the largest structure of the reticuloendothelial system
    b. The primary objective of the spleen is to filter the peripheral blood
    c. The spleen has a convex inferior margin and a concave superior border
    d. The spleen is considered the largest lymphatic organ

39. The splenic vein joins with what structure posterior to the pancreatic neck to form the portal vein?
    a. Inferior mesenteric artery
    b. Superior mesenteric vein
    c. Inferior mesenteric artery
    d. Main hepatic vein

40. Small echogenic foci scattered throughout the spleen most likely represent:
    a. Multiple benign hemangioma
    b. Multiple benign hematomas
    c. Multiple benign granulomas
    d. Malignant lymphoma

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7

The Urinary Tract

Introduction

This chapter provides an overview of the anatomy of the kidneys, ureters, and bladder. In addition, pathology of the urinary tract is explained. This chapter provides important vascular anatomy of the urinary tract, as well as renal vascular complications and basic transplant assessment.

Key Terms

acquired renal cystic disease—a cystic disease of the kidney that is often the result of chronic hemodialysis

acute pyelonephritis—an inflammation of the kidney or kidneys

acute renal failure—a sudden decrease in renal function

acute tubular necrosis—damage to the tubule cells within the kidneys that results in renal failure

amyloidosis—the accumulation of the abnormal protein amyloid in the kidneys and other organs that can lead to organ damage, as well as renal failure

angiomyolipoma—a common benign renal tumor that consists of a network of blood vessels, muscle, and fat

autosomal dominant polycystic kidney disease—an inherited disease that results in the development of renal, liver, and pancreatic cysts late in life; also referred to as adult polycystic kidney disease

autosomal recessive polycystic kidney disease—an inherited renal disease that results in bilateral enlargement of the fetal kidneys and microscopic renal cysts; also referred to as infantile polycystic kidney disease

azotemia—an excess of urea or other nitrogenous compounds in the blood

bacteriuria—the presence of bacteria in the urine

benign prostatic hypertrophy—benign enlargement of the prostate gland

bladder diverticulum—an outpouching of the urinary bladder wall

blood urea nitrogen—a measure of the amount of nitrogen in the blood in the form of urea

chronic pyelonephritis—chronic inflammation of the kidney or kidneys

chronic renal failure—the gradual decrease in renal function over time

columns of Bertin—an extension of the renal cortex located between the renal pyramids

congenital hydronephrosis—the dilation of the renal collecting system at birth

cortical nephrocalcinosis—the accumulation of calcium within the cortex of the kidney

cortical thinning—the thinning of the (renal) cortex

corticomedullary differentiation—the ability to sonographically distinguish between the normal cortex and medullary portions of the kidney

creatinine—a chemical waste molecule that is generated from muscle metabolism and excreted in the urine

cystitis—inflammation of the urinary bladder

detrusor muscle—the muscle that controls the appropriate emptying of the urinary bladder

dirty shadowing—shadowing seen posterior to gas or air

dysuria—painful or difficult urination

emphysematous pyelonephritis—the formation of air within the kidney parenchyma secondary to bacterial infiltration

end-stage renal disease—medical condition in which the kidneys fail to function adequately, thus requiring the use of dialysis

exophytic—growing outward

flank pain—pain in one side of the body between the upper abdomen and the back

Gerota fascia—the fibrous envelope of tissue that surrounds the kidney and adrenal gland

glomerulonephritis—an infection of the kidney glomeruli

gross hematuria—blood within the urine that is visible to the naked eye

hematoma—a localized collection of blood

hematuria—blood within the urine; can be described as microscopic or gross

hemodialysis—form of dialysis that utilizes a machine that essentially acts as a kidney whereby it extracts the patient's blood, filters it, and returns the filtered blood to the patient

Henoch–Schonlein purpura—an autoimmune disorder and form of vasculitis associated with purple spots on the skin, gastrointestinal complications, joint pain, and possibly kidney failure; mostly occurs in childhood

homeostasis—maintenance of normal body physiology

hydronephrosis—the dilation of the renal collecting system resulting from the obstruction of the flow of urine from the kidney(s) to the bladder; also referred to as pelvocaliectasis or pelvicaliectasis

hydroureter—distension of the ureter with fluid because of obstruction

hyperkalemia—abnormally high levels of potassium in the blood

hypernephroma—carcinoma of the kidney; also referred to as renal cell carcinoma

hypovolemia—decreased blood volume

immunocompromised—the state of having an immune system that is impaired for some reason

infantile polycystic kidney disease—an inherited renal disease that results in bilateral enlargement of the fetal kidneys and microscopic renal cysts; also referred to as autosomal recessive polycystic kidney disease

lactate dehydrogenase—an enzyme found within the blood that may be used to monitor renal function; may also be used as a tumor marker

lymphocele—a collection of lymphatic fluid

malaise—the feeling of uneasiness

medullary nephrocalcinosis—the accumulation of calcium within the medulla of the renal parenchyma

medullary sponge kidney—a congenital disorder characterized by the accumulation of calcium within abnormally dilated collecting ducts located within the medulla

megacystis—an abnormally enlarged urinary bladder

megaureter—an enlarged ureter; can be congenital or acquired

moiety—division of the duplex collecting system, as in the upper pole moiety and the lower pole moiety

multicystic dysplastic kidney disease—a renal disease thought to be caused

by an early renal obstruction; leads to the development of multiple noncommunicating cyst of varying sizes in the renal fossa

mural nodules—a small mass located on the wall of a structure

nephroblastoma—the most common solid malignant pediatric abdominal mass; may also be referred to as Wilms tumor

nephrocalcinosis—an accumulation of calcium within the renal parenchyma

nephrolithiasis—the urinary stones located within the kidney; kidney stones

nephron—the functional unit of the kidney

nephrotic syndrome—a kidney disorder caused by damage to the glomeruli that results in excess amounts of protein in the urine and the swelling of the ankles, face, and feet because of accumulation of excess water

neurogenic bladder—a bladder that is poorly functioning secondary to any type of neurologic disorder

nocturia—frequent urination at night

nuclear cystogram—a nuclear medicine examination of the urinary bladder and ureters

oliguria—scant or decreased urine output

oncocytoma—a benign renal tumor that is often found in men in their 60s

papillary projection—a small protrusion of tissue

pelvic kidney—a kidney located within the pelvis

perinephric abscess—an abscess that surrounds the kidney

peritoneal dialysis—a form of dialysis that uses a solution that is instilled into the abdomen; uses diffusion and osmosis to filter waste products from the blood

pheochromocytoma—a benign, solid adrenal tumor associated with uncontrollable hypertension

posterior urethral valves—irregular thin membranes of tissue located within the male posterior urethra that do not allow urine to exit the urethra

proteinuria—protein within the urine

prune belly syndrome—a syndrome that is a consequence of the abdominal wall musculature being stretched by an extremely enlarged urinary bladder

pyonephrosis—the condition of having pus within the collecting system of the kidney

pyuria—pus within the urine

renal adenoma—a benign renal mass

renal artery stenosis—the narrowing of the renal artery

renal cell carcinoma—the carcinoma of the kidney; also referred to as hypernephroma

renal colic—a sharp pain in the lower back that radiates into the groin and is typically associated with the passage of a urinary stone through the ureter

renal cortex—the outer part of the renal parenchyma that is responsible for filtration

renal:aorta ratio—a ratio calculated by dividing the highest renal artery velocity by the highest aortic velocity obtained at the level of the renal arteries

renal hamartoma—see angiomyolipoma

renal hemangioma—a benign renal mass that consists of blood vessels

renal hematoma—a collection of blood on or around the kidney that is typically associated with some form of trauma or perhaps an invasive kidney procedure

renal infarction—an area in the kidney that becomes necrotic because of a lack of oxygen

renal lipoma—a fatty tumor on the kidney

renal medulla—the inner part of the renal parenchyma that is responsible for absorption

renal pyramids—cone-shaped structures located within the renal medulla that contains part of the nephron

renal sinus—the portion of the kidney containing the minor calices, major calices, renal pelvis, and infundibula

renal vein thrombosis—a blood clot located within the renal vein

renin—enzyme produced by the kidneys that helps regulate blood pressure

renunculi—the two embryonic parenchymal tissue masses that combine to create the kidney; singular form is renunculus

retroperitoneal fibrosis—a disease characterized by the buildup of fibrous tissue within the retroperitoneum; this mass may involve the abdominal aorta, inferior vena cava, ureters, and sacrum

reverberation artifact—an artifact that results from a sound wave interacting with a large acoustic interface that repeatedly bounces back and forth from the interface to the transducer

septation—a partition separating two or more cavities

staghorn calculus—a large urinary stone that completely fills and takes the shape of the renal pelvis

subureteral Teflon injection—a treatment method for vesicoureteral reflux disease that uses a bulking agent to elevate the ureteral orifice and distal ureter, allowing for the normal flow of urine from the ureter into the bladder

tardus–parvus—the combination of a slow systolic upstroke and a

decreased systolic velocity

trabeculae—muscular bundles

transitional cell carcinoma—a malignant tumor of the urinary tract that is often found within the urinary bladder or within the renal pelvis

trigone of the urinary bladder—the area within the urinary bladder where the two ureteral orifices and urethral orifice are located

tuberous sclerosis—a systemic disorder that leads to the development of tumors within various organs

tubo-ovarian abscess—a pelvic abscess involving the uterine tubes and ovaries that is often caused by pelvic inflammatory disease

twinkle sign—an artifact noted as an increased color Doppler signal posterior to a kidney stone or biliary stone

urachus—a tubular structure that is a remnant of embryonic development which extends from the umbilicus to the apex of the bladder

ureteral jets—jets of urine that are the result of urine being forced into the urinary bladder from the ureters; can be demonstrated with color Doppler imaging

ureterocele—an abnormality in which the distal ureter projects into the urinary bladder

ureteropelvic junction—the junction of the ureter and renal pelvis

ureterovesicular junction—the junction of the ureter and urinary bladder

urethritis—inflammation of the urethra

urinoma—a localized collection of urine

urolithiasis—a urinary stone

uterine leiomyoma—a benign, smooth muscle tumor of the uterus; may also be referred to as a fibroid or uterine myoma

vesicoureteral reflux—the abnormal retrograde flow of urine from the urinary bladder into the ureter and possibly into the kidney(s)

voiding cystourethrogram—a radiographic examination that involves the assessment of the urinary bladder and distal ureter for urinary reflux and other abnormalities

von Hippel–Lindau syndrome—an inherited disorder characterized by tumors of the central nervous system and the development of cysts within the kidneys, renal cell carcinoma, and pheochromocytomas

Wilms tumor—the most common solid malignant pediatric abdominal mass; a malignant renal mass that may also be referred to as nephroblastoma

xanthogranulomatous pyelonephritis—a rare chronic form of pyelonephritis that is typically the result of a chronic obstructive process

ANATOMY AND PHYSIOLOGY OF THE KIDNEY

The urinary system consists of the upper urinary tract (kidneys and ureters) and the lower urinary tract (bladder and urethra). The functional unit of the kidney is the nephron. The nephron begins to function by the ninth week of gestation, although urine production begins between 11 and 13 weeks. A functional urinary tract is vital for the fetus because urine—produces by the fetal kidneys—comprises the majority of amniotic fluid.

Fundamentally, the kidneys are organs that are vital for homeostasis. The kidneys detoxify and filter the blood; excrete metabolic waste; dynamically reabsorb amino acids, ions, glucose, and water; and maintain normal pH, iron, and salt levels in the blood. The kidneys also work to regulate blood pressure by producing the enzyme renin. Each kidney is formed when two embryonic parenchymal masses combine. These kidney tissue masses are referred to as the renunculi or ranunculi. The kidneys initially develop within the pelvis and ascend into the fetal abdomen by 12 weeks gestation. This explains the occurrence of ectopic kidney locations, such as a pelvic kidney, which is the most common location of an ectopic kidney. However, this ascension can be arrested anywhere along the typical migratory path.



SOUND OFF

The most common location of an ectopic kidney is within the pelvis.

Adult kidneys are bean-shaped organs that are retroperitoneal in location. The left kidney is located higher than the right because of the size of the liver, which occupies most of the right upper quadrant of the abdomen. The left kidney is also on average a little longer than the right kidney, although there is typically no more than a 2 cm difference between kidney lengths. However, suspicion of functional renal abnormalities may abound if there is a significant difference between kidney length, and certainly in these situations, clinical history should be correlated closely. Although the coverings of the kidney are indistinguishable on a sonogram, there are four that are present. The pararenal fat layer covers Gerota fascia, and an additional fat layer known as the perirenal fat layer. The innermost covering of the kidney is the renal capsule. These layers protect the kidney and act as shock absorbers.

The kidneys are made up of two parts: the renal parenchyma and the renal sinus (Fig. 7-1). The parenchyma of the kidney consists of the renal medulla and renal cortex. The renal medulla, the inner part of the parenchyma, is responsible for absorption. It includes the renal pyramids. The renal cortex, which is responsible for filtration of the blood, is the outer part of the renal

parenchyma. The renal sinus contains the renal collecting system that is composed of the minor calices, major calices, renal pelvis, and infundibula. The renal pelvis is a funnel-shaped structure that collects the urine before it moves into the ureter.

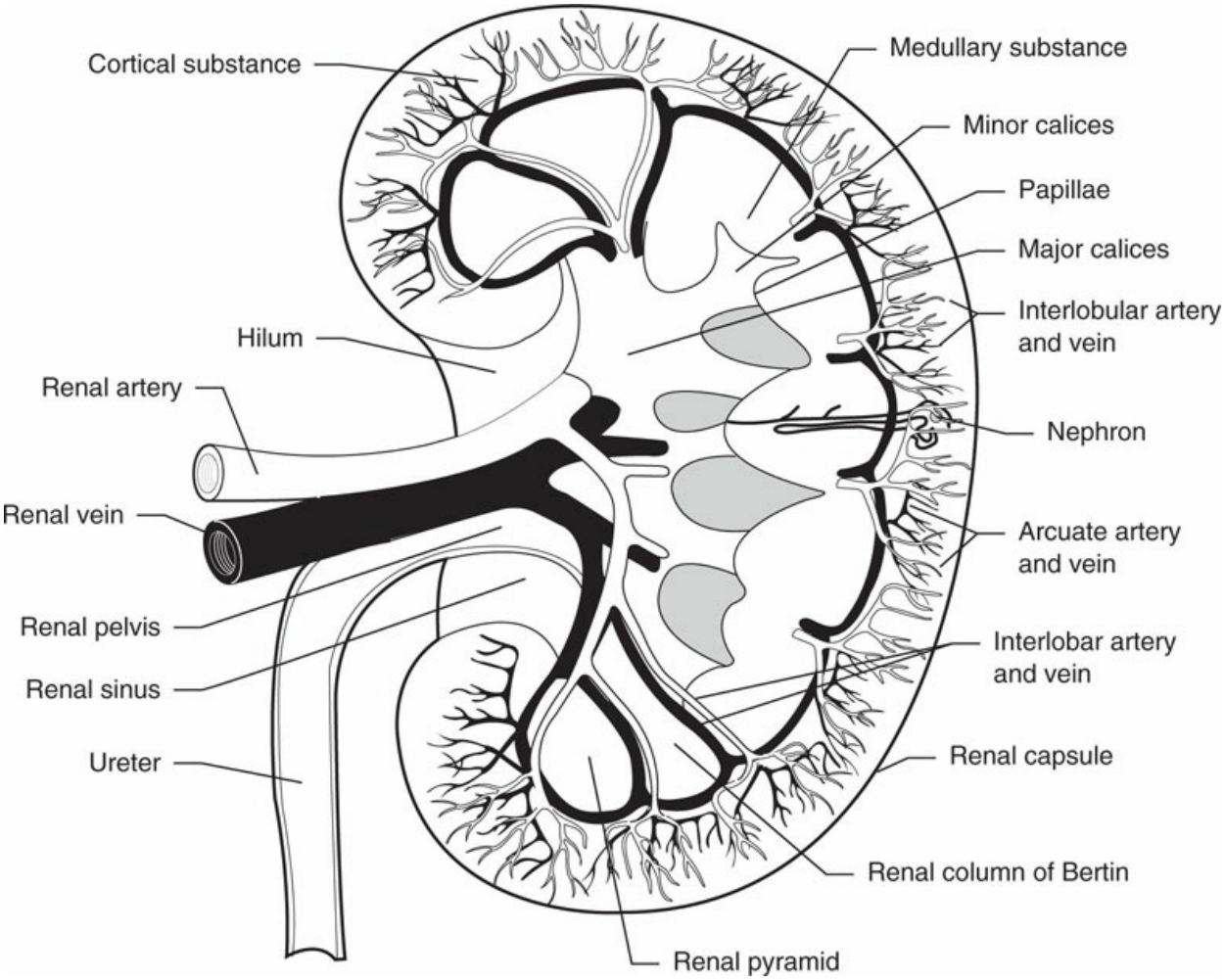


Figure 7-1 Kidney anatomy. A cut section through a normal kidney shows the renal pelvis, the renal vessels, and the parenchyma.

VASCULATURE A NATOMY OF THE KIDNEYS

The renal arteries are branches of the abdominal aorta that are located just below the level of the superior mesenteric artery. Oxygenated blood travels through the renal arteries, which enter the renal hilum, and then into the segmental branches and subsequently into the interlobar arteries, which can be noted traveling between the renal pyramids (Fig. 7-1). The interlobar arteries branch into the much smaller arcuate arteries at the base of the pyramids. The arcuate arteries then branch into the interlobular arteries, and into the afferent arterioles, which carry blood into the glomerulus for filtration. The right renal artery travels posterior to the inferior vena cava

(IVC), and is therefore longer than the left renal artery.

The renal veins exit the kidneys at their respective renal hilums and connect to the lateral aspects of the IVC. The left renal vein has to travel across the abdomen, between the superior mesenteric artery and abdominal aorta, and is therefore longer than the right renal vein. It is normal for the left renal vein to be smaller in diameter as it travels between the superior mesenteric artery and abdominal aorta, and then to appear more prominent beyond that point as it travels to the left kidney.

LABORATORY TESTS

Both urine and blood tests are used to evaluate renal function. A urinalysis for renal function includes, but is not limited to, an evaluation of the urine for bacteria (bacteriuria), pus (pyuria), blood (hematuria), and protein (proteinuria) (Table 7-1). Blood tests may be used to analyze levels of blood urea nitrogen (BUN), creatinine, glomerular filtration rate (GFR), and lactate dehydrogenase (LDH) (Table 7-2). BUN measures the amount of urea nitrogen, a byproduct of protein metabolism that occurs within the liver and is excreted by the kidneys. Creatinine, also excreted by the kidneys, measures the amount of creatinine phosphate found in the skeletal muscles. An elevation in either BUN or creatinine indicates some form of renal disease. The GFR—which utilizes creatinine, age, body size, and gender—can be used to evaluate the overall function of the kidneys. LDH is an additional enzyme found within the blood that may be used to monitor renal function and other abnormalities, including some forms of cancer. LDH is found in nearly all tissues of the body. LDH elevates as a result of cell death. Therefore, an elevation in LDH is not a specific indicator for renal disease.

TABLE 7-1 Urinalysis and associated abnormalities

Urinalysis Results	Associated Abnormality
Bacteriuria	**Acute pyelonephritis**
	Urinary tract infections
Pyuria	Urinary tract infections
	Usually accompanied by bacteria
Hematuria	Acute and **chronic pyelonephritis**
	Hypernephroma (renal cell carcinoma)
	Renal infarction
	Trauma
	Urinary calculi

Proteinuria	Benign and malignant masses **Glomerulonephritis** Infection **Nephrotic syndrome** Acute or chronic pyelonephritis Urinary calculi
Urine pH (abnormal)	Urinary calculi (used to determine composition of stones)
Specific gravity	Low: renal failure and pyelonephritis High: dehydration
Elevated white blood cells (in urine)	Urinary tract infection

TABLE 7-2 Blood tests and associated abnormalities

Blood Test (Serum)	Elevation	Reduction
Blood urea nitrogen	Renal failure Parenchymal disease Renal obstruction Dehydration Diabetes mellitus Hemorrhage	Liver disease and failure Malnutrition Overhydration Smoking Pregnancy
Creatinine	Renal failure Chronic nephritis Renal obstruction Diabetes mellitus Reduced renal blood flow	N/A
Glomerular filtration rate	N/A	Renal insufficiency or chronic renal disease
Lactate dehydrogenase	Renal infarction Chronic renal disease	N/A
Total white blood cell	Infection or inflammation	Chemotherapy Radiation therapy Toxic reaction
Hematocrit	N/A	Acute hemorrhage

SONOGRAPHY OF THE KIDNEYS

The sonographic appearance of the kidneys differs with age, and multiple variants may be noted with sonography (Table 7-3). The most common congenital anomaly of the urinary tract is the duplex or duplicated collecting system (Fig. 7-2). Neonatal and pediatric kidneys may appear lobulated, have prominent renal pyramids, and/or have subtle sonographic distinctions between the renal cortex and renal sinus. Normal adult kidneys are elliptical in shape in the longitudinal plane and rounded in the transverse plane. Though renal size varies with age, gender, and other factors, in the adult, they typically measure approximately 8 to 13 cm in length, 2 to 3 cm in the anteroposterior dimension, and 4 to 5 cm in width.

SOUND OFF
The most common congenital anomaly of the urinary tract is the duplex or duplicated collecting system.

The renal sinus is central in the kidney and has an echogenic appearance. The renal cortex appears as medium- to low-level echoes surrounding the central sinus. The normal cortex should be more hypoechoic than, or isoechoic to, the liver or the spleen. It should measure more than 1 cm in thickness. The term for this reduction in the thickness of the renal cortex is cortical thinning. Monitoring cortical thickness may especially be helpful for patients with chronic renal disease as well. Increased echogenicity of the renal cortex suggests intrinsic renal disease. Within the cortex, the triangular-shaped medullary pyramids may be noted separated by the columns of Bertin. Occasionally, the renal capsule may be observed in some cases. It appears as a highly reflective hyperechoic line surrounding the kidney.

SOUND OFF
Echogenicities of the kidney and adjacent structures are as follows: renal medulla < renal cortex ≤ liver < spleen < pancreas < diaphragm > renal sinus.

KIDNEY PATHOLOGY

Renal Failure

Acute Renal Failure

A sudden decrease in renal function, typically over the course of days or weeks, is termed acute renal failure (ARF). The most common cause of ARF is acute tubular necrosis. With acute tubular necrosis, the kidney suffers from

ischemic damage and subsequent cell destruction. Other causes of ARF include renal artery stenosis, renal infection, urinary tract obstruction, polycystic kidney disease, metabolic disorders such as amyloidosis, and inflammatory conditions like Henoch–Schonlein purpura. Henoch–Schonlein purpura is an autoimmune, inflammatory vascular disease that mostly affects children and can permanently damage the kidneys. Clinical findings of ARF include elevated BUN, elevated creatinine, oliguria, hypertension, leukocytosis, hematuria, edema, and hypovolemia. Sonographically, the kidneys may appear normal or the cortex may appear hyperechoic. Once ARF is established, sonography is valuable at evaluating the overall appearance of the kidneys and determining if hydronephrosis is present in cases caused by urinary tract obstruction.

TABLE 7-3 Renal variants in appearance and location

Renal Variant	Description
Compensatory hypertrophy	Enlargement of the unaffected contralateral kidney with unilateral renal agenesis or compromised renal function
Dromedary hump	Bulge on the lateral border of the kidney (often on the left kidney) Will have the same echogenicity as the adjacent renal cortex
Duplex (duplicated) collecting system (the most common congenital anomaly of the urinary tract)	Division of the renal sinus. In this variant, there are two separate renal sinuses; they are referred to as an upper pole **moiety** and lower pole moiety Obstruction to one or both of these collecting systems can occur Two ureters drain separate portions of the kidney Kidney with duplex collecting system will typically measure longer than a normal size kidney
Ectopic kidney	Pelvic kidney: one or both kidneys may be located within the pelvis; the pelvis is the most common location of an ectopic kidney Crossed fused ectopia: both kidneys are fused and on the same side of the body Thoracic kidney: kidney sits partially or completely in the chest
Extrarenal pelvis	The renal pelvis is located outside of the renal hilum
Fetal lobulation	Lobulated or bumpy outline to the kidney(s); can

	be seen in adults
Horseshoe kidneys	Two kidneys that cross the midline and connect at their lower poles by an isthmus The isthmus of the horseshoe kidneys travels anterior to the abdominal aorta and inferior vena cava
Hypertrophic column of Bertin	Enlargement of a renal column seen as an indentation of the renal sinus Actually are double layers of renal cortex
Junctional parenchymal defect (junctional line) (Fig. 7-3)	Results from the incomplete fusion of the two embryologic components (renunculi) of the kidney Appears as a hyperechoic, wedge-shaped structure on the anterior portion of the kidney; located between the upper and middle sections of the kidney
Malrotated kidney	The kidney sits in the renal fossa but is positioned off of the normal axis
Renal agenesis	Congenital absence of the kidney Bilateral renal agenesis is typically not consistent with life
Renal hypoplasia	The underdevelopment of the kidney in which there are too few nephrons Kidney will be smaller than normal
Renal sinus lipomatosis (fibrolipomatosis)	Excessive fat within the renal pelvis Renal sinus will be large and echogenic
Supernumerary kidney	A third, smaller kidney

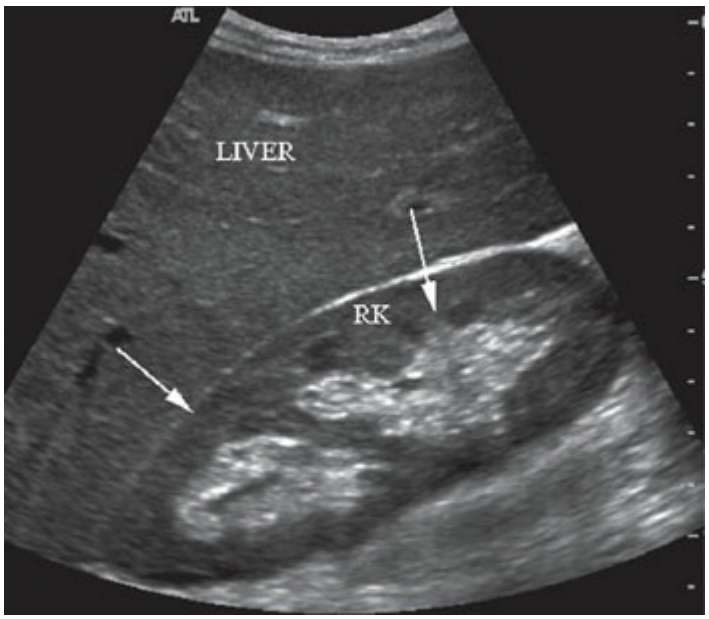


Figure 7-2 Duplex collecting system. Sagittal image of the right kidney (RK) revealing two distinct renal sinuses (*arrows*), separated by a band of parenchyma, denoting a duplicated collecting system.

CLINICAL FINDINGS OF ACUTE RENAL FAILURE

1. Elevated BUN and creatinine
2. Oliguria
3. Hypertension
4. Leukocytosis
5. Hematuria
6. Edema
7. Hypovolemia

SONOGRAPHIC FINDINGS OF ACUTE RENAL FAILURE

1. Normal kidneys
2. May appear more echogenic
3. Hydronephrosis may be present

SOUND OFF
The most common cause of ARF is acute tubular necrosis.

Chronic Renal Failure

The gradual decrease in renal function over time, typically months or years, is referred to as chronic renal failure (CRF). Kidneys that fail to function normally will lead to end-stage renal disease. The most common cause of CRF is diabetes mellitus. Other causes of CRF include, but are not limited to, glomerulonephritis, chronic pyelonephritis, metabolic disorders, chronic urinary tract obstruction, tuberculosis, renal vascular disease, and infection. Clinical findings include diabetes, malaise, elevated BUN, elevated creatinine, fatigue, hypertension, and hyperkalemia. Patients are typically placed on dialysis or a donor kidney may be needed. Sonographically, the kidneys will have cortical thinning, appear small and echogenic, and may contain cysts (Fig. 7-4). There is also typically loss of normal corticomedullary differentiation.

CLINICAL FINDINGS OF CHRONIC RENAL FAILURE

1. Diabetes mellitus
2. Malaise
3. Elevated BUN and creatinine
4. Fatigue

5. Hypertension
6. Hyperkalemia

SONOGRAPHIC FINDINGS OF CHRONIC RENAL FAILURE

1. Small, echogenic kidneys
2. Cortical thinning
3. Loss of normal corticomedullary differentiation
4. Renal cysts may be seen as well

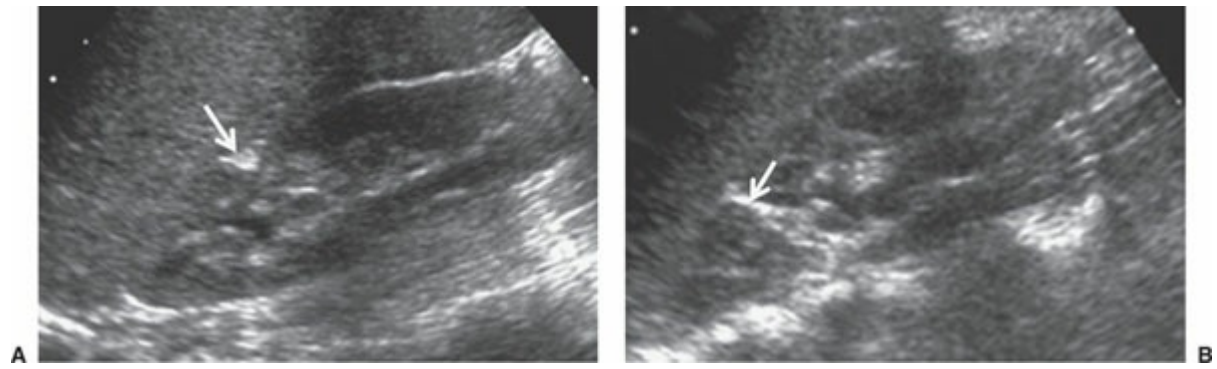


Figure 7-3 Junctional parenchymal defect or junctional line. The *arrows* in these images (**A** and **B**) denote the sonographic appearance of a junctional parenchymal defect.

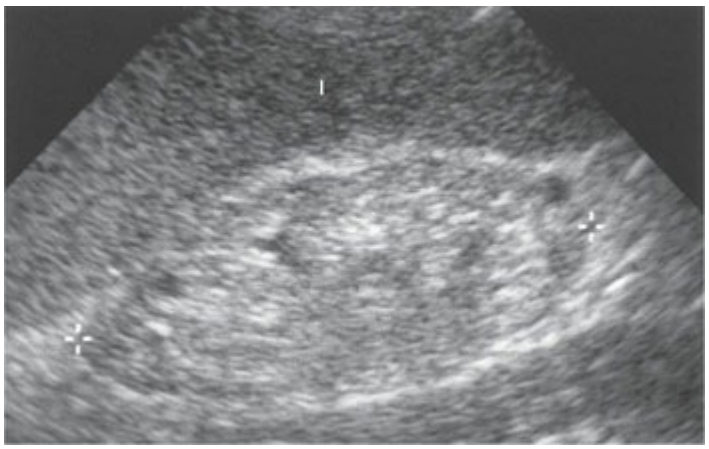


Figure 7-4 Chronic renal failure. The kidney (*between calipers*) is significantly more echogenic than the adjacent liver parenchyma (*l*). The kidney is small, and there is also loss of the normal corticomedullary differentiation.

SOUND OFF
The most common cause of CRF is diabetes mellitus.

Renal Failure and Dialysis

Patient suffering from renal failure may be forced to undergo dialysis treatment. This form of treatment is used to remove the accumulated urea,

other waste materials, and excess water from patients whose kidney function is inadequate. Oftentimes, these patients are awaiting renal transplantation. Dialysis may be either in the form of hemodialysis, hemofiltration, or peritoneal dialysis.

Both hemodialysis and hemofiltration utilize a machine that essentially acts as a kidney whereby it extracts the patient's blood, filters it, and returns the filtered blood to the patient. Peritoneal dialysis uses a solution that is instilled into the abdomen via a catheter. Through diffusion and osmosis, the solution allows for the filtration of waste. Because of the solution utilized in peritoneal dialysis, patients will often have a minimal amount of ascites noted during a sonographic examination of the abdomen and pelvis.

Renal Cystic Disease

Simple Renal Cyst

The simple cyst is the most common renal mass. A simple renal cyst should appear sonographically as an anechoic mass that is spherical, has smooth walls, posterior acoustic enhancement, and no internal echoes (Fig. 7-5). An anechoic mass that does not specifically meet all of these criteria is not considered a simple renal cyst. Although larger cysts may cause some pain as they compress adjacent renal tissue, they are typically asymptomatic and clinically insignificant. However, once one renal cyst is identified, the sonographer should more closely examine the kidneys for further cyst involvement.

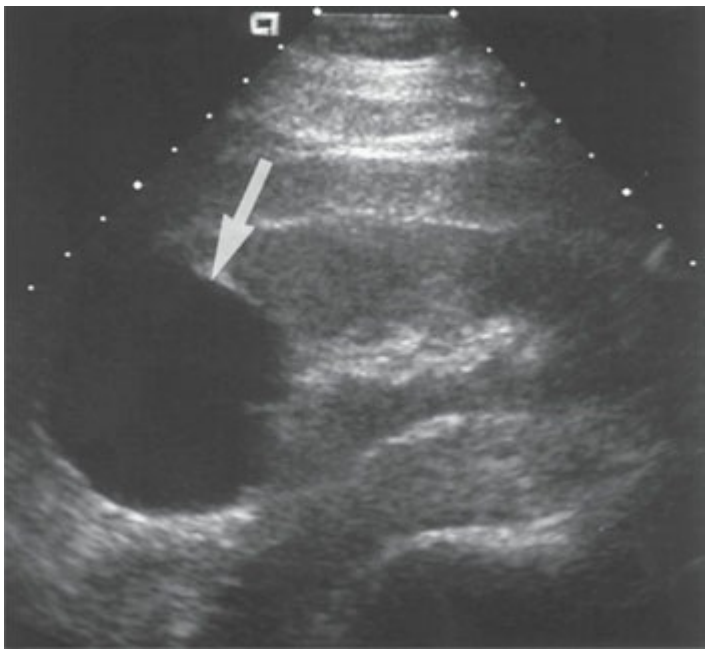


Figure 7-5 Simple renal cyst. Anechoic internal fluid, sharp interface with the renal parenchyma, thin wall, and posterior enhancement are features of this simple renal cyst (*arrow*).

Renal cysts can be peripelvic, parapelvic, cortical, or exophytic in location. A parapelvic cyst is one that originates in the renal parenchyma and protrudes into the renal sinus. They may be difficult to differentiate from a dilated renal pelvis. Peripelvic cysts are renal cysts that originate in the renal sinus. They may be difficult to differentiate from hydronephrosis. Small cortical cysts are located within the cortex and may be difficult to differentiate from prominent renal pyramids, especially if they are solitary. Renal cysts that appear to be projecting out away from the kidney may be termed exophytic.

CLINICAL FINDINGS OF A SIMPLE RENAL CYST

1. Asymptomatic

SONOGRAPHIC FINDINGS OF A SIMPLE RENAL CYST

1. Spherical
2. Anechoic mass
3. Smooth walls (including a well-defined posterior wall)
4. Posterior acoustic enhancement
5. No internal echoes

Complex Renal Cysts

A cyst that does not meet all of the characteristics of a simple cyst will fall into the complex cyst category. It is important to note that renal cell carcinoma (RCC) may manifest as a multicystic mass. Therefore, when a cyst has characteristics that include a septation, internal debris, mural nodules, a papillary projection, or irregular borders, it becomes more worrisome for malignancy and is often followed up with further imaging or surgical intervention (Fig. 7-6). A wide range of sonographic findings may be noted with complex renal cysts (Table 7-4).

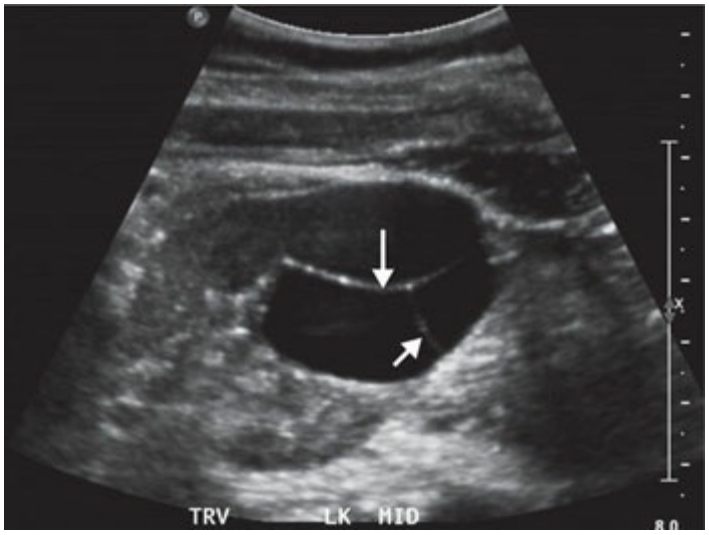


Figure 7-6 Complex renal cyst. This renal cyst has several septations (*arrows*).

Autosomal Dominant Polycystic Kidney Disease

Autosomal dominant polycystic kidney disease (ADPKD) is a hereditary disorder that may also be referred to as adult polycystic kidney disease. ADPKD can lie dormant for many years, often not manifesting in clinical symptoms until the person is in the third to fourth decade of life. Clinical symptoms include hypertension and decreasing renal function. In addition, the patient may suffer from a urinary tract infection, renal calculi, flank pain, hematuria, and have a palpable mass in the abdomen.

With ADPKD, the patient will develop numerous cortical renal cysts of varying sizes (Fig. 7-7). Cysts may also be found in other organs, including the pancreas, liver, and spleen. In fact, ADPKD has a 40% association with polycystic liver disease. Many times, these patients ultimately suffer from end-stage renal disease and must be placed on dialysis. Sonographically, the kidneys will appear enlarged and contain numerous renal cysts, with possible cysts identified in the pancreas, liver, and/or spleen.

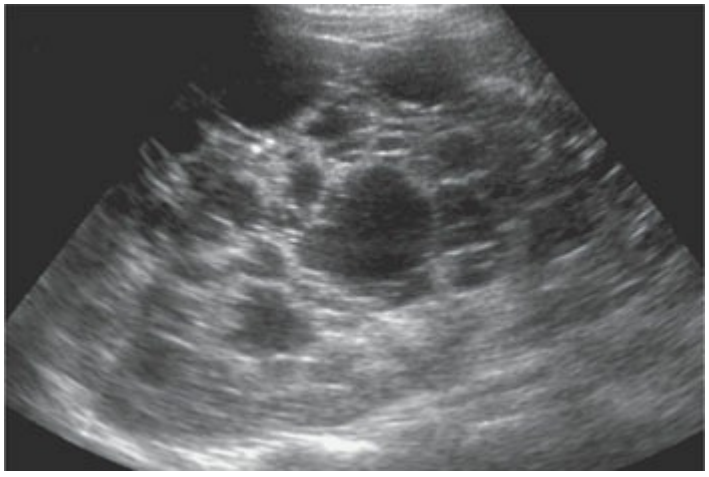


Figure 7-7 Autosomal dominant polycystic kidney disease. Advanced renal cystic

disease results in the parenchyma being replaced by numerous noncommunicating cysts of varying sizes.

TABLE 7-4 Complex renal cysts clinical and sonographic findings

Complex Renal Cyst	Clinical Findings	Sonographic Findings
Renal cyst with internal calcifications	Previous history of a hemorrhagic or infected cyst Asymptomatic	Posterior shadowing from the calcification within the cyst
Hemorrhagic renal cyst	Simple cysts may bleed into themselves Possible history of trauma Flank pain Hematuria	Anechoic, hypoechoic, hyperechoic, or complex mass, depending on the stage of hemolysis
Infected renal cyst	Urinary tract infection Fever Flank pain Hematuria Leukocytosis	Internal debris Thick walls
Milk of calcium cyst	Asymptomatic	Fluid-fluid level within the cyst Milk of calcium will shadow and layer within the cyst
Multilocular renal cyst	Previous history of a hemorrhagic or infected cyst Asymptomatic	Thin septations separating the locules of fluid No blood flow within the septations

CLINICAL FINDINGS OF AUTOSOMAL DOMINANT POLYCYSTIC KIDNEY DISEASE

1. Asymptomatic until third or fourth decade of life
2. Decreased renal function
3. Urinary tract infections
4. Renal calculi
5. Flank pain
6. Hematuria
7. Palpable abdominal mass

SONOGRAPHIC FINDINGS OF AUTOSOMAL DOMINANT POLYCYSTIC KIDNEY DISEASE

1. Bilateral enlarged kidneys that contain numerous cortical renal cysts
2. Possible cysts identified in the pancreas, liver, and/or spleen



SOUND OFF

ADPKD is most often seen in adults. Just remember, adults are dominant.

Autosomal Recessive Polycystic Kidney Disease

Autosomal recessive polycystic kidney disease (ARPKD) is a hereditary disorder that may also be referred to as autosomal recessive polycystic renal disease or infantile polycystic kidney disease. ARPKD is characterized by dilation of the renal collecting tubules. This disorder is often recognized in the fetus and can be confirmed with a postnatal sonographic examination. If perinatal death does not occur, patients often die secondary to complication of renal failure and portal hypertension from hepatic fibrosis. The typical sonographic findings of a newborn affected by ARPKD are bilateral, enlarged, echogenic kidneys, with a loss of corticomedullary differentiation.

CLINICAL FINDINGS OF AUTOSOMAL RECESSIVE POLYCYSTIC KIDNEY DISEASE

1. Clinical findings of renal failure
2. Abnormal liver function tests because of hepatic disease

SONOGRAPHIC FINDINGS OF THE AUTOSOMAL RECESSIVE POLYCYSTIC KIDNEY DISEASE

1. Bilateral, enlarged echogenic kidneys
2. Loss of corticomedullary differentiation

Multicystic Dysplastic Kidney Disease

Multicystic dysplastic kidney disease (MCDK) may also be referred to as multicystic dysplastic renal disease or multicystic renal dysplasia. MCDK is thought to be caused by an early, first-trimester obstruction of the ureter. There is typically no normal functioning renal tissue present in the kidney affected by MCDK. Therefore, if this condition is bilateral, it is fatal.

Clinically, MCDK may be asymptomatic and incidentally identified in the adult patient. The sonographic finding of MCDK is the identification of

several, smooth-walled, noncommunicating cysts of varying sizes in the area of the renal fossa, which completely replaces all renal parenchyma (Fig. 7-8). In addition, as a result of the nonfunctioning MCDK kidney, the contralateral kidney will take over the function of the abnormal kidney and undergo compensatory hypertrophy.

CLINICAL FINDINGS OF MULTICYSTIC DYSPLASTIC KIDNEY DISEASE

1. Asymptomatic
2. Normal renal function

SONOGRAPHIC FINDINGS OF MULTICYSTIC DYSPLASTIC KIDNEY DISEASE

1. Unilateral, smooth-walled, noncommunicating cysts of varying sizes located within the renal fossa
2. Compensatory hypertrophy of the contralateral kidney

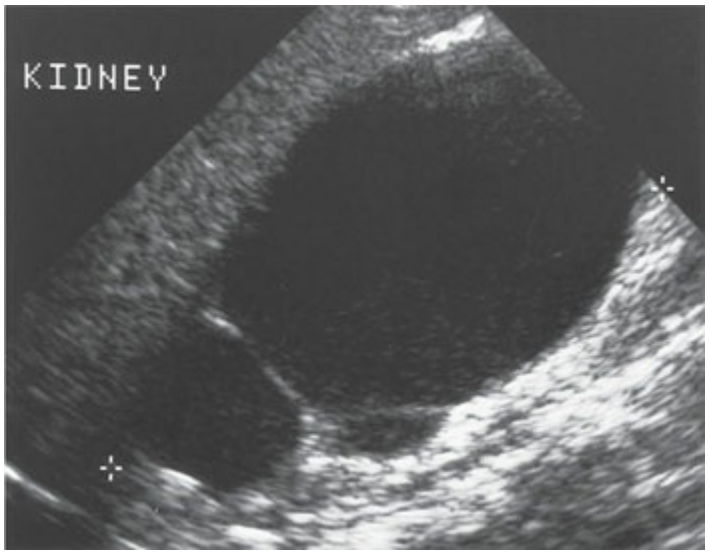


Figure 7-8 Multicystic dysplastic kidney. The parenchyma of this multicystic dysplastic kidney has been completely replaced by large cysts.

SOUND OFF
MCDK is thought to be caused by an early urinary tract obstruction. The MCDK kidney is nonfunctional.

Acquired Renal Cystic Disease

Acquired renal cystic disease is often the result of chronic hemodialysis. Patients with a history of dialysis and who have acquired renal cystic disease

are at an increase risk for developing RCC. Sonographically, the kidneys will appear small initially during end-stage renal disease, with the development of some small cysts. However, with time, the kidneys will enlarge and have numerous small cysts noted throughout the renal parenchyma. These cysts may also appear complex, and a thorough analysis for signs of RCC is warranted in these patients.

CLINICAL FINDINGS OF ACQUIRED RENAL CYSTIC DISEASE

1. Clinical findings of CRF
2. History of hemodialysis

SONOGRAPHIC FINDINGS OF ACQUIRED RENAL CYSTIC DISEASE

1. The kidney will appear small initially during end-stage renal disease with some small cysts
2. With time, the kidneys may enlarge and have numerous small cysts noted throughout the renal parenchyma



SOUND OFF
Acquired renal cystic disease can result from hemodialysis.

von Hippel–Lindau Syndrome

von Hippel–Lindau syndrome is an inherited disorder characterized by tumors of the central nervous system and orbits. Patients with this syndrome also have the propensity to develop cysts within the kidneys, RCC, and pheochromocytomas. Clinical symptoms are most often associated with the tumors in the central nervous system or eyes and not with the coexisting renal cystic disease. Sonographically, the kidneys affected by von Hippel–Lindau syndrome will have multiple renal cysts. These cysts have the potential to progress to RCC, so an evaluation for solid components within the cysts is exceedingly important.

CLINICAL FINDINGS OF VON HIPPEL–LINDAU SYNDROME

1. Symptoms of a brain and/or an eye tumors

SONOGRAPHIC FINDINGS OF VON HIPPEL–LINDAU SYNDROME

1. Multiple renal cysts
2. Cysts may be complex and have mural nodules (sign of RCC)
3. Cysts within the pancreas
4. Pheochromocytoma may be present

Tuberous Sclerosis

Tuberous sclerosis is a systemic disorder that leads to the development of tumors within various organs. It is also seen in association with renal cystic disease and the accumulation of angiomyolipomas in the kidneys. Clinical findings of tuberous sclerosis include epilepsy and skin lesions of the face. Sonographically, a person suffering from tuberous sclerosis may have signs of bilateral, multiple renal cysts and evidence of bilateral angiomyolipomas.

CLINICAL FINDINGS OF TUBEROUS SCLEROSIS

1. Epilepsy
2. Skin lesions of the face

SONOGRAPHIC FINDINGS OF TUBEROUS SCLEROSIS

1. Bilateral renal cysts
2. Bilateral angiomyolipomas

SOUND OFF

Tuberous sclerosis is associated with multiple, bilateral renal angiomyolipomas.

Renal Infection

Acute Pyelonephritis

Acute pyelonephritis is an inflammation of the kidney or kidneys. Bacteria can spread to the kidney through the bloodstream or, more commonly, from the lower urinary tract. This type of infection is referred to as an ascending infection. The infection begins in the bladder and refluxes up through the ureters and into the kidney. It is most commonly encountered in women and is treated by antibiotics. Clinically, patients present with flank pain, bacteriuria, pyuria, dysuria, urinary frequency, and leukocytosis. A patient with acute pyelonephritis may not have any sonographically identifiable abnormalities. However, some findings consistent with acute pyelonephritis include renal enlargement, focal areas of altered echotexture, and compression of the renal sinus (Fig. 7-9). Complications of acute pyelonephritis include the development of a renal abscess, pyonephrosis, xanthogranulomatous pyelonephritis, emphysematous pyelonephritis, and chronic pyelonephritis.

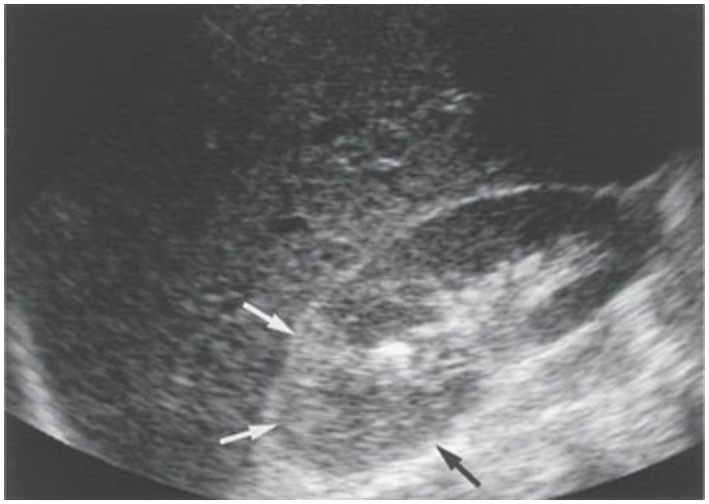


Figure 7-9 Acute pyelonephritis. Acute renal infection with interstitial hemorrhage produces hyperechoic focal swelling in the upper pole of this kidney (*arrows*).

CLINICAL FINDINGS OF ACUTE PYELONEPHRITIS

1. Flank pain
2. Bacteriuria
3. Pyuria
4. Leukocytosis
5. Dysuria
6. Urinary frequency

SONOGRAPHIC FINDINGS OF ACUTE PYELONEPHRITIS

1. May appear normal
2. Renal enlargement
3. Focal areas of altered echotexture
4. Compression of the renal sinus

Pyonephrosis

Pyonephrosis describes the condition of having pus, also referred to as purulent material, within the collecting system of the kidney. The accumulation of pus is most likely caused by some obstructive process or infection that leads to urinary stasis, as seen in many cases of pyelonephritis. The patient will likely present with pyuria, bacteriuria, fever, flank pain, and leukocytosis. Sonographically, hydronephrosis will be evident. Within the dilated collecting system, thick pus or debris will appear as dependent layering, low-level echoes (Fig. 7-10).

CLINICAL FINDINGS OF PYONEPHROSIS

1. Pyuria

2. Bacteriuria
3. Fever
4. Flank pain
5. Leukocytosis

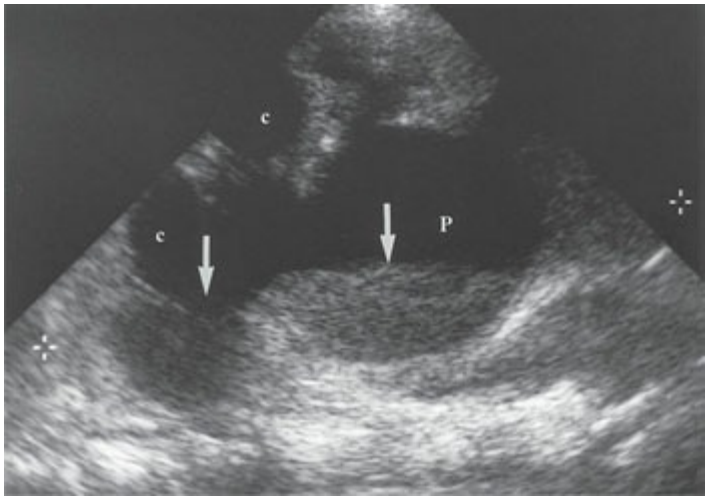


Figure 7-10 Pyonephrosis. Pus (*arrows*) is noted within the dilated calices (*c*) and renal pelvis (*P*) in this kidney (*between calipers*).

SONOGRAPHIC FINDINGS OF PYONEPHROSIS

1. Hydronephrosis
2. Pus and debris appear as internal, layering, and low-level echoes within the dilated collecting system

Chronic Pyelonephritis

Recurrent kidney infections or chronic obstruction may lead to scarring of the calices and renal pelvis. This is referred to as chronic pyelonephritis. Chronic pyelonephritis can lead to xanthogranulomatous pyelonephritis and end-stage renal disease. Children with a history of vesicoureteral reflux (VUR) are at increased risk for developing chronic pyelonephritis (Fig. 7-11). Patients present clinically much like the patients with acute pyelonephritis in that they suffer from flank pain, fever, and evidence of a urinary tract infection. Sonographically, the kidneys will appear small, echogenic, and have lobulated borders. This lobulation is secondary to parenchymal scarring. A scar will appear as an echogenic area that extends from the renal sinus through the renal parenchyma.

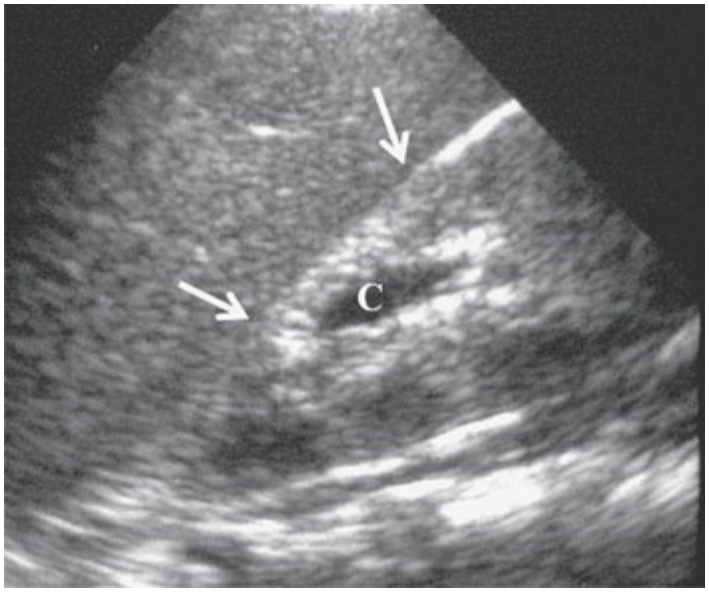


Figure 7-11 Chronic pyelonephritis. Longitudinal image of a 10-year-old boy showing a small echogenic left kidney with a dilated calyx (*C*) and overlying parenchymal atrophy (*arrows*).

CLINICAL FINDINGS OF CHRONIC PYELONEPHRITIS

1. Flank pain
2. Bacteriuria
3. Pyuria
4. Leukocytosis
5. Dysuria
6. Urinary frequency
7. History of VUR

SONOGRAPHIC FINDINGS OF CHRONIC PYELONEPHRITIS

1. Small, echogenic kidneys that have lobulated borders
2. Renal scar appears as an echogenic area within the kidney that extends from the renal sinus through the renal parenchyma

SOUND OFF
A renal scar will appear as an echogenic area that extends from the renal sinus through the renal parenchyma.

Renal or Perinephric Abscess

A renal abscess can occur in regions of the kidney affected by pyelonephritis or be located adjacent to the kidney. A perinephric abscess is a collection of purulent material that has leaked through the capsule into the tissue surrounding the kidney. Patients with a renal abscess present with signs of a

urinary tract infection, including high fever, flank pain, and leukocytosis. An abscess on sonography may appear anechoic, hypoechoic, or complex, depending on its contents. Gas development within the abscess produces dirty shadowing or reverberation artifact.

CLINICAL FINDINGS OF A RENAL OR PERINEPHRIC ABSCESS

1. Symptoms of pyelonephritis (pyuria, hematuria, and flank pain)
2. High fever
3. Flank pain
4. Leukocytosis

SONOGRAPHIC FINDINGS OF A RENAL OR PERINEPHRIC ABSCESS

1. Can appear anechoic, hypoechoic, or complex
2. Gas shadows or dirty shadowing may be present within the mass

Emphysematous Pyelonephritis

A rare, and yet life-threatening, complication of pyelonephritis is emphysematous pyelonephritis. Although emphysematous pyelonephritis may be the result of a long-standing urinary tract obstruction, it is found more often in patients who have diabetes mellitus or who are immunocompromised. The term emphysematous denotes the formation of air within an organ. Consequently, with emphysematous pyelonephritis, bacterial formation allows gas to accumulate within the renal parenchyma. Escherichia coli infection is the most common culprit. These patients will be extremely ill and will present with a fever and flank pain. Sonographically, a highly echogenic area within the parenchyma containing air that produces reverberation artifact or dirty shadowing will be noted.

CLINICAL FINDINGS OF EMPHYSEMATOUS PYELONEPHRITIS

1. Diabetes mellitus
2. Immunocompromised patient
3. Fever
4. Flank pain
5. Leukocytosis

SONOGRAPHIC FINDINGS OF EMPHYSEMATOUS PYELONEPHRITIS

1. Gas or air within the renal parenchyma
2. Dirty shadowing or reverberation artifact coming from the renal parenchyma

Xanthogranulomatous Pyelonephritis

Xanthogranulomatous pyelonephritis is uncommon and is typically caused by a chronic urinary tract obstruction and subsequent infection. The word part "xantho" means yellow. Clinical findings are consistent with urinary tract infection symptoms with dull or persistent flank pain, fever, and weight loss. With xanthogranulomatous pyelonephritis, a staghorn calculus, hydronephrosis, and perinephric fluid are often present. If antibiotic therapy is not effective, a nephrectomy is typically required.

CLINICAL FINDINGS OF XANTHOGRANULOMATOUS PYELONEPHRITIS

1. Dull or persistent flank pain
2. Pyuria
3. Hematuria
4. Fever
5. Leukocytosis

SONOGRAPHIC FINDINGS OF XANTHOGRANULOMATOUS PYELONEPHRITIS

1. Hydronephrosis
2. Staghorn calculus
3. Perinephric fluid collection

Renal Fungal Disease

The most common cause of fungal urinary tract infections is Candida albicans. Immunocompromised patients are at increased risk for developing a fungal infection within their kidneys. In addition, patients with a history of diabetes mellitus, intravenous drug abuse, and infants who have long-standing, indwelling catheters are more likely to suffer from renal fungal disease. Clinical symptoms include flank pain, fever, and chills. The sonographic findings may mimic several other abnormalities. However, when fungal balls are noted within the collecting system, the diagnosis of a renal fungal disease can be made (Fig. 7-12). Sonographically, fungal balls appear as echogenic, mobile, nonshadowing structures within the renal collecting system.

CLINICAL FINDINGS OF RENAL FUNGAL DISEASE

1. Immunocompromised person
2. Diabetes mellitus, intravenous drug abuse or long-standing indwelling catheter
3. Infant with an indwelling catheter

4. Flank pain
5. Fever
6. Chills



Figure 7-12 Fungus ball. Transverse image of the kidney in a 2-month-old infant with *Candida albicans* showing a dilated renal pelvis (*p*) and calices (*c*) that contain echogenic urine and a mobile fungal ball (*arrow*).

SONOGRAPHIC FINDINGS OF RENAL FUNGAL DISEASE

1. Fungal balls appear as hyperechoic, nonshadowing, mobile structures within the renal collecting system

Glomerulonephritis

Glomerulonephritis can be caused by a distant infection, such as strep throat, or an autoimmune reaction. Some conditions, such as lupus, have glomerulonephritis as a characteristic feature. The infection can lead to significant glomerular damage, and the kidneys can slowly shut down secondary to diminished filtration capabilities. Patients typically present with smoky urine, fever, proteinuria, hematuria, hypertension, and azotemia.

Glomerulonephritis can be acute or chronic. In the acute stage, the kidney may appear normal, enlarged, and have an overall increase in echogenicity. The renal pyramids may appear more prominent with acute glomerulonephritis. Chronic glomerulonephritis, the result of a long-standing infection, can lead to end-stage renal disease. Sonographically, chronic glomerulonephritis appears as an increase in the cortical echogenicity.

CLINICAL FINDINGS OF GLOMERULONEPHRITIS

1. Recent throat infection (acute)
2. Smoky urine
3. Hematuria

4. Proteinuria
5. Fever
6. Hypertension
7. Azotemia

SONOGRAPHIC FINDINGS OF ACUTE GLOMERULONEPHRITIS

1. Enlarged kidney(s) with increased echogenicity
2. Prominent renal pyramids

SONOGRAPHIC FINDINGS OF CHRONIC GLOMERULONEPHRITIS

1. Small, echogenic kidney(s)



SOUND OFF

Glomerulonephritis can be caused by a distant throat infection like strep throat.

Parasitic Urinary Tract Infections

The most common renal parasitic infection is from schistosomiasis, which is a worm that enters humans by penetrating the skin. Although rare in the United States, clinically these patients present with hematuria, and may also have persistent fever. Sonographically, schistosomiasis is most often seen in the bladder, causing thickening of the bladder wall. Like the liver, the kidney can also succumb to Echinococcus granulosus, with the development of a hydatid cyst. Sonographically, the renal hydatid cyst depends on the stage of its maturation, as it may appear completely anechoic, contain a daughter cyst with internal debris, or as a complex mass with calcifications. Hydatid disease is most often found in sheep- and cattle-raising countries such as the Middle East, Australia, and the Mediterranean.

CLINICAL FINDINGS OF PARASITIC URINARY TRACT INFECTION

1. Hematuria
2. Flank pain
3. Pyuria
4. Dysuria
5. Possible recent travel out of the country (hydatid cyst: Middle East, Australia, and Mediterranean)

SONOGRAPHIC FINDINGS OF PARASITIC URINARY TRACT INFECTION

1. Schistosomiasis: bladder wall thickening
2. Hydatid cyst: depends on the stage of its maturation, as it may appear completely anechoic, contain a daughter cyst with internal debris, or as a complex mass with calcifications

Urinary Tract Obstruction and Stones

Determining the Level of Urinary Tract Obstruction

To determine the level of urinary tract obstruction, one must have a fundamental understanding of the normal flow of urine from the kidneys to the external orifice of the urethra. Essentially, urine is created within the kidneys, travels down the ureters, collects in the bladder, and exits the urethra. Dilation of the urinary tract occurs proximal to the level of obstruction. Therefore, if there is distention of the ureter and dilation of the renal collecting system with a normal urinary bladder, the level of obstruction must be proximal to the urinary bladder, either within the ureter or at the level of the ureterovesicular junction. This is a simple concept and functional for both clinical practice and the national certification examinations.

Hydronephrosis and Renal Obstruction

Hydronephrosis is a broad term that is defined as the dilation of the renal collecting system secondary to the obstruction of normal urine flow. Accordingly, hydronephrosis is dilation of the calices, infundibula, and renal pelvis. Hydronephrosis may also be referred to as pyelocaliectasis, and described more specifically according to which part of the kidney is dilated (Table 7-5). It may also be classified as mild, moderate, and severe or marked. Mild hydronephrosis is noted as distension of the renal pelvis, whereas moderate hydronephrosis is described as further progression of distension into the calices and medullary pyramids. Marked hydronephrosis extends into the cortex and causes severe thinning of the parenchyma.

TABLE 7-5 Terminology associated with hydronephrosis

Terminology for Hydronephrosis	Description
Caliectasis	Dilation of the calices
Pelviectasis (pyelectasis)	Dilation of the renal pelvis
Pelvicaliectasis (pelvocaliectasis)	Dilation of the calices and renal pelvis

Irregularities that lead to renal obstruction that are located inside the urinary tract are called intrinsic causes of hydronephrosis, and abnormalities

that are located outside the urinary tract that leads to renal obstruction are referred to as extrinsic causes of hydronephrosis (Tables 7-6 and 7-6). Sonographically, hydronephrosis will appear as anechoic fluid filling all or part of the renal collecting system (Fig. 7-13). Hydronephrosis can also alter the renal artery resistive index (RI) within the arcuate or interlobar vessels, often leading to an RI that will be greater than 0.7.

TABLE 7-6 Intrinsic causes of hydronephrosis

Urolithiasis
Congenital abnormality (vesicoureteral reflux, **posterior urethral valves**, and **ureterovesicular junction** obstruction)
Hematoma (blood clot)
Neoplasm
Ureteropelvic junction obstruction or ureteral stricture
Ureterocele

TABLE 7-7 Extrinsic causes of hydronephrosis

Benign prostatic hypertrophy
Neurogenic bladder
Pelvic masses (**uterine leiomyoma**, ovarian masses, **tubo-ovarian abscess**, and bowel masses)
Pregnancy
Retroperitoneal fibrosis
Surgery
Trauma
Urethritis

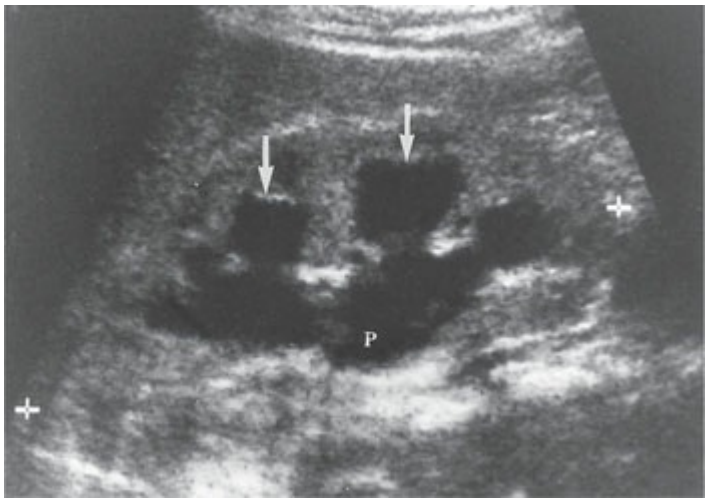


Figure 7-13 Moderate hydronephrosis. Urine-filled dilated renal pelvis (*P*) and calices (*arrows*) are sonographic findings consistent with moderate hydronephrosis.

False-Positive Hydronephrosis

The diagnosis of false-positive hydronephrosis can occur. For example, overdistention of the urinary bladder, parapelvic cysts, a prominent renal vein, and an extrarenal pelvis may all be a source of false-positive hydronephrosis. The use of color Doppler imaging and emptying the patient's bladder (post-void imaging) are two methods that may be used to alleviate the uncertainty in these cases.

Urolithiasis

Urolithiasis are kidney stones located anywhere within the urinary tract. Stones within the kidney may be referred to as renal calculi, kidney stones, renal stones, or nephrolithiasis. They are most often made of calcium oxalate and more frequently found in males. Stones can form in the kidney or in the bladder. A stone that completely fills and takes on the shape of the renal pelvis is called a staghorn calculus.

If created in the kidney, urolithiasis can pass into the collecting system or ureter and cause obstruction. The most common location for a stone to become lodged in the urinary tract is the ureterovesicular junction, near the urinary bladder. Other frequently encountered places for stones to get trapped are just past the ureteropelvic junction, and at the pelvic brim where the ureter crosses the iliac vessels.

SOUND OFF

The most common location for a stone to become lodged in the urinary tract is the ureterovesicular junction, near the urinary bladder.

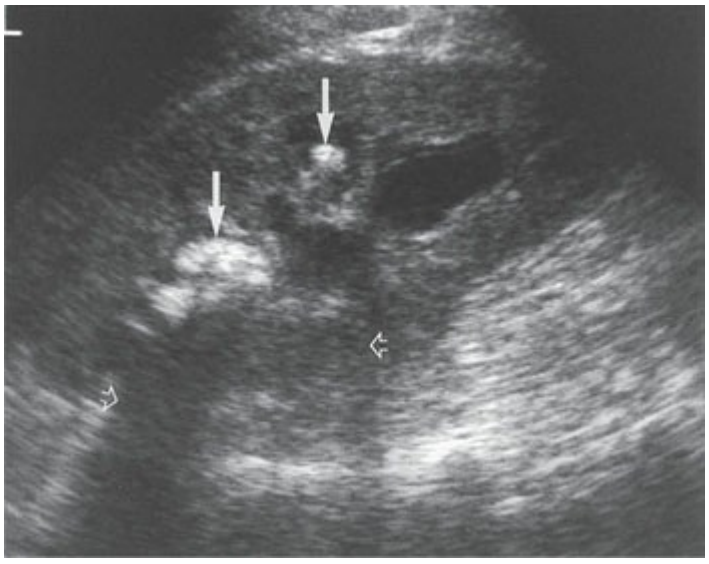


Figure 7-14 Kidney stones. Numerous renal stones are seen within the dilated calices as echogenic foci (*closed arrows*) with posterior shadowing (*open arrows*).

Kidney stones that are nonobstructing may not cause pain. Alternatively, obstructive stones can cause hematuria, renal colic, oliguria, and may lead to considerable urinary tract infections. Renal colic in men can cause testicular pain on the affected side. Renal stones less than 5 mm may be difficult to visualize sonographically. When seen, a kidney stone will be seen as an echogenic focus that produces posterior acoustic shadowing (Fig. 7-14). The sonographic "twinkle sign" or "twinkle artifact" will be noted as an increased color Doppler signal posterior to a kidney stone. A urolithiasis that becomes lodged within the distal ureter may be better imaged with transvaginal scanning or by using a transperineal approach.

CLINICAL FINDINGS OF UROLITHIASIS

1. Hematuria
2. Renal colic
3. Oliguria
4. Urinary tract infection

SONOGRAPHIC FINDINGS OF UROLITHIASIS

1. Echogenic focus that produces acoustic shadowing
2. "Twinkle sign" seen posterior to the stone with the use of color Doppler
3. Hydronephrosis and dilatation of ureter may be present

Nephrocalcinosis and Medullary Sponge Kidney

Nephrocalcinosis is an accumulation of calcium within the renal parenchyma. There are two forms of nephrocalcinosis defined by their location: medullary nephrocalcinosis and cortical nephrocalcinosis. Although medullary nephrocalcinosis is commonly caused by hyperparathyroidism and associated with hypercalcemia, it may also be caused by a congenital defect known as medullary sponge kidney. Medullary sponge kidney is the accumulation of calcium within abnormally dilated collecting ducts located within the medulla. Clinically, patients with medullary sponge kidney may be asymptomatic or can have signs of infection and a history of urinary calculi. Medullary sponge kidney appears sonographically as highly echogenic renal pyramids that may shadow (Fig. 7-15). Nephrocalcinosis that occurs within the cortex is termed cortical nephrocalcinosis. It may be caused by hyperparathyroidism, AIDS, or found in association with some malignancies. Sonographically, cortical nephrocalcinosis appears as small calculi within the cortex.

CLINICAL FINDINGS OF NEPHROCALCINOSIS

1. Hypercalcemia
2. Hyperparathyroidism
3. Urinary tract infection
4. History of urinary calculi

SONOGRAPHIC FINDINGS OF NEPHROCALCINOSIS

1. Medullary nephrocalcinosis—echogenic renal pyramids—medullary sponge kidney
2. Cortical nephrocalcinosis—echogenic foci within the cortex

Benign Masses of the Kidney

Angiomyolipoma

The angiomyolipoma is the most common benign renal tumor. It consists of a network of blood vessels, muscle, and fat. It may also be referred to as a renal hamartoma. These masses are frequently incidentally encountered and are unilateral and asymptomatic in the general population. However, patients with tuberous sclerosis have a tendency to have multiple and bilateral angiomyolipomas (Fig. 7-16). If symptoms do occur, they will be secondary to hemorrhage within the mass. These symptoms include hematuria, pain, and/or hypertension.

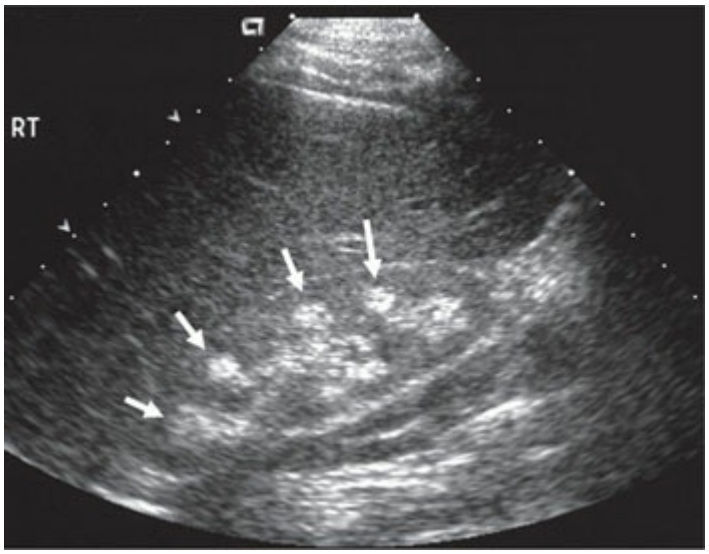


Figure 7-15 Medullary nephrocalcinosis. With nephrocalcinosis, the pyramids (*arrows*) are filled with small stones that may or may not produce acoustic shadowing.



Figure 7-16 Multiple angiomyolipomas. A patient with tuberous sclerosis had multiple small echogenic masses distributed throughout the kidneys. These were proven to be angiomyolipomas.

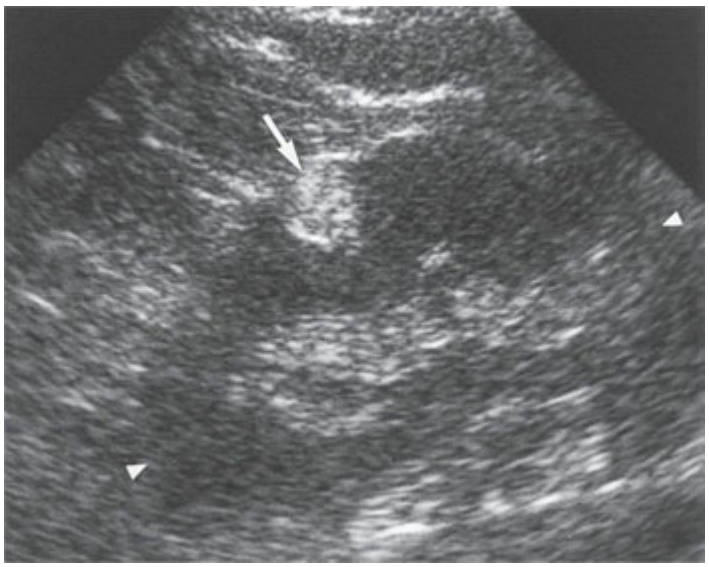


Figure 7-17 Angiomyolipoma. A small echogenic mass (*arrow*) is noted within this kidney (arrowheads). This is a highly characteristic sonographic findings of an angiomyolipoma.

Classically, the sonographic appearance of an angiomyolipoma is a solid, echogenic mass (Fig. 7-17). However, depending on the composition of the mass, the sonographic appearance may vary. Angiomyolipomas, in 20% to 30% of the cases, will shadow secondary to its high-fat component. Because RCC rarely shadows, the acoustic shadowing seen posterior to a hyperechoic mass is helpful, but not always indicative of an angiomyolipoma.

CLINICAL FINDINGS OF ANGIOMYOLIPOMA

1. Asymptomatic in most individuals
2. Patient may have a history of tuberous sclerosis
3. Pain, hematuria, and hypertension can occur with hemorrhage of the mass

SONOGRAPHIC FINDINGS OF ANGIOMYOLIPOMA

1. Solid, hyperechoic mass
2. May produce acoustic shadowing
3. Tend to be multiple and bilateral with tuberous sclerosis



SOUND OFF
Angiomyolipoma is the most common benign renal tumor.

Oncocytoma

The oncocytoma is a benign renal tumor that is often found in men in their 60s and is the second most common renal mass after the angiomyolipoma. An oncocytoma is often asymptomatic but may produce pain or hematuria. A stellate (star-shaped) central scar may be noted within an oncocytoma. This scar results from a previous infarction within an oncocytoma. Sonographically, the mass is often difficult to differentiate from a RCC. It may appear as an isoechoic, hyperechoic, or hypoechoic mass. It may also contain the sonographically identifiable aforementioned hypoechoic central scar, although this finding is appreciated most often on a computed tomography study. Nonetheless, a central scar within a renal mass does not necessarily indicate that the mass is an oncocytoma because RCC may also have a central scar. For this reason, surgical excision or biopsy is often warranted to differentiate the oncocytoma from RCC.

CLINICAL FINDINGS OF AN ONCOCYTOMA

1. Asymptomatic
2. May produce pain or hematuria

SONOGRAPHIC FINDINGS OF AN ONCOCYTOMA

1. Isoechoic, hyperechoic, or hypoechoic mass
2. May also contain a hypoechoic central scar



SOUND OFF
Oncocytomas often contain a central scar.

Renal Hemangioma

Like benign hemangiomas found elsewhere in the body, the renal hemangioma consists of a mass of blood vessels. They are most often asymptomatic and are encountered during the third or fourth decade of life.

Again, pain and hematuria may result from hemorrhage within the mass. A hemangioma most often appears as a small hyperechoic mass on the kidney. Like other solid tumors of the kidney, a hemangioma may mimic RCC, and therefore further imaging, surgical intervention, or a biopsy may be performed.

CLINICAL FINDINGS OF A RENAL HEMANGIOMA

1. Asymptomatic
2. Hemorrhage of the mass can lead to pain and hematuria

SONOGRAPHIC FINDINGS OF A RENAL HEMANGIOMA

1. Small, hyperechoic mass

Renal Lipoma

A lipoma is a benign fatty tumor. The renal lipoma is most often found in women, and they are typically asymptomatic. Sonographically, a renal lipoma will appear as well-circumscribed hyperechoic mass that typically measures less than 5 mm in diameter.

CLINICAL FINDINGS OF A RENAL LIPOMA

1. Asymptomatic

SONOGRAPHIC FINDINGS OF A RENAL LIPOMA

1. Well-circumscribed, hyperechoic mass

Renal Adenoma

A renal adenoma is a benign mass that appears sonographically similar to its malignant counterpart, the RCC. Clinically, patients are most often asymptomatic, although larger tumors may lead to hematuria. Sonographically, a renal adenoma appears as a vascular hyperechoic mass with areas of internal calcifications that may produce acoustic shadowing. They typically measure less than 1 cm. Surgical excision or biopsy is often warranted to differentiate the renal adenoma from the RCC.

CLINICAL FINDINGS OF RENAL ADENOMA

1. Asymptomatic
2. May complain of hematuria

SONOGRAPHIC FINDINGS OF RENAL ADENOMA

1. Hyperechoic, vascular mass with internal calcifications
2. May produce acoustic shadowing

Trauma and Renal Hematoma

Hematomas are localized collections of blood. A renal hematoma may be the result of blunt trauma to the kidney region, surgical intervention or biopsy, and lithotripsy. Rarely, spontaneous hematomas can occur and can be the result of preexisting pathologic conditions or may be entirely idiopathic. Patients who have suffered trauma to the kidney(s) may complain of flank pain and/or general abdominal pain. They will also have evidence of decreased hematocrit and may have hematuria.

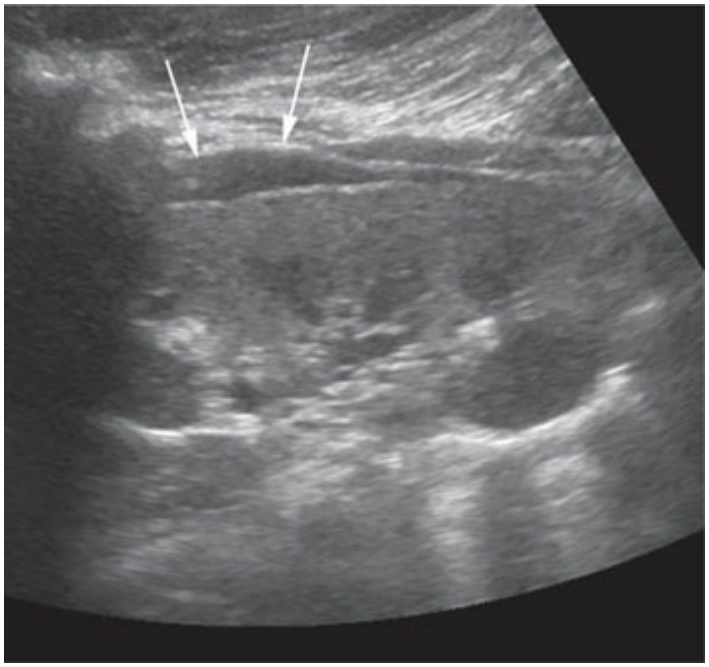


Figure 7-18 Renal hematoma. Longitudinal image of the left kidney demonstrating a hypoechoic collection anterior to the kidney (*arrows*). The collection lies between the echogenic renal capsule and the renal cortex. The hematoma follows the contour of the kidney.

A renal fracture may be observed sonographically. The fracture appears as the linear absence of echoes, or a linear anechoic or hypoechoic region in the renal parenchyma. Blood may accumulate under the capsule (subcapsular), in the perinephric area (in Gerota fascia), pararenal area (anterior or posterior), or intramuscular (in the psoas muscle) (Fig. 7-18).

Sonographically, the appearance of a hematoma is directly related to its location and the amount of time that has elapsed since the traumatic event. An acute hemorrhage may appear anechoic initially, and then hyperechoic as

clot collects in the area. With time, the blood can form into a focal tumor—a hematoma—which may appear complex, with varying degrees of anechoic, hypoechoic, and hyperechoic components. Eventually, the fluid will become anechoic again, as liquefaction takes place. Chronic hematomas may calcify and produce acoustic shadowing.

CLINICAL FINDINGS OF A RENAL HEMATOMA

1. History of some form of trauma to the kidney(s) (blunt trauma, stab wound, biopsy, or lithotripsy)
2. Flank pain
3. Abdominal pain
4. Hematuria
5. Decreased hematocrit

SONOGRAPHIC FINDINGS OF A RENAL HEMATOMA

1. Variable appearance depending on the stage of the blood and location
2. Blood may accumulate under the capsule (subcapsular), in the perinephric area (in Gerota fascia), pararenal area (anterior or posterior), or intramuscular (in the psoas muscle)
3. Chronic hematomas may calcify and produce acoustic shadowing

Malignant Renal Masses

Renal Cell Carcinoma

RCC may also be referred to as a hypernephroma or adenocarcinoma of the kidney. It is a primary form of renal cancer, meaning this form of cancer begins in the kidney, specifically originating from the renal tubular epithelium. Smoking, hypertension, obesity, and tuberous sclerosis increase the risk for developing RCC. In addition, there seems to be a strong association between RCC and von Hippel–Lindau disease. Patients who have acquired renal cystic disease from long-term dialysis are especially susceptible to develop RCC as well.

Unfortunately, frequently symptoms manifest late in the disease when the tumor is moderately large. Patients may present with flank pain, a palpable mass, and gross hematuria. They may also suffer from unexplained weight loss and anorexia. The tumor can spread into the renal vein and IVC, which is termed tumor thrombus. The sonographic findings of RCC vary (Fig. 7-19). Often, the tumor is either hypoechoic or isoechoic to normal renal tissue, but can be hyperechoic as well. RCC can even have a complex cystic appearance. The ipsilateral renal vein and IVC should be analyzed closely for tumor invasion.

SOUND OFF
RCC may be referred to as a hypernephroma. It has a strong link with smoking.

CLINICAL FINDINGS OF RENAL CELL CARCINOMA

1. Anorexia
2. Flank pain
3. Gross hematuria
4. Hypertension
5. Palpable mass
6. Smoker
7. Weight loss

SONOGRAPHIC FINDINGS OF RENAL CELL CARCINOMA

1. Hypoechoic, isoechoic, or hyperechoic solid mass on the kidney
2. Can have a complex cystic appearance as well
3. Check the renal vein and IVC for tumor invasion

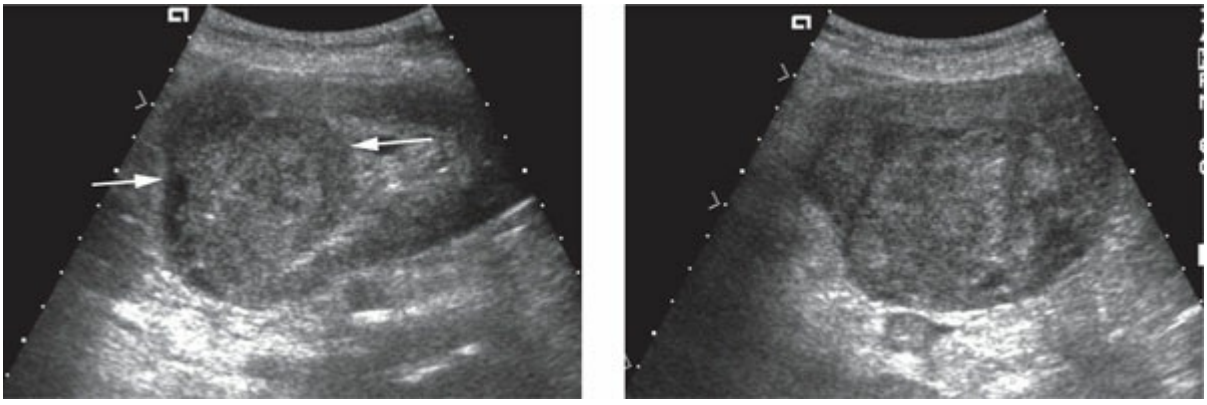


Figure 7-19 Renal cell carcinoma. Longitudinal (**left**) and transverse images (**right**) of the left kidney showing a heterogeneous solid lesion (*arrows*) in the superior pole.

Renal Transitional Cell Carcinoma

Transitional cell carcinoma (TCC) of the kidney is a malignant tumor that is most often found in the area of the renal pelvis. TCC may also be found within the ureter and urinary bladder (see section "Transitional Cell Carcinoma of the Bladder" in this chapter). Like RCC, patients who smoke are also at an increase risk for TCC.

TCC can cause focal dilation of the calices, and small lesions can be difficult to identify with sonography. Larger masses most often appear as hypoechoic or isoechoic masses within the renal sinus. Patients may present with gross hematuria and pain secondary to renal obstruction.

Clinical Findings of Renal Transitional Cell Carcinoma

1. Gross hematuria
2. Pain secondary to renal obstruction
3. History of smoking

Sonographic Findings of Renal Transitional Cell Carcinoma

1. Hypoechoic or isoechoic mass within the renal sinus
2. Varying degrees of hydronephrosis may be present



SOUND OFF
TCC found in the kidney is most often located within the renal pelvis.

Metastases to the Kidney and Other Malignancies

Metastases to the kidneys are most often from the lungs or breast, with prostate, pancreas, and melanoma occurring less frequently. RCC can also metastasize from the contralateral kidney. These tumors appear as solid masses that are often hypoechoic or hyperechoic. Lymphoma and leukemia of the kidney will appear sonographically similar. Both can either result in a multiple, hypoechoic masses or be seen as bilateral, renal enlargement with a decrease in overall renal echogenicity. Lymphoma, which is most likely in the form of non-Hodgkin lymphoma, typically affects both kidneys. Patients who have a history of primary malignancy should be thoroughly evaluated for renal metastasis. Clinical findings may include hematuria, flank pain, fever, and weight loss.

Clinical Findings of Other Renal Malignancies

1. History of primary cancer (often lung or breast)
2. Hematuria
3. Fever
4. Weight loss

Sonographic Findings of Other Renal Malignancies

1. Bilateral, hypoechoic masses with lymphoma
2. Lymphoma or leukemia can manifest as an enlarged kidney
3. Metastases have varying sonographic findings but are most often solid tumors that are hypoechoic or hyperechoic

RENAL VASCULAR ABNORMALITIES AND TRANSPLANT ASSESSMENT

Nutcracker Syndrome

Compression or entrapment of the left renal vein as it passes between the superior mesenteric artery and abdominal aorta is termed nutcracker syndrome or renal vein entrapment. Sonographically, the left renal vein will reveal elevated pressure with Doppler evaluation. Patients with nutcracker syndrome can present with proteinuria, hematuria, left-sided abdominal or flank pain, and pelvic pain. Male patients may complain of left testicular pain as well. There can be many varied vascular variants of the renal vessels, including duplication and branching anomalies.

CLINICAL FINDINGS IN NUTCRACKER SYNDROME

1. Hematuria
2. Proteinuria
3. Possible left-sided abdominal or flank pain
4. Pelvic pain
5. Left-sided testicular pain

SONOGRAPHIC FINDINGS OF NUTCRACKER SYNDROME

1. Compression of the left renal vein
2. Elevated pressure within the left renal vein

Renal Artery Stenosis

Renal artery stenosis is a decrease in the diameter of the renal arteries. A common cause of renal artery stenosis is atherosclerosis. Patients who have a history of smoking, diabetes, high cholesterol, and high blood pressure are inclined to develop renal artery stenosis. Patients who have existing renal artery stenosis often suffer from hypertension that does not respond to treatment. In younger female patients, fibromuscular disease may be the cause of renal artery stenosis.

The narrowing of the renal artery may be hemodynamically significant. The diagnosis of renal artery stenosis can be made sonographically, but it is often a challenging endeavor secondary to the patient's body habitus, the inability of the patient to suspend respiration, and overlying bowel gas. Renal artery stenosis can lead to renal infarction and irreparable renal compromise. Sonographic findings of renal artery stenosis include thickening and calcification of the renal artery, along with a renal:aorta ratio that is greater than 3.5, and possibly a tardus–parvus spectral waveform downstream from

the stenosis, although this may not always be present (Fig. 7-20).

CLINICAL FINDINGS OF RENAL ARTERY STENOSIS

1. Smoker
2. High blood pressure
3. High cholesterol
4. Diabetes
5. Hypertension that does not respond to treatment

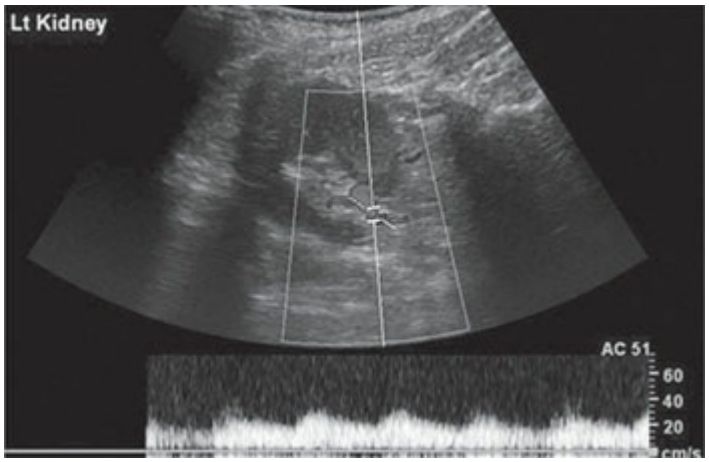


Figure 7-20 Renal artery stenosis. Tardus–parvus waveform indicating renal artery stenosis. (From Sarkodieh JE, Walden SH, Low D. Imaging and management of atherosclerotic renal artery stenosis. Clin Radiol 2013;68:627–635.)

SONOGRAPHIC FINDINGS OF RENAL ARTERY STENOSIS

1. Thickening and calcification of the renal artery may be noted
2. Renal to aorta ratio that is greater than 3.5
3. Possibly a tardus–parvus spectral waveform downstream from the stenosis.

Renal Vein Thrombosis

Blood clot within the renal vein is termed renal vein thrombosis. It may be caused by renal tumors, trauma, renal infections, or be seen following a renal transplant. Patients typically present with flank pain and hematuria. The kidney that is completely blocked will increase in size and have a heterogeneous sonographic appearance. The renal vein itself will also enlarge, and Doppler signals will be absent. Sonographic identification of the clot is vital, although this can often be difficult.

CLINICAL FINDINGS OF RENAL VEIN THROMBOSIS

1. Pain
2. Hematuria

SONOGRAPHIC FINDINGS OF RENAL VEIN THROMBOSIS

1. Heterogeneous renal echotexture
2. Enlarged renal vein
3. Absent renal vein Doppler signals
4. Thrombus may not be seen

Renal Transplant and Postsurgical Complications

Renal biopsy is often the best indicator of renal transplant rejection. However, although sonography is not the typical means for the diagnosis of renal transplant rejection, it is often utilized to provide an overall assessment for complications following transplantation. There are various conditions that lead to renal failure and the need for a renal transplant. The transplanted kidney, also referred to as the allograft, is placed within the right or left lower quadrant. The donor artery and vein is typically anastomosed (connected) to the external iliac artery and external iliac vein of the recipient. The donor ureter is attached to the recipient urinary bladder. The donor kidney should appear sonographically similar to a normal kidney. Mild pelviectasis is considered normal in the transplanted kidney. The native kidneys should be examined as well.

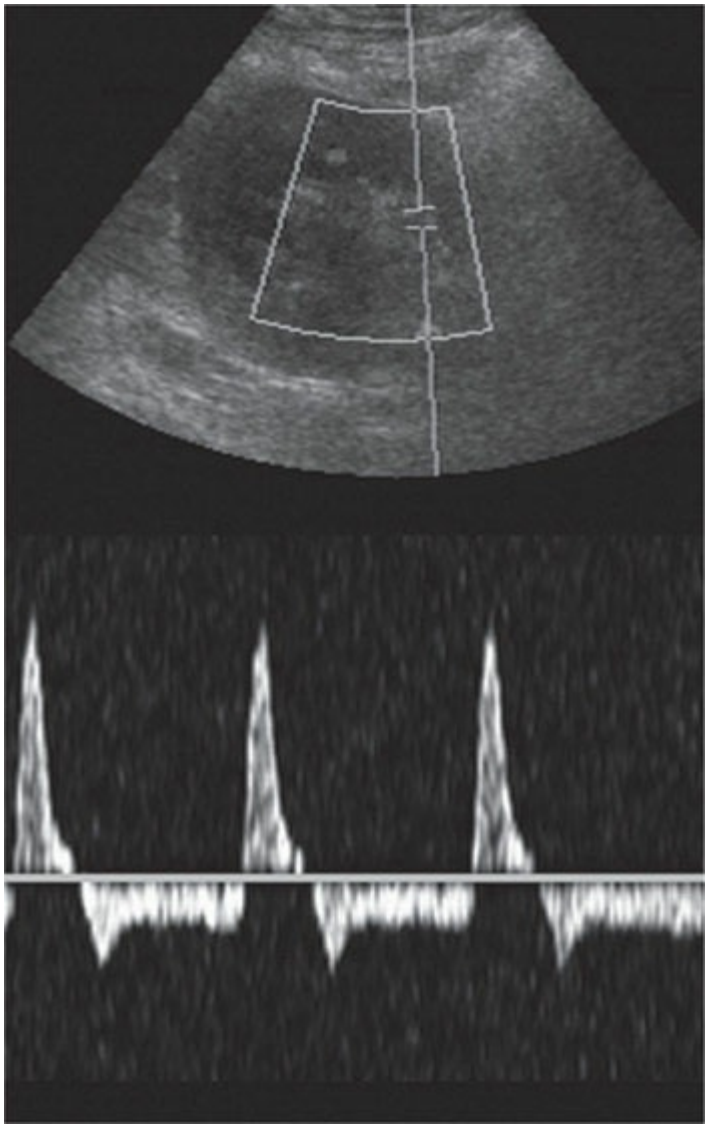


Figure 7-21 Renal vein thrombosis. A spectral Doppler waveform from a segmental renal artery in the renal sinus demonstrating reversed diastolic flow in a patient presented with abrupt anuria 3 hours postsurgery. Thrombosis of the main renal vein was found at surgery.

Doppler and spectral imaging is warranted to fully assess the functional state of the transplanted kidney. Spectral analysis of the interlobar arteries should be obtained in the upper, mid, and lower regions of the kidney. The main renal artery should be analyzed with color and spectral Doppler at the anastomosis, proximal, and distal segments. The normal waveform should yield low resistance with continuous diastolic flow. The resistive indices should be 0.6 to 0.8, and anything over 0.9 is considered abnormal. The renal vein should demonstrate normal continuous flow away from the kidney, and may be examined at the anastomosis site with the iliac vein as well.

Postrenal transplant fluid collections are common and could be a lymphocele, urinoma, hematoma, or abscess. These fluid collections may appear similar with sonography, with most appearing echogenic, complex, or

anechoic. Clinical signs of transplant rejection include anuria, oliguria, elevated creatinine and BUN, proteinuria, hypertension, and enlargement of the transplant.

Complications of a renal transplant include rejection, infection, obstruction, vascular stenosis, renal artery stenosis, renal artery thrombosis, renal vein thrombosis, pseudoaneurysm, and fistulas (Fig. 7-21). Renal artery stenosis is the most common vascular complication following renal transplantation. The sonographic indication of renal artery stenosis includes color aliasing and turbulent flow at the level of the anastomosis site. The diagnosis of renal artery stenosis in a renal transplant includes an elevated peak systolic velocity greater than 200 to 250 cm per second, renal artery to external iliac ratio greater than 2.0 to 3.0, and poststenotic turbulence.

PEDIATRIC KIDNEY PATHOLOGY

Congenital Hydronephrosis

Congenital hydronephrosis can occur as a result of several conditions, which are mentioned in Table 7-8. The most common cause of congenital hydronephrosis in infants and children is a ureteropelvic junction obstruction. VUR may also be the cause of congenital hydronephrosis. VUR is the backward flow of urine from the urinary bladder into the ureter, and possibly all the way back into the kidney (discussed later in this chapter). It is graded based on its severity (Table 7-9).

Other causes of congenital hydronephrosis include posterior urethral valves and prune belly syndrome. Posterior urethral valves are folds of excessive urethral tissue found exclusively in males. Posterior urethral valves cause dilation of the bladder, both ureters, and both renal collecting systems. Prune belly syndrome is typically caused by megacystis, a massively dilated urinary bladder. This syndrome is mostly seen in male fetuses and is the result of a urethral abnormality, which in turn leads to a bladder outlet obstruction. Prune belly describes the result of the abdominal wall musculature being stretched by the extremely enlarged urinary bladder. Enlargement of the bladder, ureter, and the renal collecting system will occur. The triad of absent abdominal musculature, undescended testis, and urinary tract abnormalities is consistent with the diagnosis of prune belly syndrome.

TABLE 7-8 Clinical and sonographic findings for causes of congenital hydronephrosis

Cause of Congenital Hydronephrosis	Clinical Findings	Sonographic Findings
Ureteropelvic junction obstruction	Palpable abdominal mass Abdominal distension Hematuria	Dilated renal collecting system Distal ureter not seen
Vesicoureteral reflux	Urinary tract infection Proteinuria	Kidneys may appear normal Hydronephrosis may be present and may reduce after micturition Possible scar formation in the kidneys
Posterior urethral valves	Male patient Urinary tract infection Voiding abnormalities	Large urinary bladder Dilated ureters Dilated bilateral renal collecting systems
Prune belly syndrome	Often discovered in utero Urinary tract infection Failure to thrive	Large urinary bladder Varying degrees of hydronephrosis Varying degrees of ureteral dilation

TABLE 7-9 Grades of vesicoureteral reflux

Grade of Vesicoureteral Reflux	Description
I	Urine refluxes into the ureter only
II	Urine refluxes into the ureter and the renal pelvis without hydronephrosis
III	Urine refluxes into the ureter and the renal pelvis with hydronephrosis
IV	Moderate hydronephrosis
V	Severe hydronephrosis

Pediatric Vesicoureteral Reflux

VUR, which is the retrograde flow of urine from the bladder to the ureter, is a widespread malady in the pediatric population. Urine-containing bacterium that travels from the bladder, up the ureter, and into the kidney, can result in a kidney infection with subsequent scarring and permanent damage to the renal parenchyma. VUR is most commonly caused by an abnormal angle of

insertion of the distal ureter into the bladder at the ureterovesicular junction, resulting in a faulty valve. Patients with duplicated pelvicaliceal systems and complete uteteral duplication may suffer from VUR. With these individuals, the upper pole moiety in the duplex kidney is often prone to obstruction because of an irregular insertion of the ureter into the urinary bladder. This leads to the development of an obstructing ureterocele. The lower pole moiety in these individuals is prone to reflux. This assumption about the obstruction and refluxing components of the duplicated system is referred to as the Weigert–Meyer rule (Fig. 7-22).

SOUND OFF

The upper pole moiety in the duplex kidney is often prone to obstruction because of an irregular insertion of the ureter into the urinary bladder. This leads to the development of an obstructing ureterocele. The lower pole moiety in these individuals is prone to reflux.

Clinically, patients with VUR present with signs and symptoms of a urinary tract infection, such as an unexplained fever, irritability, flank pain, leukocytosis, bacteriuria, hematuria, urgency to void, and dysuria. Sonography is not highly sensitive for detecting VUR. Often, patients with minimal reflux have normal sonographic findings because reflux can be transient. However, long-standing and severe reflux can cause obvious enlargement of the ureter and dilation of the renal collecting system. A voiding cystourethrogram or a nuclear cystogram can be performed to provide a more definitive diagnosis of this condition. In patients with VUR and a duplicated system, the upper pole tends to demonstrate hydronephrosis secondary to the obstructing ureterocele, while the lower pole can also demonstrate hydronephrosis secondary to reflux. Bladder debris may be seen as well.

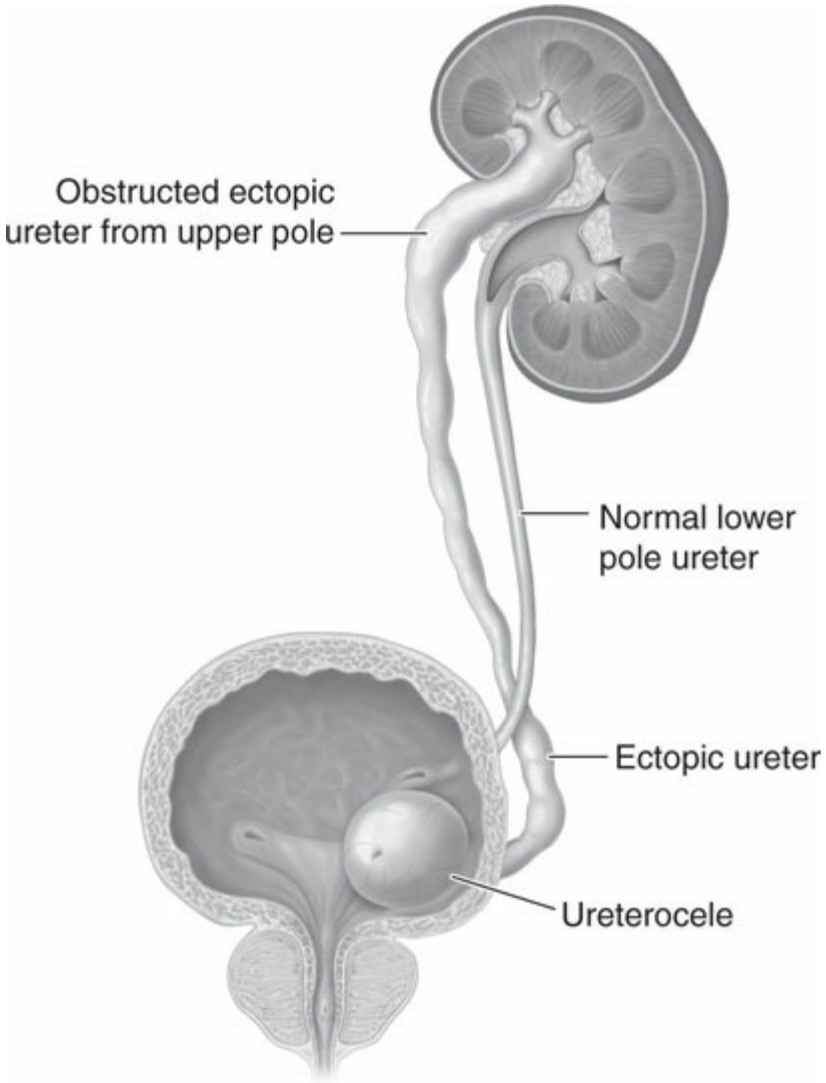


Figure 7-22 Weigert–Meyer rule. The upper pole moiety in the duplex kidney is often prone to obstruction because of an irregular insertion of the ureter into the urinary bladder. This leads to the development of an obstructing ureterocele. The lower pole moiety in these individuals is prone to reflux.

Treatment is focused on preventing renal scarring, which increases the risk of complications from permanent renal damage and even end-stage-renal disease later in life. Mild VUR is typically treated with antibiotics, whereas severe forms may require surgical intervention or the use of a synthetic bulking agent that is injected endoscopically. The administration of this bulking agent may be referred to as a subureteral Teflon injection (STING). These STING agents elevate the ureteral orifice and distal ureter, allowing for the normal flow of urine from the ureter into the bladder. Although often effective, the STING procedure may not be as successful as other surgical mean of treatment. Sonographically, the bulking agent appears as a hyperechoic structure in the area of the vesicoureteral junction that may produce acoustic shadowing (Fig. 7-23).

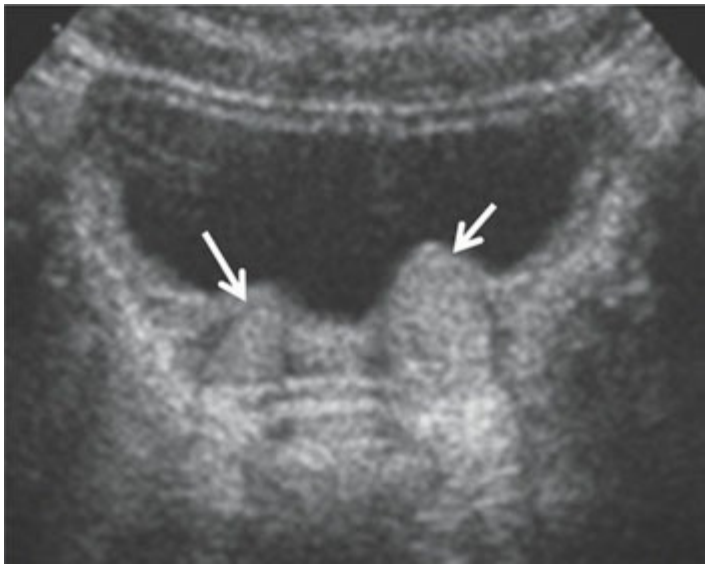


Figure 7-23 STING procedure. Transverse sonogram showing round echogenic foci (*arrows*) protruding into the bladder lumen representing the bulking agents effect. STING, subureteral Teflon injection.

CLINICAL FINDINGS OF VESICOURETERAL REFLUX

1. May be asymptomatic
2. Unexplained fever
3. Irritability
4. Flank pain
5. Leukocytosis
6. Bacteriuria
7. Hematuria
8. Dysuria
9. Urgency to void

SONOGRAPHIC FINDINGS OF VESICOURETERAL REFLUX

1. Patients with minimal reflux may have normal appearing kidneys
2. Hydronephrosis and/or hydroureter may be present
3. Ureterocele may be seen in the bladder
4. Bladder debris may be seen

Pediatric Wilms Tumor

A Wilms tumor may also be referred to as a nephroblastoma. The Wilms tumor is the most common solid malignant pediatric abdominal mass. It is typically discovered before the age of 5, with a mean age of 3. These tumors can grow reasonably large before discovery and can invade the renal vein and IVC. Nephroblastomas tend to metastasize to the liver and lungs. Clinically, these patients present with a palpable abdominal mass, abdominal pain, hematuria, fever, and hypertension. In addition, pediatric patients with

Beckwith-Wiedemann syndrome have a tendency to develop Wilms tumors. Sonographically, a Wilms tumor appears as a large, solid, mostly echogenic mass that may contain anechoic or hypoechoic region (Fig. 7-24). Tumor invasion of the renal vein and IVC should be evaluated. In addition, a thorough evaluation of the abdominal organs for metastasis is necessary.

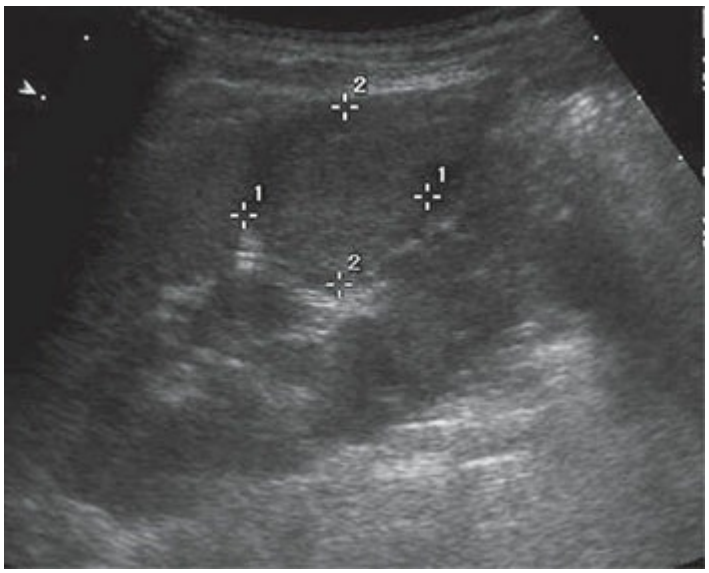


Figure 7-24 Wilms tumor. Longitudinal image of the kidney revealing an isoechoic mass (*between calipers*). It was proven to be a nephroblastoma (Wilms tumor).

CLINICAL FINDINGS OF WILMS TUMOR

1. Palpable abdominal mass
2. Abdominal pain
3. Hematuria
4. Fever
5. Hypertension

SONOGRAPHIC FINDINGS OF WILMS TUMOR

1. Large, solid, mostly echogenic masses that may contain anechoic or hypoechoic areas

SOUND OFF

The Wilms tumor is the most common solid malignant pediatric abdominal mass. It may also be referred to as the nephroblastoma.

Urachal Anomalies

The urachus is a remnant of embryonic development. It is a tubular structure that extends from umbilicus to the apex of the bladder. During fetal life, the

urachus normally closes. Failure of the urachus to close can result in a urachal anomaly. These include patent urachus, urachal cyst, urachal sinus, or urachal diverticulum. A patent urachus will appear as an anechoic tube that extends from the umbilicus to the apex of the urinary bladder. Urachal cysts or a urachal sinus may also be encountered if closure is not complete. Urachal cyst and urachal diverticulum will appear as a cystic structure between the bladder and the umbilicus. A urachal sinus will appear as a linear, fluid-filled structure that is continuous with the umbilicus. Patients may be asymptomatic or can have signs of infection or a palpable anterior abdominal mass between the umbilicus and the urinary bladder.

CLINICAL FINDINGS OF URACHAL ANOMALIES

1. Possible signs of urinary tract infection
2. Palpable abdominal mass between the umbilicus and the urinary bladder

SONOGRAPHIC FINDINGS OF URACHAL ANOMALIES

1. Patent urachus will appear as an anechoic tube that extends from the umbilicus to the apex of the urinary bladder
2. Urachal cyst and urachal diverticulum will appear as a cystic structure between the bladder and the umbilicus
3. Urachal sinus will appear as a linear, fluid-filled structure that is continuous with the umbilicus

ANATOMY AND PHYSIOLOGY OF THE URETERS

The ureters are bilateral muscular tubes that extend from the renal pelvis to the urinary bladder. The most proximal portion of the ureter is the point at which the ureter is attached to the renal pelvis. This is referred to as the ureteropelvic junction. The point at which the ureter meets the urinary bladder is referred to as the ureterovesicular junction. The ureters enter the bladder posteriorly at the superolateral margin of the trigone of the bladder. The purpose of the ureters is to propel urine from the kidneys to the urinary bladder. The ureters achieve this by means of peristalsis and gravity.

SONOGRAPHY OF THE URETERS

Normal ureters are not routinely imaged with sonography secondary to their small size. However, when enlarged and distended with urine, the ureters will appear as anechoic, tubular structures. Whenever identified with sonography, the ureters should be thoroughly evaluated for obstructive

processes.

Ureteral jets can be demonstrated as well. These jets result from urine being forced into the urinary bladder from the ureters. Color Doppler is employed over the inferoposterior aspect of the urinary bladder in the area of the ureteral orifices and trigone. Imaging of ureteral jets is performed to demonstrate ureteral patency in suspected cases of urinary obstruction. Urinary jets typically occur at least once every minute.

URETERAL PATHOLOGY

Ureteral Stones

The most common place for a urinary stone to become lodged is within the ureterovesicular junction, near the urinary bladder. A patient with a stone passing through the ureter may present with renal colic, pain in the groin, labia, or testicle on the side of stone, and possibly hematuria. A ureteral stone will appear as an echogenic focus within the ureter that produces an acoustic shadow. The twinkle sign can be used to prove the presence of a ureteral stone. Typically, the ureter is dilated proximal to the level of the stone.

CLINICAL FINDINGS OF A URETERAL STONE

1. Renal colic
2. Pain in the groin, labia, or testicle on the side of the stone
3. Possible hematuria

SONOGRAPHIC FINDINGS OF A URETERAL STONE

1. Echogenic focus within the ureter that produces acoustic shadowing
2. Dilatation of the ureter proximal to the stone

Ureterocele

A ureterocele is the cystic dilatation of the ureter as it enters the bladder. Although ureteroceles are often asymptomatic, urinary stasis may result in the dilated area, and therefore infection and stone formation can occur. Ureteroceles are often associated with duplicated collecting systems, specifically the ureter that originates from the upper moiety. They may also be ectopic in location, causing obstruction of the contralateral ureter. Sonographically, a ureterocele appears as an anechoic, balloon-like structure within the lumen of the urinary bladder near the ureterovesicular junction (Fig. 7-25).

CLINICAL FINDINGS OF A URETEROCELE

1. Asymptomatic
2. Signs of a urinary tract infection

SONOGRAPHIC FINDINGS OF A URETEROCELE

1. Anechoic, balloon-like structure within the lumen of the urinary bladder near the ureterovesicular junction
2. Can be ectopic in location

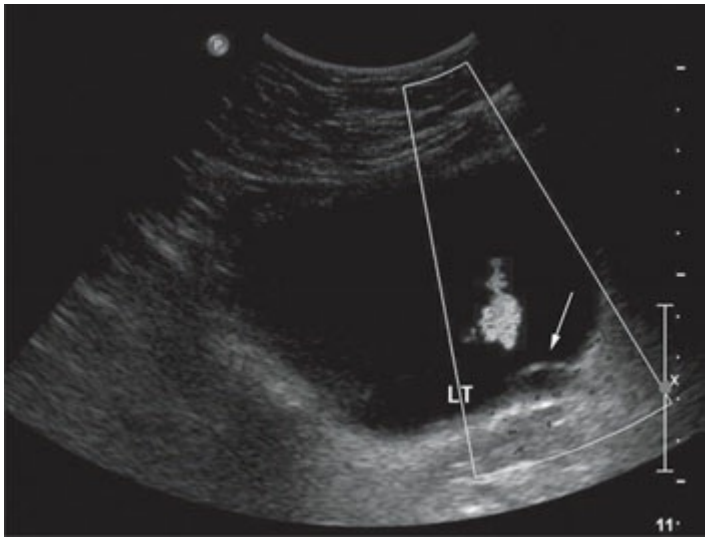


Figure 7-25 Ureterocele. A small, left-sided (LT) ureterocele is noted in the transverse image of the bladder (*arrow*).

Megaureter and Hydroureter

A large ureter may be termed megaureter or hydroureter based on the cause of the enlargement. The ureter may be congenitally enlarged, megaureter, or associated with reflux or obstruction, hydroureter. Patients may be asymptomatic or have signs of a urinary tract infection. Sonographically, a dilated ureter will appear as an anechoic tube.

CLINICAL FINDINGS OF MEGAURETER AND HYDROURETER

1. Asymptomatic
2. Urinary tract infection

SONOGRAPHIC FINDINGS OF MEGAURETER AND HYDROURETER

1. Large, anechoic tubular structure that extends from the kidney to the urinary bladder; only a section may be enlarged, however

ANATOMY AND PHYSIOLOGY OF THE URINARY BLADDER

The urinary bladder is a retroperitoneal organ that functions as a reservoir for urine. It is located in the pelvis, posterior to the symphysis pubis. In males, the urinary bladder is also positioned superior to the prostate gland and anterior to the seminal vesicles. In females, the urinary bladder is located anterior to the vagina, uterus, and rectum.

The bladder wall consists of four layers. From inner to outer, the layers of the bladder wall are the mucosa, submucosa, muscularis, and serosa. The detrusor muscle is located within the muscularis portion of the wall. This muscle controls the appropriate emptying of the urinary bladder. The trigone of the bladder is located inferiorly, at the base of the urinary bladder. Its location marks the single urethral opening and bilateral ureteral openings.

SONOGRAPHY OF THE URINARY BLADDER

Sonographically, the normal distended bladder appears as a smooth-walled, anechoic structure within the pelvis. In the transverse plane, it appears as a square-shaped organ; whereas in sagittal, the urinary bladder appears more elliptical. Much like a balloon, the normal empty urinary bladder will have a more evident or thicker appearing wall, whereas the bladder that is fully distended will have a thin wall. When the bladder wall is thickened, its diameter will exceed 4 mm in a distended state. The wall should be analyzed closely for irregularities. The volume of the bladder can be evaluated sonographically. A bladder volume can be obtained using the following formula: $L \times W \times H \times 0.56$. In addition, patency of the ureters can be proven sonographically by demonstrating ureteral jets with color Doppler in the area of the trigone.

URINARY BLADDER PATHOLOGY

Neurogenic Bladder

A neurogenic bladder is a one that is poorly functioning secondary to any type of neurologic disorder. Thus, a neurogenic bladder may be caused by brain or spinal trauma, congenital spinal abnormalities, diabetes, and several other conditions. In effect, what is really not working properly is the detrusor muscle surrounding the bladder. Clinical symptoms of a neurogenic bladder vary, as do sonographic findings. Patients may suffer from an unnecessary urgency to void or may rarely feel the need to urinate. Sonographic findings

may include a normal bladder wall or a thickened bladder wall with identifiable trabeculae—termed trabeculated bladder. A trabeculated bladder can also result from chronic bladder infections; therefore, a thorough clinical history is warranted. The patient may have an extremely distended urinary bladder, although he or she may lack the urgency to void. Postvoid images may demonstrate excessive urinary retention, thus bladder volume pre- and postvoid can be useful.

CLINICAL FINDINGS OF A NEUROGENIC BLADDER

1. Past history of brain or spinal trauma, congenital spinal abnormalities, or diabetes
2. Unnecessary urgency to void
3. Rarely feel the need to urinate

SONOGRAPHIC FINDINGS OF A NEUROGENIC BLADDER

1. Urinary bladder wall thickening
2. Trabeculae of the bladder wall
3. Postvoid images will show excessive urinary retention
4. The patient may have a distended bladder but does not feel the need to urinate
5. Bladder stones may be present

Bladder Diverticulum

A bladder diverticulum is an outpouching in the bladder wall. A diverticulum of the bladder may be associated with a urethral obstruction, or it may be congenital. Complications of a bladder diverticulum include bladder infection, ureteral obstruction, tumor development, and the spread of infection to the upper urinary tract. Patients can be asymptomatic. However, those who present with a urinary tract infection do so as a result of urinary stasis within the diverticulum. Sonographically, a bladder diverticulum will be noted as an outpouching of the bladder wall (Fig. 7-26). The sonographer should try to visualize and demonstrate the neck of the diverticulum. A color Doppler jet may be noted at the level of the neck of the diverticulum.

CLINICAL FINDINGS OF A BLADDER DIVERTICULUM

1. Can be asymptomatic
2. Urinary tract infection

SONOGRAPHIC FINDINGS OF A BLADDER DIVERTICULUM

1. Anechoic outpouching of the bladder wall
2. A visible neck connecting the diverticulum to the bladder

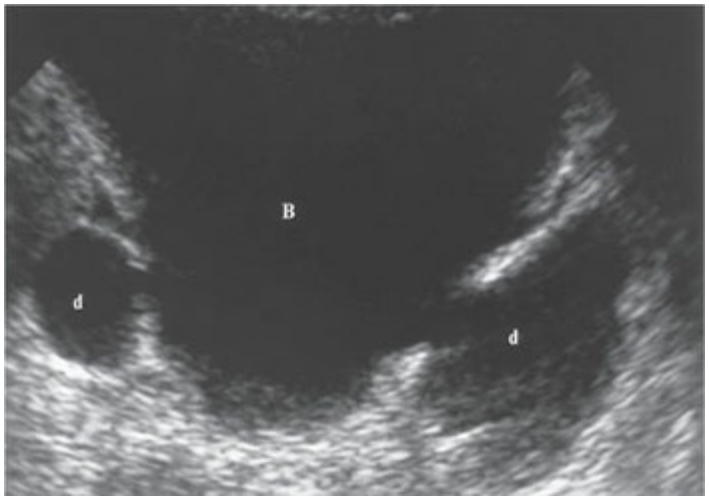


Figure 7-26 Bladder diverticuli. Transverse image of the urinary bladder (*B*) revealing two-bladder diverticuli (*d*).

SOUND OFF
When a bladder diverticulum is suspected, the sonographer should try to visualize and demonstrate the neck of the diverticulum.

Cystitis

Inflammation of the urinary bladder is referred to as cystitis. Most likely, cystitis will appear sonographically as bladder wall thickening. When the bladder wall is thickened, its diameter will exceed 4 mm in a distended state. Cystitis is more common in women secondary to the short length of the urethra. The infection continues as an ascending infection, moving from the urethra into the bladder. Cystitis can present clinically with dysuria, urinary frequency, lower abdominal pain, nocturia, and even hematuria. Sonographically, the bladder wall may appear focally or diffusely thickened with decreased echogenity and measure greater than 4 mm in thickness. Chronic cystitis can lead to scarring and trabeculation of the bladder wall (Fig. 7-27). Within the lumen, echogenic, layering material may be noted. Decubitus positioning can be helpful to differentiate bladder debris from focal wall thickening and bladder tumors.

CLINICAL FINDINGS OF CYSTITIS

1. Dysuria
2. Urinary frequency
3. Lower abdominal pain
4. Nocturia
5. Hematuria

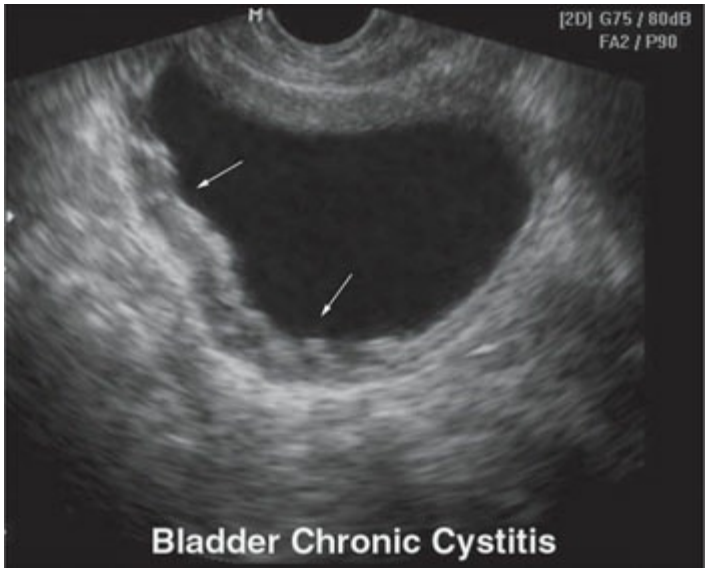


Figure 7-27 Urinary bladder wall thickening. Endovaginal image of the urinary bladder showing a thickened irregular bladder wall (*arrows*) consistent with chronic cystitis.

SONOGRAPHIC FINDINGS OF CYSTITIS

1. Hypoechoic bladder wall that may appear focally or diffusely thickened, measuring greater than 4 mm in thickness
2. Bladder may contain echogenic, layering material within its lumen

SOUND OFF

The urinary bladder wall does not typically exceed 4 mm in a distended state.

Bladder Stones and Other Intraluminal Objects

Urolithiasis may be created or become trapped within the urinary bladder. They appear as echogenic, mobile structures that produce posterior acoustic shadowing. Blood clots may also be noted within the urinary bladder. A blood clot within the bladder will appear as an echogenic, nonshadowing mass that may be mobile or adhered to the bladder wall. Decubitus positioning can be helpful to differentiate mobile intraluminal bladder objects from focal wall thickening and bladder tumors.

SONOGRAPHIC APPEARANCE OF BLADDER STONES

1. Echogenic, mobile, shadowing foci within the lumen of the urinary bladder

SONOGRAPHIC APPEARANCE OF BLOOD CLOTS IN THE BLADDER

1. Echogenic, nonshadowing mass that may be mobile or adhered to the wall of the bladder

SOUND OFF
When an intraluminal bladder object or bladder wall mass is suspected, the sonographer should ask the patient to move into a decubitus position to determine the mobility of the object or mass.

Transitional Cell Carcinoma of the Bladder

The most common malignant tumor of the bladder is TCC. Patients typically present with gross hematuria and may pass some blood clots. The sonographic appearance of TCC within the urinary bladder is a smooth or papillary hypoechoic or hyperechoic mass that projects into the lumen of the bladder (Fig. 7-28). These masses must be differentiated from other intraluminal bladder abnormalities such as blood clots because blood clots may accompany a TCC. This can often be achieved by utilizing color Doppler. Color Doppler will often reveal vascularity within a solid tumor, whereas a blood clot will not yield any Doppler signals. In addition, a blood clot may be mobile, whereas a tumor will maintain its location as the patient changes position.

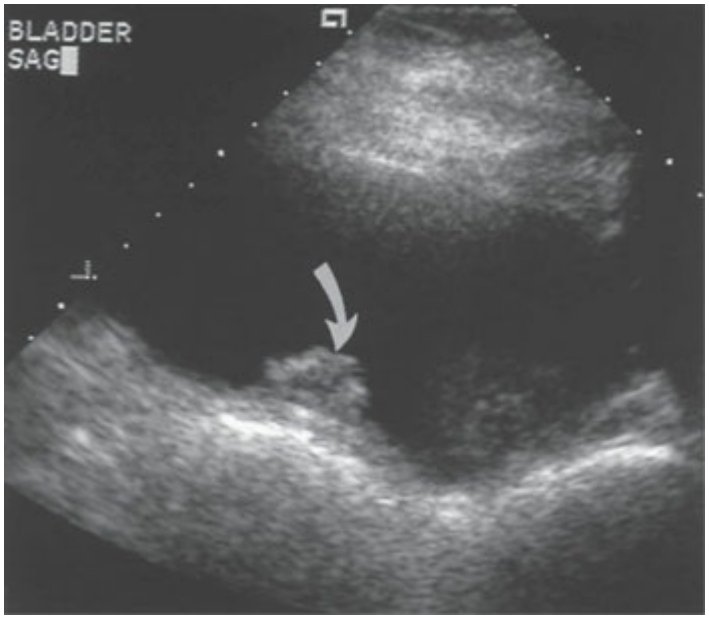


Figure 7-28 Transitional cell carcinoma. Longitudinal image of the bladder revealing a broad-based mass (*arrow*) originating from the bladder mucosa.

CLINICAL FINDINGS OF TRANSITIONAL CELL CARCINOMA OF THE BLADDER

1. Gross hematuria
2. May urinate blood clots

SONOGRAPHIC FINDINGS OF TRANSITIONAL CELL CARCINOMA OF THE BLADDER

1. Smooth or papillary hypoechoic or hyperechoic mass that projects into the lumen of the bladder
2. A solid tumor will not be mobile and will often demonstrate vascularity



SOUND OFF
The most common malignancy of the urinary bladder is TCC.

THE URETHRA

The urethra begins at the trigone of the urinary bladder and ends at the urethral orifice. Its purpose, for both sexes, is to transport urine from the urinary bladder out of the body. The male urethra is longer than the female urethra. The urethra may be noted during sonographic examination of the female and male genital tracts. A portion of the male urethra is surrounded by the prostate gland. Therefore, enlargement of the gland, often occurring with benign prostatic hypertrophy, can lead to compression of the urethra, causing urinary obstruction. The female urethra can be better visualized with endovaginal, transperineal, or translabial sonographic imaging compared with the traditional transabdominal approach.

REVIEW QUESTIONS

1. Which of the following is a childhood, autoimmune disease that results in the development of purple spots on the skin and possible renal failure?
   a. Henoch–Schonlein purpura
   b. Azotemia
   c. von Hippel–Lindau syndrome
   d. Xanthogranulomatous pyelonephritis

2. What is the functional unit of the kidney?
   a. Nephron
   b. Medulla
   c. Cortex
   d. Bowman capsule

3. Which of the following would be most indicative of renal artery stenosis?
   a. Decreased cortical echogenicity
   b. A renal to aorta ratio that is greater than 3.5
   c. Enlarged kidney
   d. Tardus–parvus waveform upstream to the stenosis

4. The kidneys are:
   a. Intraperitoneal organs
   b. Retroperitoneal organs
   c. Both intraperitoneal and retroperitoneal organs
   d. Neither intraperitoneal nor retroperitoneal organs

5. The protective capsule of the kidney is referred to as:
   a. Glisson capsule
   b. Perirenal capsule
   c. Renal capsule
   d. Renal cortex

6. The vessel located anterior to the abdominal aorta and posterior to the superior mesenteric artery is the:
   a. Celiac artery
   b. Left renal artery
   c. Right renal vein
   d. Left renal vein

7. Which of the following would not be a typical clinical feature of renal transplant failure?
   a. Oliguria
   b. Proteinuria
   c. Hypotension
   d. Elevated creatinine

8. Enlargement of the unaffected contralateral kidney with unilateral renal agenesis or compromised renal function is referred to as:
   a. Dromedary hypertrophy
   b. Renal hypoplasia
   c. Supernumerary kidney
   d. Compensatory hypertrophy

9. A bulge on the lateral border of the kidney is referred to as:
   a. Duplicated kidney
   b. Renal hypoplasia
   c. Dromedary hump

d. Supernumerary kidney

10. The most common congenital anomaly of the urinary tract is:
    a. Horseshoe kidney
    b. Duplicated collecting system
    c. Renal agenesis
    d. Renal hypoplasia

11. A renal scar most likely appears as:
    a. A hypoechoic mass in the renal parenchyma
    b. A linear anechoic space in the renal cortex
    c. A hyperechoic, rounded structure within the renal pyramid that shadows
    d. A echogenic area that extends from the renal sinus through the renal parenchyma

12. What is the most common location of an ectopic kidney?
    a. Thoracic cavity
    b. Pelvis
    c. Contralateral fossa
    d. Left upper quadrant

13. All of the following are clinical findings of ARF except:
    a. Hematuria
    b. Hypertension
    c. Oliguria
    d. Decreased BUN and creatinine

14. Which of the following is true regarding a duplex collecting system with complete ureteral duplication?
    a. The upper pole of the kidney suffers from reflux.
    b. The lower pole suffers from obstruction because of a varicocele.
    c. The upper pole suffers from obstruction because of a ureterocele.
    d. The lower pole suffers from deflux and hypertrophy.

15. Which of the following is the most common cause of CRF?
    a. Hypertension
    b. Diabetes mellitus
    c. ARPKD
    d. Acute tubular necrosis

16. What renal cystic disease would be most likely caused by, and thus associated with hemodialysis?

a. MCDK
b. ADPKD
c. Acquired renal cystic disease
d. ARPKD

17. Sonographically, compared to normal kidneys, those affected by CRF will appear:
a. Normal in size with a decreased echogenicity
b. Smaller in size and hypoechoic
c. Larger in size and more echogenic
d. Smaller in size and more echogenic

18. Renal cysts that project out away from the kidney are termed:
a. Exophytic
b. Perapelvic
c. Cortical
d. Peripelvic

19. A female patient presents with a history of leukocytosis, dysuria, lower abdominal pain, and hematuria. Sonographically, the kidneys appear normal, although the bladder wall measures 6 mm in the distended state. What is the most likely diagnosis?
a. Glomerulonephritis
b. Xanthogranulomatous pyelonephritis
c. Cystitis
d. TCC of the bladder

20. The inherited disorder associated with the development of tumors of the central nervous system and orbits, renal cysts, and adrenal tumors is:
a. Tuberous sclerosis
b. Tuberculosis
c. von Hippel–Lindau syndrome
d. MCDK

21. What is the most likely location of TCC in the kidney?
a. Cortex
b. Medulla
c. Minor calyx
d. Renal pelvis

22. Which of the following is the most common cause of ARF?
a. Hypertension
b. Diabetes mellitus

c. ARPKD
d. Acute tubular necrosis

23. All of the following are characteristics of a complex cyst except:
a. Internal echoes
b. Smooth walls
c. Mural nodules
d. Septations

24. Which of the following renal findings would most likely present with a clinical finding of hematuria?
a. Hemorrhagic renal cyst
b. Milk of calcium renal cyst
c. Simple renal cyst
d. Angiomyolipoma

25. Which of the following would be considered the most common solid renal mass?
a. Renal hematoma
b. Angiomyolipoma
c. Oncocytoma
d. Hypernephroma

26. Infantile polycystic kidney disease may also be referred to as:
a. ARPKD
b. ADPKD
c. MCDK
d. Acquired renal cystic disease

27. Which of the following best describes the sonographic appearance of a kidney affected by ARPKD?
a. Bilateral enlarged, echogenic kidneys
b. Unilateral, smooth-walled, noncommunicating cysts of varying sizes located within the renal fossa
c. Small, echogenic kidneys
d. Numerous, large, complex renal cysts

28. The systemic disorder associated with epilepsy that leads to the development of solid tumors in various organs, including angiomyolipomas of the kidneys, is:
a. Tuberous sclerosis
b. Tuberculosis
c. von Hippel–Lindau syndrome

d. MCDK

29. What is the most common clinical finding of a simple renal cyst?
    a. Hematuria
    b. Quadrant pain
    c. Elevated BUN
    d. Asymptomatic

30. Suspicion of cortical thinning should occur when the renal cortex measures:
    a. Greater than 2 mm
    b. Less than 1 cm
    c. Greater than 5 mm
    d. Less than 3 cm

31. Which of the following is not considered an extrinsic cause of hydronephrosis?
    a. Ureteral stricture
    b. Pregnancy
    c. Neurogenic bladder
    d. Uterine leiomyoma

32. Which of the following would be a common finding in a patient undergoing peritoneal dialysis?
    a. Hemorrhage
    b. Ascites
    c. Renal artery stenosis
    d. Renal vein thrombosis

33. The presence of purulent material within the renal collecting system is termed:
    a. Pylotosis
    b. Pyelonephritis
    c. Pyonephrosis
    d. Emphysematous pyelonephritis

34. The most common cause of fungal urinary tract infections is:
    a. *Candida albicans*
    b. RCC
    c. Renal tract obstruction
    d. Urolithiasis

35. Clinical findings of glomerulonephritis include all of the following

except:
a. Proteinuria
b. Throat infection
c. Azotemia
d. Hypercalcemia

36. Which of the following is not considered an intrinsic cause of hydronephrosis?
a. Ureterocele
b. Urethritis
c. Urolithiasis
d. Ureteropelvic junction obstruction

37. Clinical findings of nephrocalcinosis include all of the following except:
a. Urinary tract infections
b. Urinary calculi
c. Hyperparathyroidism
d. Weight loss

38. Which of the following renal conditions is associated with the development of cysts within the pancreas and liver?
a. ARPKD
b. ADPKD
c. MCDK
d. Acquired renal cystic disease

39. A stone that completely fills the renal pelvis is referred to as a:
a. Calculus granulosis
b. Staghorn calculus
c. Twinkle stone
d. Nephrocalcinotic calculus

40. What is the most common location for a urolithiasis to become lodged?
a. Ureteropelvic junction
b. Midureter
c. Urethra
d. Ureterovesicular junction

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8 The Adrenal Glands

Introduction

Normal structure and function of the adrenal glands are presented in this chapter. Additionally, both adult and pediatric abnormalities are discussed. It is important to have a thorough appreciation of the clinical history findings of patients who present with solid adrenal tumors because many of their sonographic findings overlap.

Key Terms

Addison disease—an endocrine disorder that results from hypofunction of the adrenal cortex

adrenal adenoma—benign solid mass located within the adrenal glands

adrenal cysts—benign simple cysts located within the adrenal glands

adrenal rests—accessory adrenal gland tissue

adrenocorticotropic hormone—hormone secreted by the anterior pituitary gland, which controls the release of hormones by the adrenal glands

anoxia—lack of oxygen supply to the body, organ, or tissue

buffalo hump—excessive amount of fat on the back between the shoulders

congenital adrenal hyperplasia—a group of disorders in which there is a deficiency of cortisol production by the adrenal glands, although other hormones produced by the adrenal may be deficient as well

Conn syndrome—a syndrome caused by a functioning tumor within the

adrenal cortex that produces excessive amounts of aldosterone

crus of the diaphragm—a tendinous structure that extends from the diaphragm to the vertebral column; there are two crura (plural for crus), a right crus and a left crus

Cushing disease—the presence of a brain tumor in the pituitary gland that increases the release of adrenocorticotropic hormone resulting in Cushing syndrome

Cushing syndrome—a syndrome that results from an anterior pituitary gland or adrenal tumor that causes overproduction of cortisol by the adrenal glands

endocrine glands—glands that release their hormones directly into the bloodstream

Gerota fascia—the fibrous envelope of tissue that surrounds the kidney and adrenal gland

hirsutism—excessive hair growth in women in areas where hair growth is normally negligible

hypercortisolism—high levels of cortisol in the blood

hyperkalemia—high levels of potassium in the blood

hypernatremia—high levels of sodium in the blood

hyperpigmentation—the darkening of the skin

hypertension—high blood pressure

hypokalemia—low levels of potassium in the blood

hyponatremia—low levels of sodium in the blood

neuroblastoma—malignant tumor that can occur within the adrenal gland and anywhere within the sympathetic nervous system

pheochromocytoma—a hyperfunctioning, benign adrenal mass that causes the adrenal gland to release excessive amounts of epinephrine and norepinephrine into the blood stream leading to uncontrollable hypertension

striae—stretch marks

suprarenal glands—another name for the adrenal glands

tachycardia—abnormally rapid heart rate

ANATOMY AND PHYSIOLOGY OF THE ADRENAL GLANDS

The paired adrenal glands, which are controlled by hormones produced by the hypothalamus, and subsequently the anterior pituitary gland, are retroperitoneal endocrine glands (Table 8-1; Fig. 8-1). This complex

feedback system is referred to as the hypothalamic–pituitary–adrenal axis. The hypothalamus controls the release of adrenocorticotropic hormone (ACTH) by the anterior pituitary gland, which in turn controls the release of hormones by the adrenal glands.

Each gland is composed of a medulla and a cortex. The cortex is the outer part of the adrenal gland. It is composed of three zones: zona glomerulosa, zona fasciculata, and zona reticularis. Among the hormones produced by the cortex is aldosterone (Tables 8-2 and 8-2). Aldosterone is responsible for regulating blood pressure by controlling the amounts of sodium and water in the body. The cortex also produces androgenic hormones, which play a part in the development of male characteristics, and cortisol, which controls the body's use of fat, carbohydrates, and protein. The inner part of the adrenal glands, the medulla, produces epinephrine and norepinephrine. Epinephrine may also be referred to as adrenaline, and it is the primary hormone produced by the medulla. Both epinephrine and norepinephrine are responsible for the "flight-or-fight" response. Like the kidneys, the adrenal glands are enclosed in the Gerota fascia.



SOUND OFF

The adrenal glands are endocrine glands that are controlled by the release of ACTH by the anterior pituitary gland.

TABLE 8-1 Location of the adrenal glands

Location of Right Adrenal Gland	Location of Left Adrenal Gland
1. Posterior and right lateral to the inferior vena cava	1. Medial to the upper pole of the left kidney
2. Medial to the right lobe of the liver	2. Superior segment is located posterior to the lesser sac
3. Lateral to the **crus of the diaphragm**	3. Inferior segment is located posterior and lateral to the pancreas

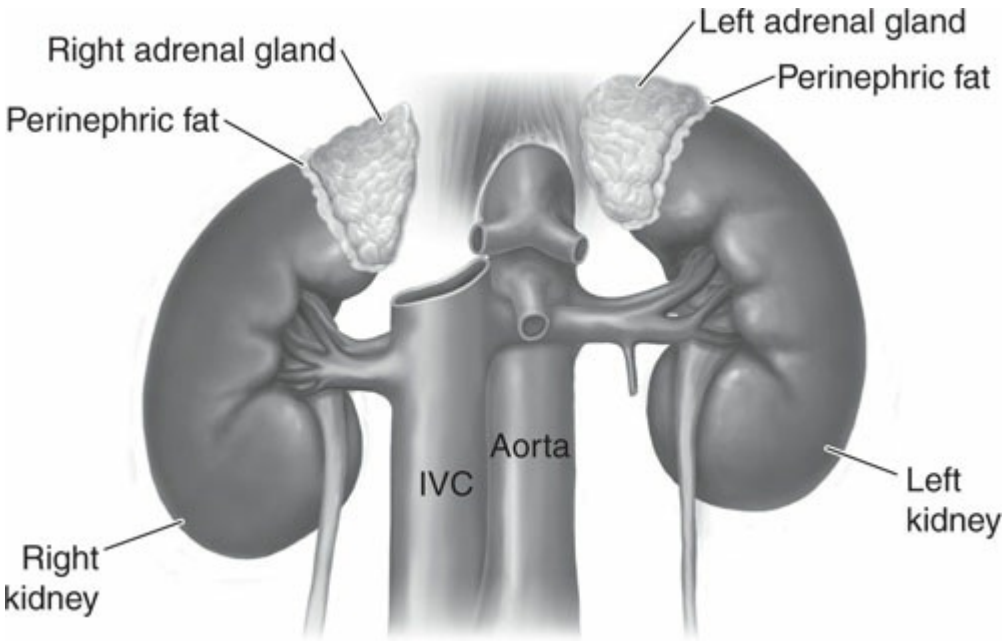


Figure 8-1 Position of the adrenal glands.

TABLE 8-2 Hormones of the adrenal cortex
Aldosterone: responsible for regulating blood pressure by controlling the amounts of sodium and water in the body
Androgens: minimal impact on the development of male characteristics
Cortisol (hydrocortisone): glucose metabolism, blood pressure regulation, immune function, inflammatory response

TABLE 8-3 Hormones of the adrenal medulla
Epinephrine (adrenaline): accelerates heart rate, increasing blood pressure, opens airways in the lungs, narrows blood vessels in the skin and intestine to increase blood flow to major muscle groups
Norepinephrine: accelerates heart rate, increases blood pressure, contracts blood vessels

Vascular Anatomy of the Adrenal Glands

The adrenal glands may also be referred to as the suprarenal glands. They receive their blood supply by means of three arteries: the suprarenal branches of the inferior phrenic arteries, the suprarenal branches of the aorta, and the suprarenal branches of the renal arteries. Venous drainage is performed by means of the suprarenal veins. The right suprarenal vein drains directly into the inferior vena cava (IVC), whereas the left suprarenal vein drains into the left renal vein (Fig. 8-2).

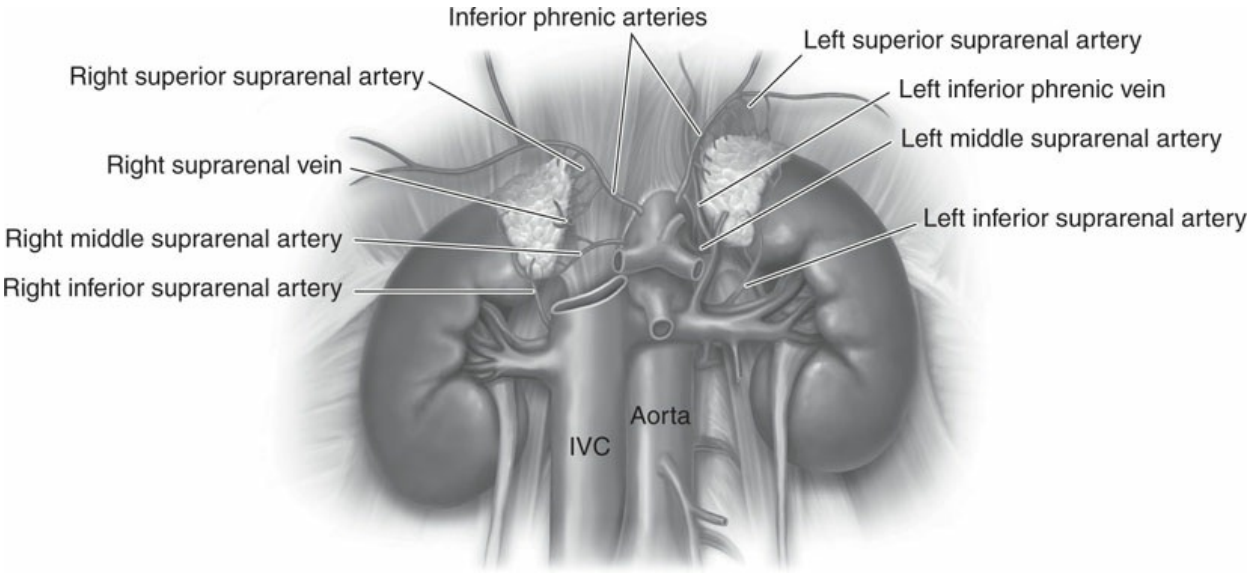


Figure 8-2 Vascular anatomy of the adrenal glands.

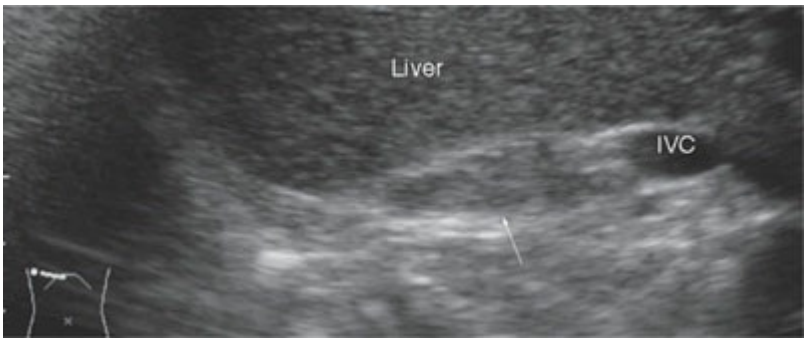


Figure 8-3 Sonographic appearance of the normal adrenal gland. The normal right adrenal gland (*arrow*) is noted in this patient in the transverse plane adjacent to the liver and inferior vena cava (*IVC*).

SONOGRAPHY OF THE ADRENAL GLANDS

Although not routinely identified in the adult patient secondary to surrounding adipose tissue, the normal adrenal glands are often easily visualized in the fetus and in the pediatric patient as hypoechoic structures anterior, medial, and superior to the upper pole of each kidney (Fig. 8-3). Many of the pathologies discussed in this chapter may be incidentally discovered during an abdominal sonogram.

ADRENAL PATHOLOGY

Addison Disease

Addison disease, also referred to as primary adrenocortical insufficiency or chronic primary hypoadrenalism, is an endocrine disorder that results from the hypofunction of the adrenal cortex. Addison disease can be idiopathic,

but it can also be caused by an autoimmune disorder, infection, or tuberculosis. With Addison disease, the cortex inadequately secretes corticosteroids resulting from partial or complete destruction of the adrenal glands. Clinical findings include an increase in the production of ACTH by the pituitary gland, hypotension, weakness and fatigue, loss of appetite and weight loss, and bronzing of the skin—termed hyperpigmentation. Addison disease can also cause elevated liver enzymes, hyperkalemia, and hyponatremia. Although computed tomography is the modality of choice for the diagnosis of Addison disease, the hemorrhagic, enlarged appearance of the adrenal glands in the acute stages of the disease could possibly be noted with sonography. The chronic form of the disease typically leads to an atrophic and calcified gland.



SOUND OFF

Addison disease can be caused by an autoimmune disorder, infection, or tuberculosis and is associated with hyperkalemia, hyponatremia, and bronzing of the skin.

CLINICAL FINDINGS OF ADDISON DISEASE

1. Hypotension
2. Weakness and fatigue
3. Loss of appetite and weight loss
4. Bronzing of the skin (hyperpigmentation)
5. Elevated liver enzymes
6. Hyperkalemia (high levels of potassium)
7. Hyponatremia (low levels of sodium)
8. Increased ACTH

SONOGRAPHIC FINDINGS OF ADDISON DISEASE

1. Enlarged appearance of the adrenal glands in the acute stages of the disease
2. Atrophic or calcified gland in the chronic stage (may be difficult to identify sonographically)

Cushing Syndrome

Cushing syndrome can result from a tumor in the anterior pituitary gland (Cushing disease) or an adrenal tumor that cause an increase in cortisol secretion by the adrenal cortex—termed hypercortisolism. Cortisol plays an important role in glucose metabolism, blood pressure regulation, immune function, and inflammatory response. This syndrome can be associated with a benign tumor that leads to the overproduction of cortisol by the adrenal

glands. The tumor is often located within the adrenal gland (most likely an adrenal adenoma) or within the pituitary gland. Patients can present with a number of ailments, including a buffalo hump, obesity, moon-shaped face, thinning arms and legs, poor wound healing, hypertension, red or purple striae over the abdomen and thighs, hirsutism, hyperglycemia, and severe fatigue (Fig. 8-4).

SOUND OFF

Cushing syndrome is the result of the overproduction of cortisol by the adrenal cortex and is associated with moon-shaped face, buffalo hump, and hypertension.

CLINICAL FINDINGS OF CUSHING SYNDROME

1. Obesity
2. Thinning arms and legs
3. Hypertension
4. Hirsutism
5. Hyperglycemia
6. Severe fatigue
7. Poor wound healing
8. Buffalo hump
9. Moon-shaped face
10. Red or purple striae over the abdomen and thighs

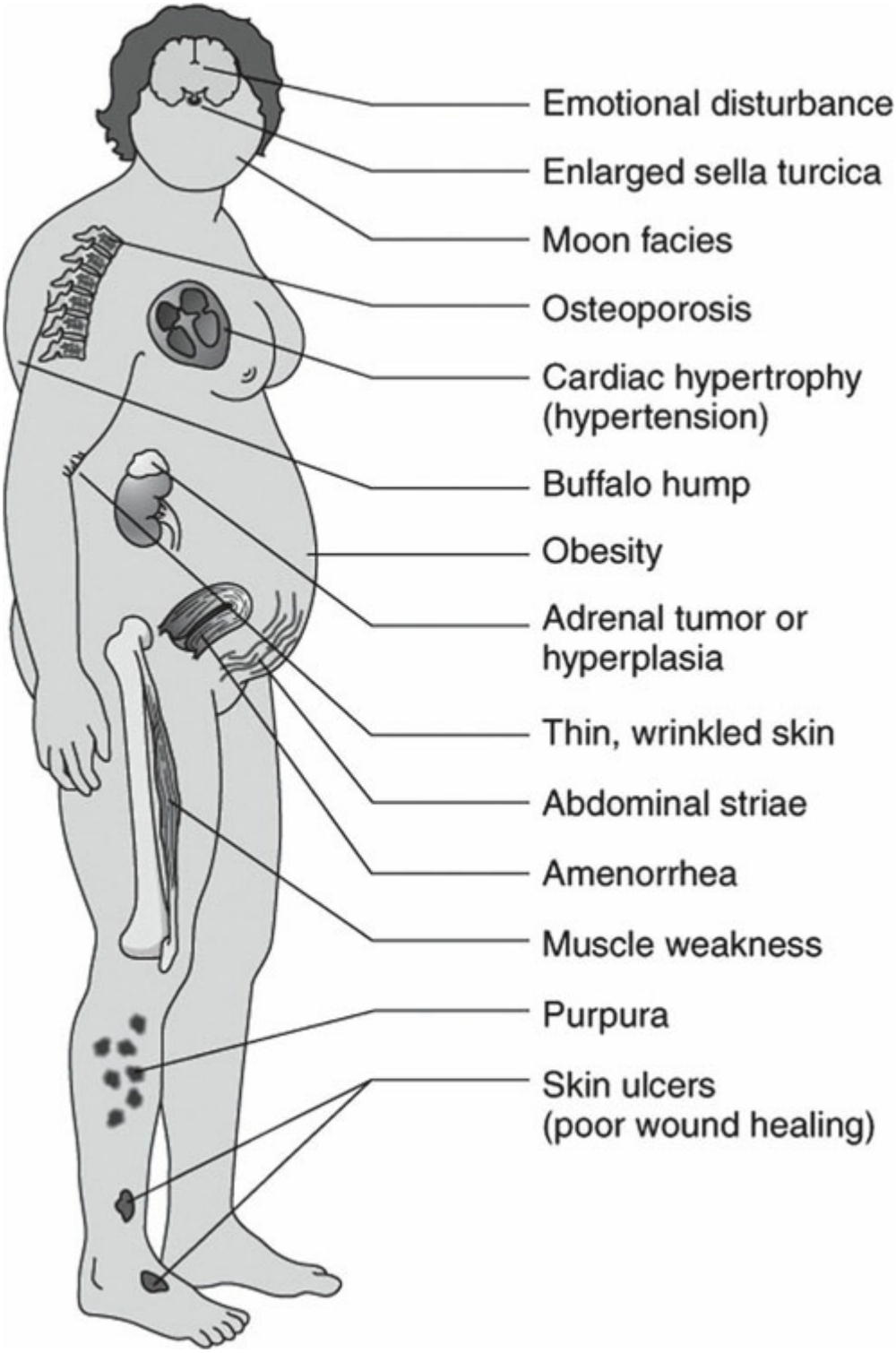


Figure 8-4 Clinical findings of Cushing syndrome.

SONOGRAPHIC FINDINGS OF CUSHING SYNDROME

1. Possible identification of an adrenal mass (most likely an adrenal adenoma)

Conn Syndrome

Conn syndrome, also referred to as primary hyperaldosteronism, results from high levels of aldosterone secretion by the adrenal cortex. Aldosterone is

responsible for regulating blood pressure by controlling the amount of sodium and water in the body. Conn syndrome, like Cushing syndrome, can be caused by a functioning tumor within the adrenal cortex—most likely a benign, aldosterone-producing adrenal adenoma—that causes the adrenal gland to produce excessive amounts of aldosterone. Patients typically present with hypertension, excessive thirst, excessive urination, high levels of sodium in the blood (hypernatremia), and low levels of potassium in the blood (hypokalemia). As a result of low-potassium level, patients often complain of muscle cramps and weakness.

CLINICAL FINDINGS OF CONN SYNDROME

1. Hypertension
2. Excessive thirst
3. Excessive urination
4. High levels of sodium in the blood (hypernatremia)
5. Low levels of potassium in the blood (hypokalemia)
6. Muscle cramps and weakness

SONOGRAPHIC FINDINGS OF CONN SYNDROME

1. Possible identification of an adrenal mass (most likely an adrenal adenoma)



SOUND OFF

Conn syndrome results from high levels of aldosterone secretion by the adrenal cortex.

Adrenal Adenoma

The adrenal adenoma is the most common benign solid mass of the adrenal gland. It can be either hyperfunctioning or nonhyperfunctioning. Hyperfunctioning adenomas are often seen in patients suffering from Cushing syndrome or Conn syndrome. Sonographically, an adrenal adenoma will most often appear as a solid, hypoechoic mass in the area of the adrenal gland (Fig. 8-5). Computed tomography or magnetic resonance imaging may be needed to differentiate this mass from masses arising from the liver or kidneys.

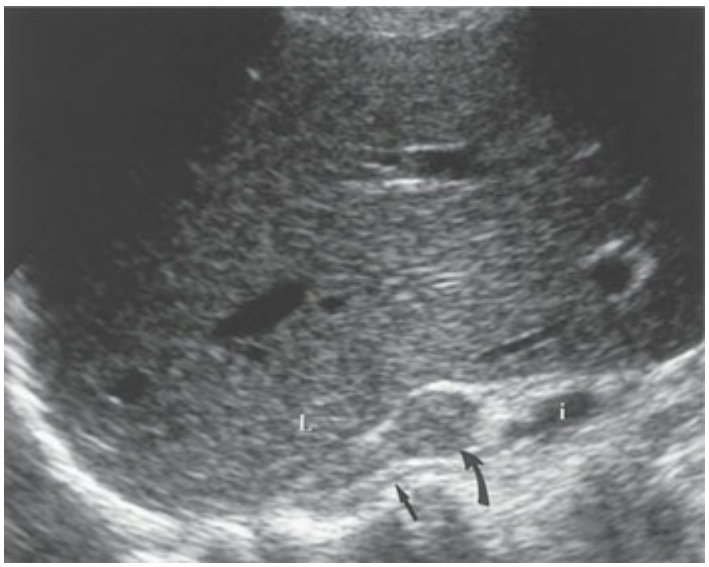


Figure 8-5 Adrenal adenoma. Transverse image showing a well-defined, small focal bulge (*curved arrow*) in the right adrenal gland. The adjacent landmarks include the inferior vena cava (*i*), the right lobe of the liver (*L*), and the right crus of the diaphragm (*straight arrow*).

CLINICAL FINDINGS OF ADRENAL ADENOMAS

1. Signs and symptoms of Cushing syndrome
2. Signs and symptoms of Conn syndrome
3. May be asymptomatic

SONOGRAPHIC FINDINGS OF ADRENAL ADENOMAS

1. Solid, hypoechoic mass in the area of the adrenal gland

SOUND OFF
Adrenal adenomas can be found in patients suffering from Cushing syndrome or Conn syndrome.

Pheochromocytoma

As stated earlier, the adrenal glands play an important role in blood pressure regulation by secreting various hormones. The pheochromocytoma, which arises from the adrenal medulla, is typically a hyperfunctioning, benign adrenal mass that causes the adrenal gland to release excessive amounts of epinephrine and norepinephrine into the blood stream, thus leading to uncontrollable hypertension. However, pheochromocytomas can be malignant. Other clinical complaints of patients who have a pheochromocytoma include headaches, tachycardia, tremors, anxiety, and excessive sweating. A pheochromocytoma may appear as a large,

hyperechoic mass in the area of the adrenal gland, but it can have various sonographic appearances, including hypoechoic or be diffusely heterogeneous (Fig. 8-6).

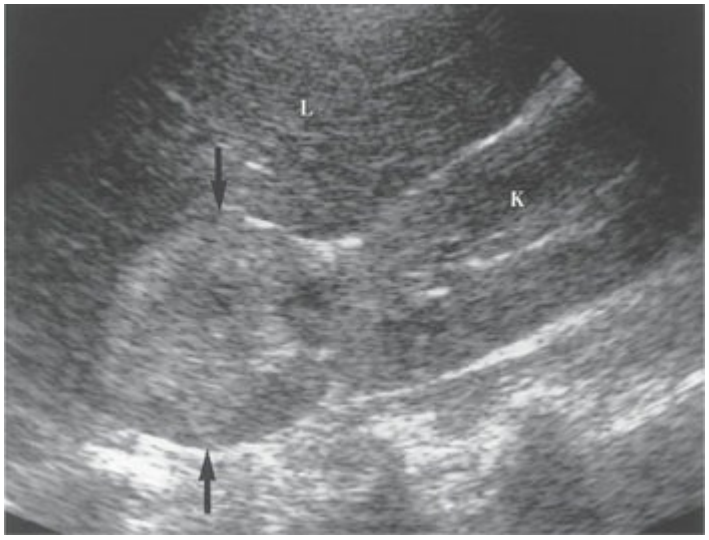


Figure 8-6 Pheochromocytoma. Longitudinal image of the liver (*L*) and right kidney (*K*) of a patient with severe hypertension revealing a heterogeneous, hyperechoic, solid right adrenal mass (*arrows*).

CLINICAL FINDINGS OF PHEOCHROMOCYTOMAS

1. Uncontrollable hypertension
2. Headaches
3. Tachycardia
4. Tremors
5. Anxiety
6. Excessive sweating

SONOGRAPHIC FINDINGS OF PHEOCHROMOCYTOMAS

1. Large, hyperechoic mass in the area of the adrenal gland
2. Can have various sonographic appearances including hypoechoic or diffusely heterogeneous

SOUND OFF

The pheochromocytoma is associated with uncontrollable hypertension.

Adrenal Cysts

Adrenal cysts may be noted in the area of the adrenal gland and can often be difficult to separate from the liver, spleen, or upper pole of the kidneys.

Simple cysts may be incidental findings with no clinical complaints provided. However, adrenal cysts that have a rim of calcification around them are much more worrisome for malignancy. Hemorrhage within an adrenal cyst, an infected cyst, and larger cysts may cause pain or other clinical symptoms. Sonographically, a simple adrenal cyst with be anechoic, round, and produce acoustic enhancement (Fig. 8-7).

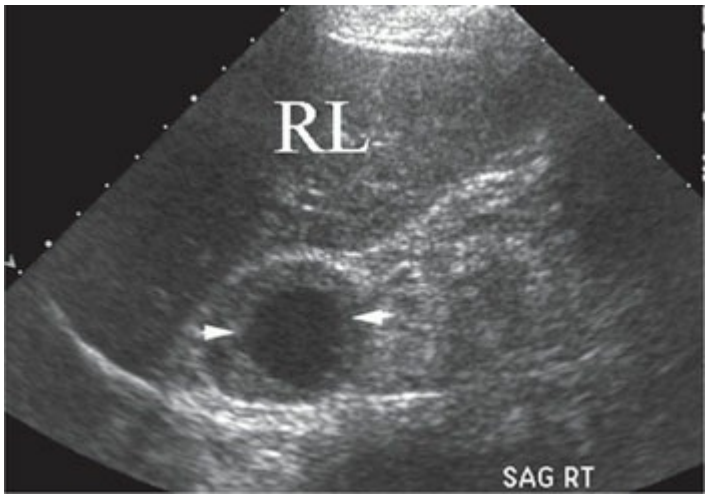


Figure 8-7 Adrenal cyst. A simple appearing cyst is noted within the right adrenal gland (*between arrowheads*). RL, right lobe of the liver.

CLINICAL FINDINGS OF ADRENAL CYSTS

1. Asymptomatic
2. Large, infected, or hemorrhagic cysts can cause pain

SONOGRAPHIC FINDINGS OF ADRENAL CYSTS

1. Anechoic
2. Round
3. Acoustic enhancement

Adrenal Rests

Accessory adrenal gland tissue, commonly referred to as adrenal rests, can be found within the testes, epididymis, ovaries, and inguinal canal. Adrenal rests disseminate during embryologic development and can form mass-like structures within the affected organs or structures. The cells are responsive to the secretion of ACTH by the pituitary gland. They are often associated with congenital adrenal hyperplasia and Cushing syndrome. More information about these masses can be found in Chapter 13.

SOUND OFF

In the male, adrenal rest tumors may be found in the testicles.

Adrenal Carcinoma and Metastasis

Primary adrenal carcinoma, such as adenocarcinoma, is rare. Malignant adrenal tumors will often produce the symptoms associated with Cushing syndrome because they may be functional tumors that impact hormones production. The adrenal glands are the fourth most common site of metastasis. Metastasis to the adrenal glands can originate in the lungs, breast, gastrointestinal tract, thyroid, pancreas, kidneys, or from lymphoma, leukemia, or melanoma. Specifically, there is a high probability that the primary sites are the lung, breast, or lymphoma in many patients. Cancer of the adrenal gland can have various sonographic appearances, including that of a solid, hypoechoic mass, thus mimicking sonographic appearance of the benign adrenal adenoma. Cortical cancers tend to be large and have the tendency to invade the adrenal vein and IVC (Fig. 8-8).

CLINICAL FINDINGS OF ADRENAL CARCINOMA

1. May mimic symptoms of Cushing syndrome

SONOGRAPHIC FINDINGS OF ADRENAL CARCINOMA

1. Solid, hypoechoic mass
2. Large, heterogeneous mass

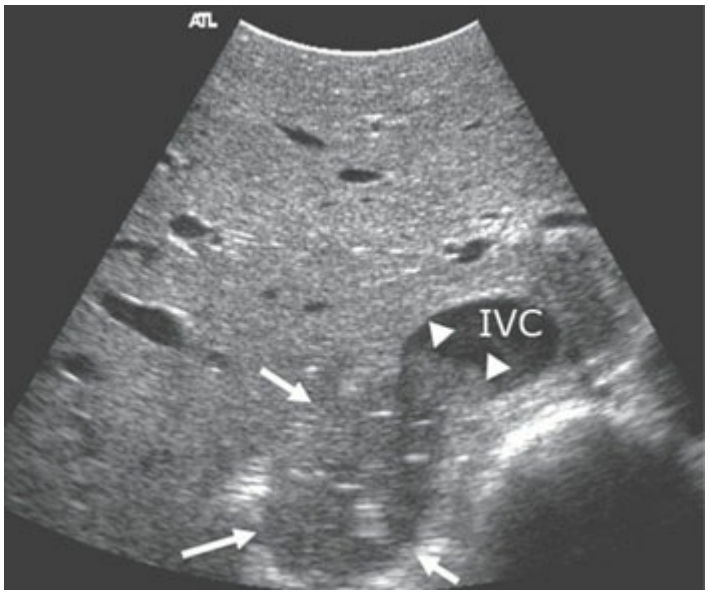


Figure 8-8 Adrenal gland carcinoma. A solid, irregular appearing mass is noted within the right adrenal gland (*arrows*) and extending into the inferior vena cava (*IVC*) (*arrowheads*).

PEDIATRIC ADRENAL PATHOLOGY

Neuroblastoma

The most common extracranial solid, malignant tumor in children is the neuroblastoma. Most patients will present with a palpable abdominal mass, abdominal pain, and bone pain, and metastasis is often present at the time of discovery. Neuroblastomas, which arise from the adrenal medulla, typically present before 5 years of age, with the median age of diagnosis being 22 months. A neuroblastoma will appear as a solid, large (average size is 8 cm), heterogeneous mass that typically contains calcifications and can spread around the IVC and aorta (Fig. 8-9). In cases of a suspected neuroblastoma, the liver and other abdominal organs should be closely examined for metastatic involvement.

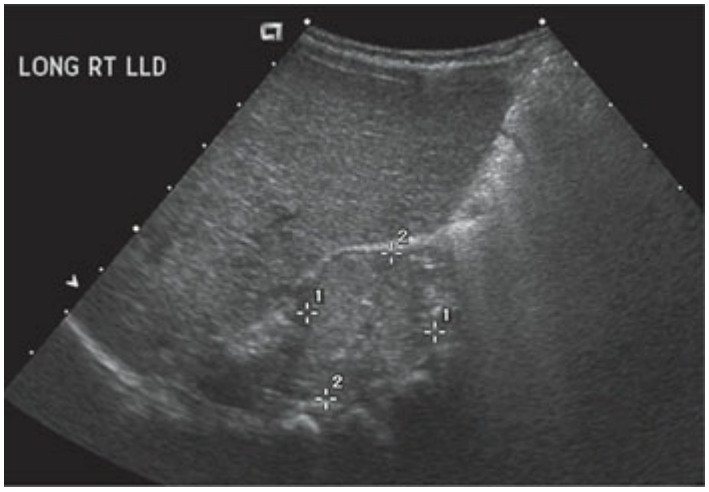


Figure 8-9 Neuroblastoma. This solid mass was proven to be a pediatric neuroblastoma. Coexisting liver metastasis was also present.

CLINICAL FINDINGS OF NEUROBLASTOMA

1. Palpable abdominal mass
2. Abdominal pain
3. Bone pain

SONOGRAPHIC FINDINGS OF NEUROBLASTOMA

1. Large, heterogeneous mass containing areas of calcification and hemorrhage located in the area of the adrenal gland
2. Metastasis often present at the time of discovery

SOUND OFF

The neuroblastoma is the most common extracranial solid, malignant

tumor in children.

Adrenal Hemorrhage

The adrenal glands, particularly in stressed neonates following a traumatic birth or perinatal anoxia, can spontaneously hemorrhage. This often results in a heterogeneous-appearing mass in the area of the adrenal gland (Fig. 8-10). The resulting hematoma will be rounded or triangular-shaped mass that appears echogenic during the acute stage, and with time it will become heterogeneous, hypoechoic, and cystic, and eventually completely resolve, although some residual calcifications may remain. Patients with adrenal hemorrhage will present with an abdominal mass, jaundice, anemia, and an acute drop in hematocrit and blood pressure.



Figure 8-10 Adrenal hemorrhage. Longitudinal image in a premature 30-week-gestation infant showing acute hemorrhage in the right adrenal gland (*curved arrow*). The right kidney (*arrowhead*) is compressed by the hemorrhage.

CLINICAL FINDINGS OF ADRENAL HEMORRHAGE

1. Abdominal mass
2. Jaundice
3. Anemia
4. Acute drop in hematocrit and blood pressure

SONOGRAPHIC FINDINGS OF ADRENAL HEMORRHAGE

1. Round or triangular-shaped mass in the area of the adrenal gland

2. Various sonographic appearances based on the age of hemorrhage
3. Echogenic during the acute stage
4. With time it will become heterogeneous, hypoechoic, and possibly cystic
5. Residual calcifications may remain following resolution of the hemorrhage

REVIEW QUESTIONS

1. An abdominal sonogram is requested for a new born in the intensive care unit. The new born is suffered from brief anoxia at birth and is now suffering from jaundice. Superior to the right kidney, you visualize a triangular-shaped, heterogeneous mass. What is the most likely diagnosis?
   a. Adrenal hemorrhage
   b. Adrenal adenoma
   c. Pheochromocytoma
   d. Cushing syndrome

2. All of the following are associated with Conn syndrome except:
   a. Adrenal adenoma
   b. Hypertension
   c. Excessive thirst
   d. Thinning arms and legs

3. When internal bleeding is suspected, what laboratory value is most useful for a sonographer to evaluate?
   a. Hematocrit
   b. Blood urea nitrogen
   c. Androgenic hormone
   d. Alkaline phosphatase

4. Which of the following mass-like lesions may be associated with congenital adrenal hyperplasia and found within the testes?
   a. Adrenal adenomas
   b. Adrenal rests
   c. Pheochromocytomas
   d. Neuroblastomas

5. The syndrome associated with hypertension, hyperglycemia, obesity, and an adrenal mass is:
   a. Edwards syndrome
   b. Cushing syndrome

c. Juliet syndrome
d. Hirschsprung syndrome

6. All of the following are true statements about the adrenal glands except:
   a. The adrenal glands are easily identified in the fetus.
   b. The adrenal glands are exocrine glands.
   c. The adrenal glands are composed of a medulla and cortex.
   d. The adrenal glands may also be referred to as the suprarenal glands.

7. The adrenal glands are surrounded by a connective tissue capsule called:
   a. Glisson capsule
   b. Adrenalocortical fascia
   c. Gerota fascia
   d. Glisson fascia

8. The left suprarenal vein drains directly into the:
   a. IVC
   b. Abdominal aorta
   c. Celiac trunk
   d. Left renal vein

9. Conn syndrome results from:
   a. Low levels of cortisol
   b. High levels of cortisol
   c. High levels of aldosterone
   d. Low levels of epinephrine

10. With active internal hemorrhage, the patient’s hematocrit will:
    a. Increase
    b. Decrease
    c. Become stable
    d. Not change

11. Which of the following would result in buffalo hump and moon-shaped face clinical findings?
    a. Conn syndrome
    b. Addison disease
    c. Adrogenism
    d. Hypercortisolism

12. Which types of glands release their hormones directly into the bloodstream?
    a. Endocrine glands

b. Exocrine glands

13. A localized collection of blood describes a:
    a. Hemangioma
    b. Hematoma
    c. Hypertoma
    d. Hydrocele

14. What is the cause of Cushing disease?
    a. Anterior pituitary gland tumor
    b. Adrenal hemorrhage
    c. Neuroblastoma
    d. Hyperaldosteronism

15. The arterial blood supply to the adrenal glands is accomplished by means of the:
    a. Celiac trunk
    b. Subphrenic arteries
    c. Suprarenal arteries
    d. Superior mesenteric artery

16. Which of the following has a clinical finding of bronzing of the skin?
    a. Addison disease
    b. Cushing disease
    c. Cushing syndrome
    d. Conn syndrome

17. Hyperfunctioning adrenal adenomas are associated with all of the following except:
    a. Cushing syndrome
    b. Conn syndrome
    c. Hypoechoic mass in the area of the adrenal gland
    d. Acute drop in hematocrit

18. Which of the following is also referred to as primary adrenocortical insufficiency?
    a. Conn syndrome
    b. Addison disease
    c. Cushing disease
    d. Congenital adrenal hyperplasia

19. The adrenal cortex produces all of the following except:
    a. Cortisol

b. Androgens
c. Aldosterone
d. Adrenaline

20. Which of the following is produced by the adrenal medulla?
    a. Cortisol
    b. Aldosterone
    c. Norepinephrine
    d. Androgens

21. What is the term for low levels of sodium in the blood?
    a. Hypokalemia
    b. Hypopigmentation
    c. Hyponatremia
    d. Hypodisuria

22. Which of the following hormones are responsible for the “flight-or-fight” response?
    a. Epinephrine and norepinephrine
    b. Cortisol and androgens
    c. Cortisol and aldosterone
    d. ACTH and aldosterone

23. Which of the following is associated with hyponatremia?
    a. Cushing syndrome
    b. Conn syndrome
    c. Pheochromocytoma
    d. Addison disease

24. Which of the following best describes the location of the right adrenal gland?
    a. Posterior and lateral to the pancreas
    b. Medial to the lower pole of the right kidney
    c. Posterior and lateral to the IVC
    d. Medial to the crus of the diaphragm

25. Upon sonographic examination of the right upper quadrant in a 32-year-old female patient complaining of generalized abdominal pain, you visualize an anechoic mass with posterior enhancement superior and medial upper pole of the right kidney. This most likely represents a(n):
    a. Adrenal metastatic lesion
    b. Pheochromocytoma
    c. Neuroblastoma

d. Adrenal cyst

26. The right suprarenal vein drains directly into the:
    a. IVC
    b. Abdominal aorta
    c. Celiac trunk
    d. Left renal vein

27. The adrenal mass often associated with uncontrollable hypertension, tachycardia, and tremors is the:
    a. Neuroblastoma
    b. Adrenal hematoma
    c. Oncocytoma
    d. Pheochromocytoma

28. A 45-year-old obese woman with thin arms and legs, hypertension, and severe fatigue presents to the ultrasound department for an abdominal sonogram. Based on these clinical findings, you should evaluate the adrenal glands closely for signs of:
    a. Addison cyst
    b. Adrenal hemorrhage
    c. Adrenal adenoma
    d. Neuroblastoma

29. The most common sonographic appearance of a pheochromocytoma is a(n):
    a. Hyperechoic mass
    b. Hypoechoic mass
    c. Anechoic mass
    d. Complex mass

30. The most common, extracranial, malignant mass in children is the:
    a. Hepatoblastoma
    b. Hypernephroma
    c. Pheochromocytoma
    d. Neuroblastoma

31. Which of the following is associated with hypernatremia?
    a. Cushing syndrome
    b. Conn syndrome
    c. Pheochromocytoma
    d. Addison disease

32. The most common sonographic appearance of a neuroblastoma is:
    a. Hyperechoic mass
    b. Heterogeneous mass with calcifications
    c. Anechoic mass
    d. Hypoechoic mass

33. The neuroblastoma typically presents before the age of:
    a. 1 year
    b. 2 years
    c. 4 years
    d. 5 years

34. Which hormone is responsible for regulating blood pressure by controlling the amounts of sodium and water in the body?
    a. Epinephrine
    b. Cortisol
    c. Aldosterone
    d. ACTH

35. Which hormone, secreted by the anterior pituitary gland, controls the release of hormones by the adrenal glands?
    a. Epinephrine
    b. Cortisol
    c. Aldosterone
    d. ACTH

36. All of the following are most likely a benign adrenal mass except:
    a. Adrenal adenoma
    b. Neuroblastoma
    c. Pheochromocytoma
    d. Adrenal hematoma

37. All of the following are clinical findings of a pheochromocytoma except:
    a. Bradycardia
    b. Uncontrollable hypertension
    c. Excessive sweating
    d. Tremors

38. Which plays a part in the development of male characteristics?
    a. Androgens
    b. Cortisol
    c. Aldosterone
    d. Hematocrit

39. The adrenal glands receive a portion of their blood supply from all of the following except the:
    a. Suprarenal branches of the inferior phrenic arteries
    b. Suprarenal branches of the aorta
    c. Suprarenal branches of the renal arteries
    d. Suprarenal branches of the celiac trunk

40. All of the following are true statements about the adrenal glands except:
    a. The adrenal glands play an important role in blood pressure regulation.
    b. The adrenal glands are easily identified in the fetus.
    c. The left adrenal gland is located lateral to the upper pole of the left kidney.
    d. The right adrenal gland is located medial to the right lobe of the liver.

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9

Abdominal Vasculature

Introduction

Although the abdominal sonographer may not be required to have vascular credentials, he or she must have a fundamental understanding of the key vascular structures found in the abdomen. This chapter offers an explicit structural anatomy review of the vascular components that are associated with the abdominal aorta, inferior vena cava (IVC), and portal venous system. Pathology of the abdominal aorta and IVC is also presented. Vascular abnormalities of abdominal organs can be found in the specific organ chapters in this text.

Key Terms

abdominal aortic aneurysm—enlargement of the diameter of the abdominal aorta to greater than 3 cm

aneurysm—any dilation of a blood vessel, whether focal or diffuse

atherosclerosis—a disease characterized by the accumulation of plaque within the walls of arteries

Budd–Chiari syndrome—a syndrome described as the occlusion of the hepatic veins, with possible coexisting occlusion of the inferior vena cava

embolism—a blockage caused by an abnormal mass (embolus) within the bloodstream that hinders circulation downstream, leading to tissue damage

endovascular aortic stent graft repair—nonsurgical method for treating abdominal aortic aneurysms

false aneurysm—a contained rupture of a blood vessel that is most likely secondary to the disruption of one or more layers of that vessel's wall

false lumen—the residual channel of a vessel created by the accumulation of a clot within that vessel

fusiform—shaped like a spindle; wider in the middle and tapering toward the ends

hepatopetal—blood flow toward the liver

high-resistance flow—the flow pattern that results from small arteries or arterioles that are contracted, which produces an increase in the resistance to blood flow to the structure that is being supplied

intimal flap—observation of the intimal layer of a vessel as a result of a dissection

IVC filter—vascular filter placed in the inferior vena cava to prevent pulmonary emboli

low-resistance flow—the flow pattern characterized by persistent forward flow throughout the cardiac cycle

Marfan syndrome—a disorder of the connective tissue characterized by tall stature and aortic and mitral valve insufficiency

mycotic aneurysm—an aneurysm caused by infection

postprandial—after a meal

pseudoaneurysm—see key term false aneurysm

pulmonary embolus—blood clot that has traveled to the lungs and is obstructing the pulmonary arterial circulation; most often the result of a deep venous thrombosis

saccular aneurysm—a saclike dilation of a blood vessel

small bowel ischemia—a condition resulting in interruption or reduction of the blood supply to the small intestines

thrombus—blood clot

transitional cell carcinoma—a malignant tumor of the urinary tract that is often found within the urinary bladder or within the renal pelvis

true aneurysm—the enlargement of a vessel that involves all three layers of the wall

true lumen—the true or original channel within a vessel

tunica adventitia—the outer wall layer of a vessel

tunica intima—the inner wall layer of a vessel

tunica media—the middle, muscular layer of a vessel

Wilms tumor—the most common solid malignant pediatric abdominal mass; a malignant pediatric renal mass that may also be referred to as

nephroblastoma

ANATOMY AND PHYSIOLOGY OF THE ABDOMINAL AORTA

The aorta, the largest artery in the body, originates at the left ventricle of the heart. The subdivision of the aorta within the chest is referred to as the thoracic aorta. Once the aorta passes through the aortic hiatus of the diaphragm, it is referred to as the abdominal aorta. It is retroperitoneal in location and positioned anterior to the spine, just left of the midline.

The wall of the aorta consists of three layers. The innermost layer, closest to the flowing blood, is the tunica intima. The middle layer, or muscular layer, is referred to as the tunica media. The outermost layer is the tunica adventitia and may also be referred to as the tunica externa (Fig. 9-1). The function of the abdominal aorta is to supply blood to the abdominal organs, pelvis, and lower extremities. The abdominal aorta has several important branches that are discussed in the following sections (Fig. 9-2). Most abdominal arteries are considered to have low-resistance flow, although some may have high-resistance flow at times (Figs. 9-3 and 9-4). The normal flow patterns of other pertinent abdominal arterial vessels are provided in Table 9-1.

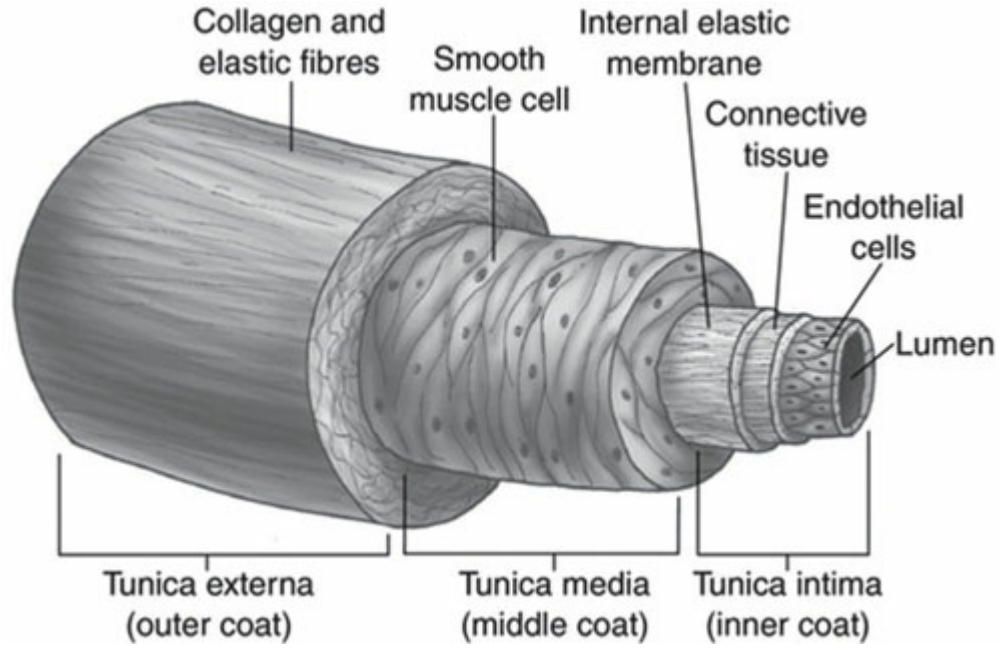


Figure 9-1 Layers of an artery. Note: The tunica externa is also referred to as the tunica adventitia.

Celiac Trunk

The celiac trunk may also be referred to as the celiac artery or celiac axis. It is the first main visceral branch of the abdominal aorta, and its branches supply blood to several vital abdominal organs. The celiac trunk arises from the anterior aspect of the abdominal aorta, between the crura of the diaphragm. It branches into three arteries: the splenic artery, the common hepatic artery, and the left gastric artery. The common hepatic artery and splenic artery are readily seen in the transverse scan plane. Combined with the celiac trunk, these vessels have a "seagull" or "T"-shaped appearance (Fig. 9-5). Because of its small size, the left gastric artery is not typically seen with sonography. Flow within the celiac artery should be continuous and forward, whereas abnormal flow will have elevated velocities (Fig. 9-6).

The splenic artery travels in the direction of the left side of the patient, toward the spleen. Its route is tortuous. It can often be noted along the superior margin of the pancreas and may be confused for the main pancreatic duct. To differentiate the two vessels, color Doppler will confirm the artery. The splenic artery enters the splenic hilum and branches further into smaller arteries. Low-resistance flow should be noted within the normal splenic artery.

The common hepatic artery travels in the direction of the right side of the patient, toward the liver. It branches into the gastroduodenal artery at the level of the pancreatic head. After this point, the common hepatic artery becomes the proper hepatic artery. The proper hepatic artery enters the liver at the porta hepatis and branches further into the right and left hepatic arteries. One significant branch of the right hepatic artery is the cystic artery, which supplies blood to the gallbladder. The hepatic artery should yield low-resistance and hepatopetal flow.

Superior Mesenteric Artery

The second main branch of the abdominal aorta is the superior mesenteric artery (SMA). The SMA typically originates along the anterior aspect of the abdominal aorta, just distal to the origin of the celiac trunk, although in some individuals the SMA and celiac originate at the same position. The SMA supplies blood to parts of the small intestines, some of the colon, and the pancreas. Sonographically, the SMA is readily identified by the echogenic fat layer surrounding it (Fig. 9-7). It is located posterior to the splenic vein and pancreas and left lateral to the superior mesenteric vein. The left renal vein should be noted posterior to the SMA and anterior to the abdominal aorta.

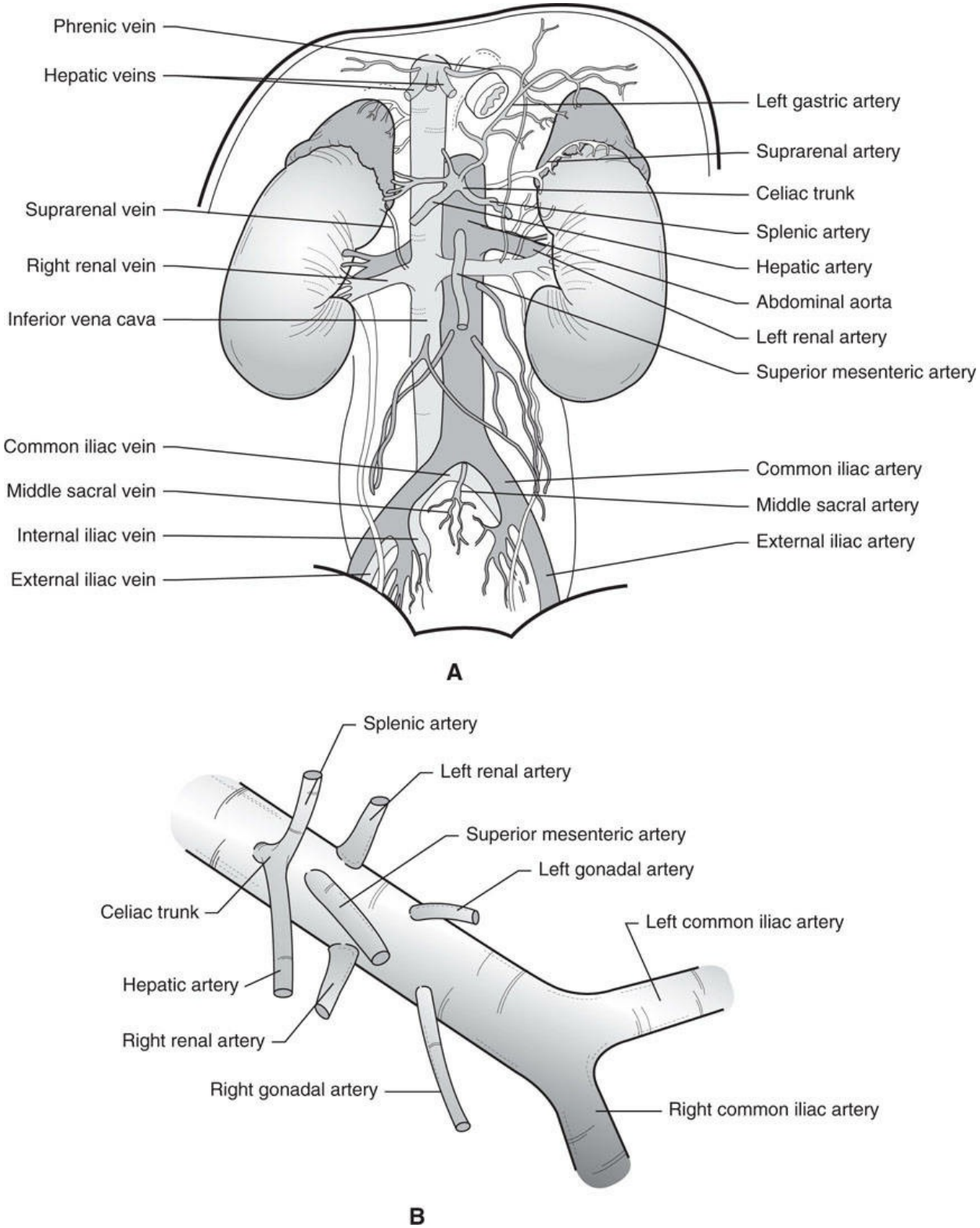


Figure 9-2 Abdominal vasculature. **A.** The abdominal aorta and inferior vena cava. **B.** The main branches of the abdominal aorta.

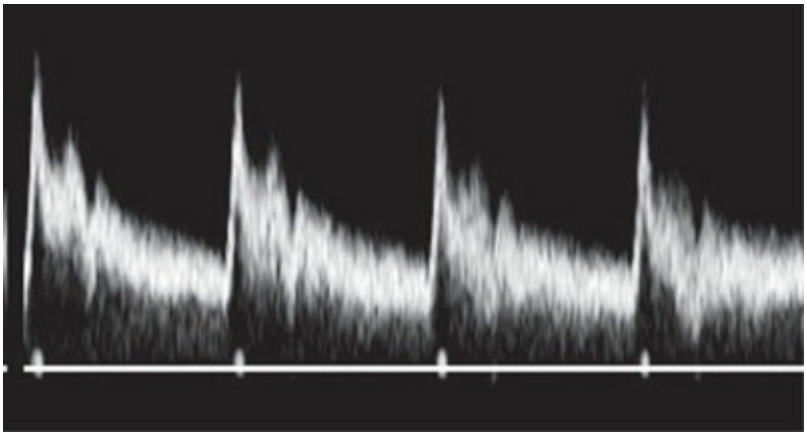


Figure 9-3 Low-resistance flow pattern.

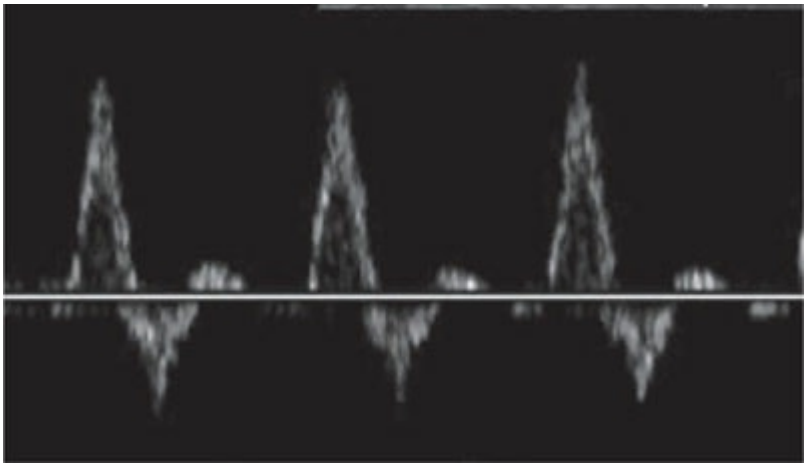


Figure 9-4 High-resistance flow pattern.

TABLE 9-1 Abdominal arteries and normal flow patterns

Abdominal Artery	Normal Flow Pattern
Abdominal aorta	Suprarenal aorta = low-resistance flow Infrarenal aorta = high-resistance flow
Celiac artery	Low-resistance flow
Common hepatic artery	Low-resistance flow
Common iliac artery	High-resistance flow
Splenic artery	Low-resistance flow
Superior mesenteric artery	Fasting patient = high-resistance flow postprandial (30–90 min) = low-resistance flow
Renal arteries	Low-resistance flow

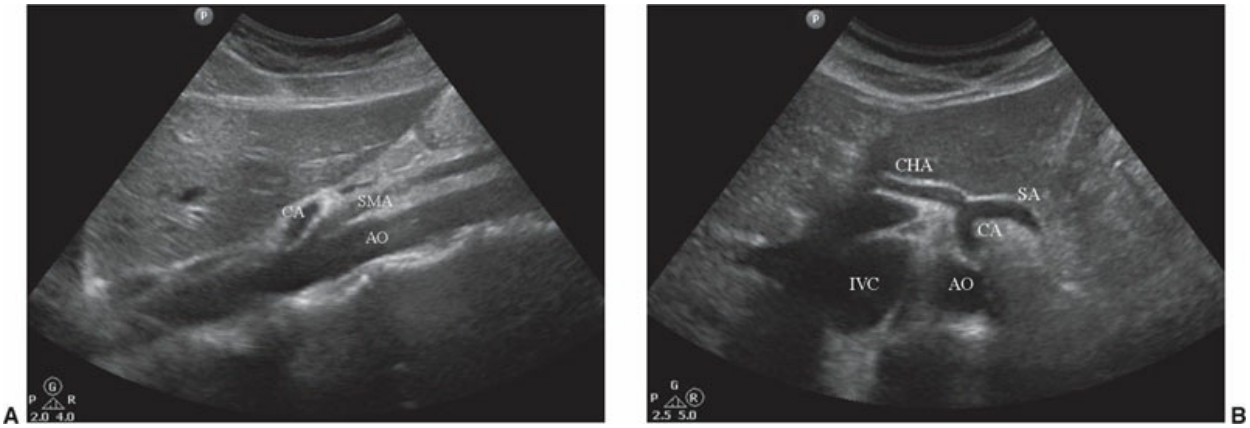


Figure 9-5 Celiac axis. **A.** In the longitudinal plane, the celiac artery (*CA*) can be seen branching from the anterior aorta (*AO*) proximal to the superior mesenteric artery (*SMA*). **B.** In the transverse plane, the CA can be seen branching from the abdominal aorta (*AO*) into the common hepatic artery (*CHA*) and splenic artery (*SA*). The inferior vena cava (*IVC*) can be noted right lateral to the aorta.

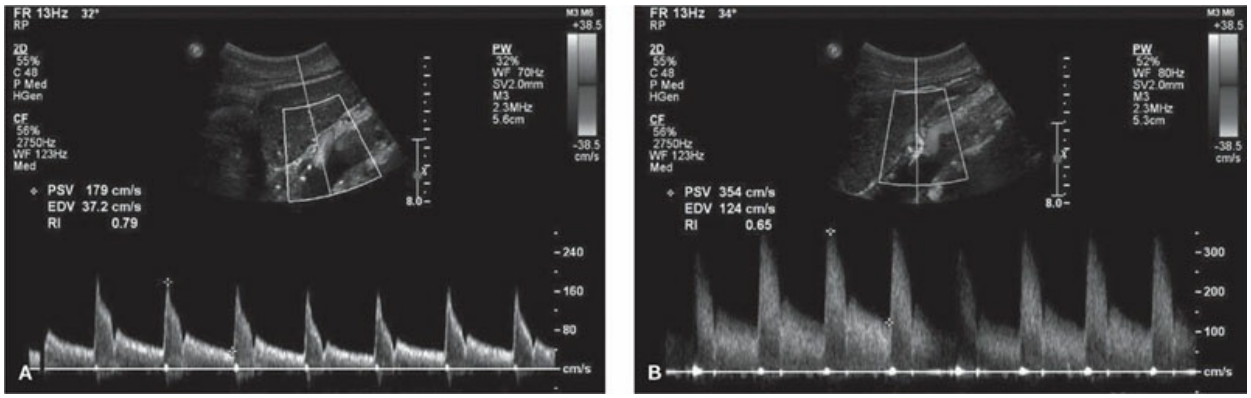


Figure 9-6 Normal and abnormal celiac artery. **A.** Normal flow within the celiac artery. **B.** Abnormal flow within the celiac artery reveals high velocities and abnormal waveforms. Color images provided online.

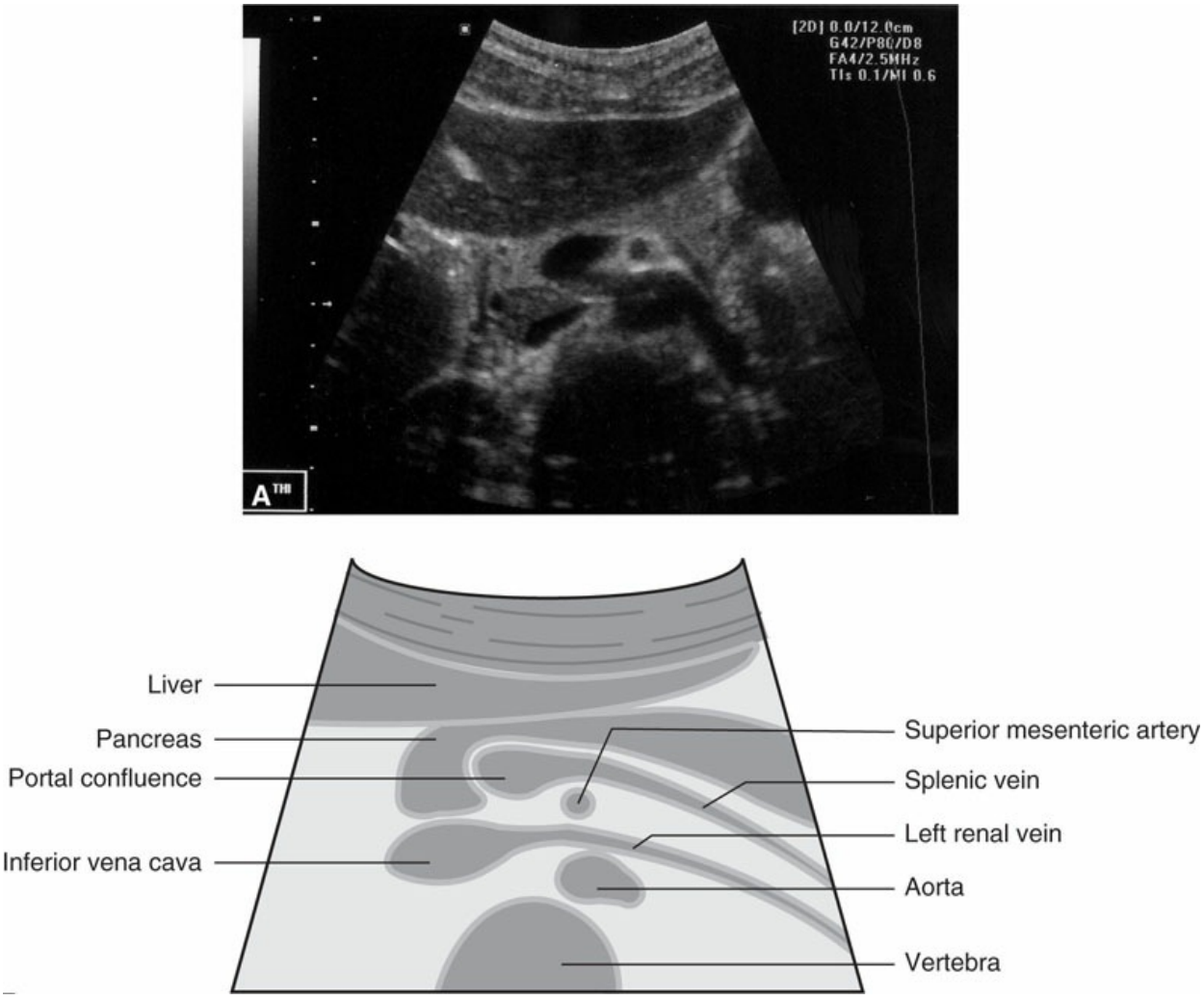


Figure 9-7 Superior mesenteric artery (SMA). Transverse view of the abdominal aorta at the level of the SMA.

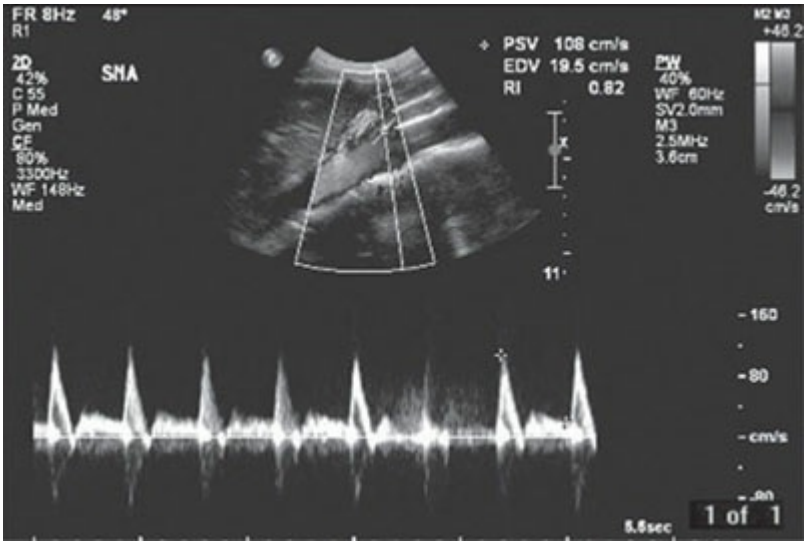


Figure 9-8 Duplex image of the superior mesenteric artery (*SMA*). A normal high-resistance pattern is demonstrated in the SMA. Color image provided online.

The SMA will exhibit high-resistance flow in the fasting patient (Fig. 9-8).

However, 30 to 90 minutes postprandial, the SMA will yield a low-resistance waveform. Sonography can aid in the diagnosis of small bowel ischemia. Patients with unexplained abdominal pain could be suffering from small bowel ischemia when this characteristic trend is not perceptible.

SOUND OFF
The SMA will exhibit high-resistance flow in the fasting patient. However, 30 to 90 minutes postprandial, the SMA will yield a low-resistance waveform.

Renal Arteries

The third main visceral branches of the abdominal aorta are the paired renal arteries. They arise just below the level of the SMA (Fig. 9-9). The right renal artery originates from the right anterolateral aspect of the aorta and travels posterior to the IVC on its way to the right renal hilum (Fig. 9-10). The left renal artery originates from the left anterolateral aspect of the aorta and travels posterior to the left renal vein as it progresses to the left renal hilum.

Because the aorta is located on the left side of the abdomen, the right renal artery is much longer than the left renal artery. Duplication of the renal arteries is common. Normal renal arteries typically demonstrate low-resistance flow. Pathology of the renal arteries is discussed in Chapter 7.

SOUND OFF
In the sagittal plane, the right renal artery may be identified as an anechoic circle posterior to the IVC.

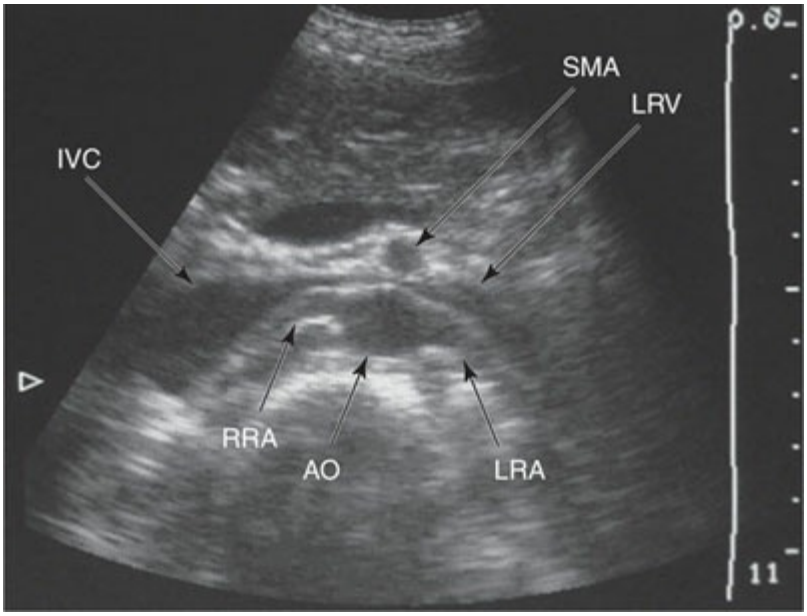


Figure 9-9 Renal arteries. Transverse image of the renal arteries revealing the inferior vena cava (*IVC*), superior mesenteric artery (*SMA*), abdominal aorta (*AO*), right renal artery (*RRA*), left renal artery (*LRA*), and the left renal vein (*LRV*).

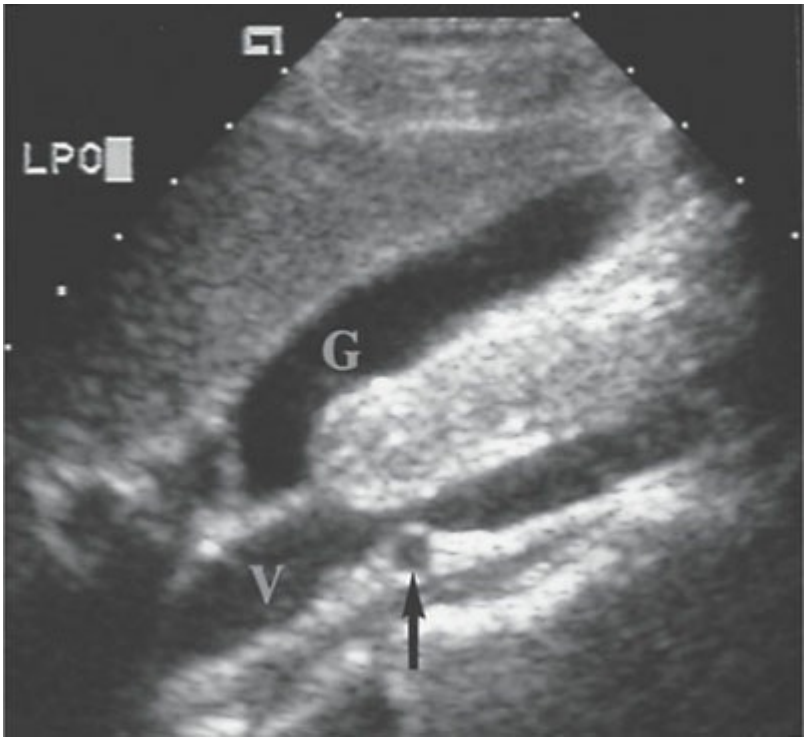


Figure 9-10 Right renal artery. Longitudinal image of the inferior vena cava (*V*) showing the right renal artery (*arrow*) crossing behind the cava. *G*, gallbladder.

Gonadal Arteries

The fourth branches, the gonadal arteries, arise from the anterior surface of the abdominal aorta, just below the renal artery level. Depending on the gender of the patient, they should be explicitly referred to as the testicular or ovarian arteries. They are not generally imaged with sonography.



Figure 9-11 Proximal abdominal aorta sonogram. An image demonstrating the normal tapering of the abdominal aorta as it travels distally.

Inferior Mesenteric Artery

The inferior mesenteric artery (IMA) arises from the anterior surface of the abdominal aorta. It supplies blood to the transverse colon, descending colon, and rectum. The IMA may be difficult to image with sonography, but may be seen in some slender patients.

Iliac Arteries

The aorta bifurcates at or near the level of the umbilicus. This point marks the origin of the right and left common iliac arteries. Color-flow Doppler may be used to identify this bifurcation.

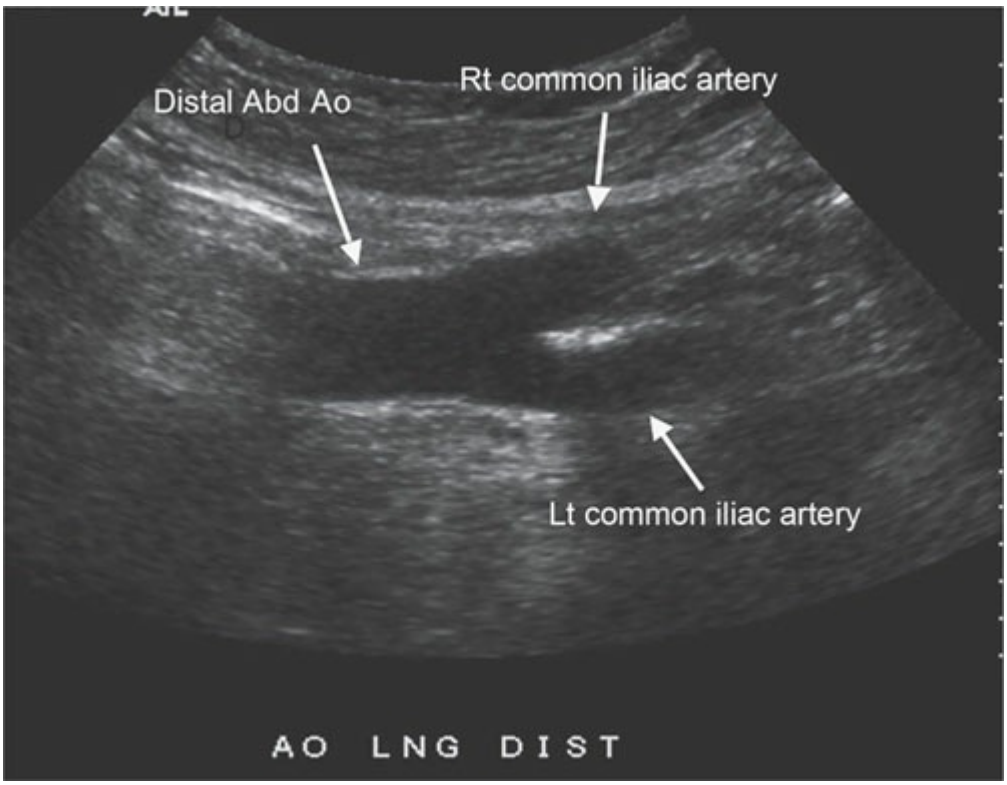


Figure 9-12 Aortic bifurcation. An image demonstrating the normal bifurcation of the abdominal aorta with both the right and left common iliac arteries visualized.

SONOGRAPHY OF THE ABDOMINAL AORTA

The sonographic assessment of the abdominal aorta may be inhibited by gas or patient body habitus. Patient fasting can aid in evaluating the abdominal aorta with sonography. Applying transducer pressure or scanning from the left side could possibly improve visualization of the abdominal aorta in some patients as well. The normal aorta will be larger in diameter just below the diaphragm and progressively taper as it approaches the umbilicus. The aorta will also gradually be located more anteriorly in the abdomen as it travels away from the diaphragm (Fig. 9-11).

The upper normal limit of the abdominal aorta just below the diaphragm is 2.5 cm in diameter. In the midabdomen, it will measure 2.0 cm or less, and the distal aorta should not exceed 1.8 cm. The common iliac arteries, which typically measure between 8 mm and 10 mm, are considered aneurysmal if their diameter exceeds 2.0 cm (Fig. 9-12). Normally, the spectral waveform of the proximal aorta superior to the abdominal visceral branches is considered low resistance, whereas the distal abdominal aorta is typically high resistance. In fact, the normal spectral Doppler findings of the infrarenal aorta should show a triphasic, high-resistant flow pattern with reversal of flow in early diastole.

SOUND OFF
Normally, the spectral waveform of the proximal aorta superior to the abdominal visceral branches is considered low resistance, whereas the distal abdominal aorta is typically high resistance.

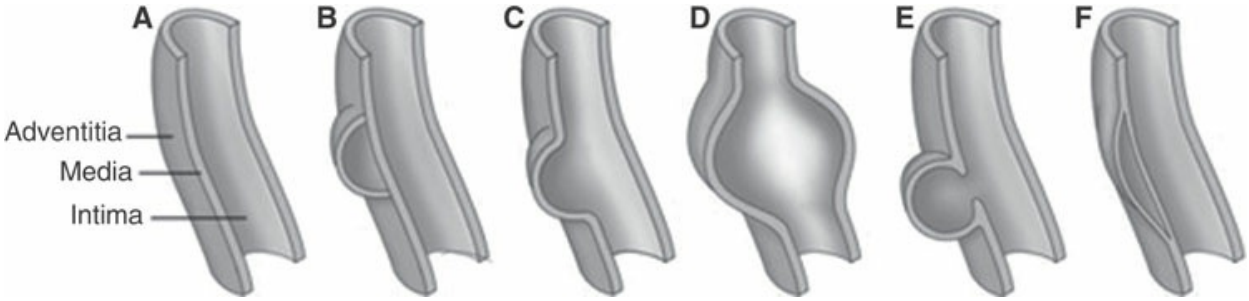


Figure 9-13 Types of abdominal aortic aneurysms. **A.** Normal artery. **B.** False aneurysm or pseudoaneurysm. **C.** True aneurysm. **D.** Fusiform aneurysm. **E.** Saccular aneurysm. **F.** Dissecting aneurysm.

PATHOLOGY OF THE ABDOMINAL AORTA AND PSEUDOANEURYSMS

Abdominal Aortic Aneurysm

Any dilation of a blood vessel, whether focal or diffuse, is referred to as an aneurysm (Fig. 9-13). An aneurysm results from the weakening of the vessel wall. It can be described by the wall layers of the vessel that are affected. A true aneurysm involves all three layers of the vessel wall. Most abdominal aortic aneurysms (AAAs) are true aneurysms.

An AAA is present when the diameter of the abdominal aorta exceeds 3 cm. The most common shape of an AAA is fusiform. A fusiform aneurysm is one that has a gradual enlargement (Fig. 9-14). Aneurysms may also be saccular, which is described as the sudden dilation of a vessel. A saccular aneurysm is often spherical and can be fairly large. Other aneurysmal shapes include berry, bulbous, eccentric, and dumbbell.

SOUND OFF
An AAA is present when the diameter of the abdominal aorta exceeds 3 cm.

The most common location of an AAA is infrarenal. Determination of whether the renal arteries are involved in the aneurysm is vital because perfusion of the kidneys may be compromised. Distal aneurysm may also include the iliac arteries. Although the source of many AAAs is unknown,

atherosclerosis has been cited as the most common cause of aneurysms in the United States. Aneurysms of the abdominal aorta have also been associated with Marfan syndrome, syphilis, familial inheritance, and infection. An aneurysms caused by infection is referred to as a mycotic aneurysm. Although many patients who have an AAA have no symptoms, clinical findings may include evidence of a pulsatile abdominal mass, abdominal bruit, back pain, abdominal pain, or lower extremity pain.

Sonographically, an AAA is present when the abdominal aorta measures greater than 3 cm in diameter. The lumen may contain mural thrombus and varying amounts of calcification at the time of detection. The true lumen can be evaluated in contrast to the false lumen. The true lumen denotes the actual lumen of the aorta, including the thrombus, whereas the false lumen is the opening available after the narrowing from the thrombus has occurred (Fig. 9-15). Complications of an AAA include distal embolism, infection, dissection, and rupture. The AAA may include dilation of the iliac vessels as well.

Treatment for an AAA includes open surgery and endovascular aortic stent graft repair (EVAR). Sonographically, an aortic graft will appear to have hyperechoic walls that are much brighter than the normal aortic walls (Fig. 9-16). The EVAR is delivered to the aorta by means of accessing the common femoral artery under angiographic guidance. The sonographic evaluation of the EVAR is for signs of patency or possibly an endoleak. An endoleak results from the failure of the graft to isolate the aneurysm from circulation, resulting in flow disturbances and a propensity for aortic rupture. There are several types of EVAR, including a straight tube graft, bifurcated tube graft, and uni-iliac graft. Normal spectral Doppler characteristics within the graft are considered triphasic.

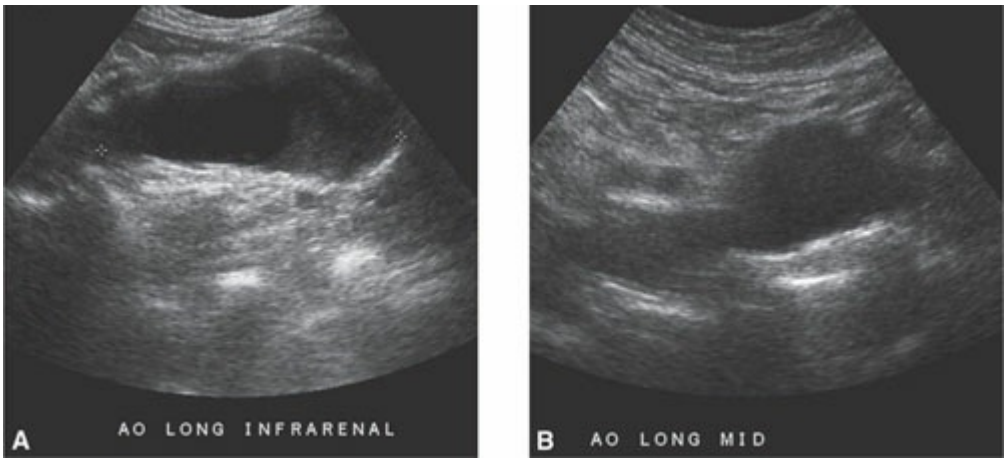


Figure 9-14 Fusiform and saccular abdominal aortic aneurysms (AAAs). **A**. A fusiform AAA. **B.** A saccular AAA.

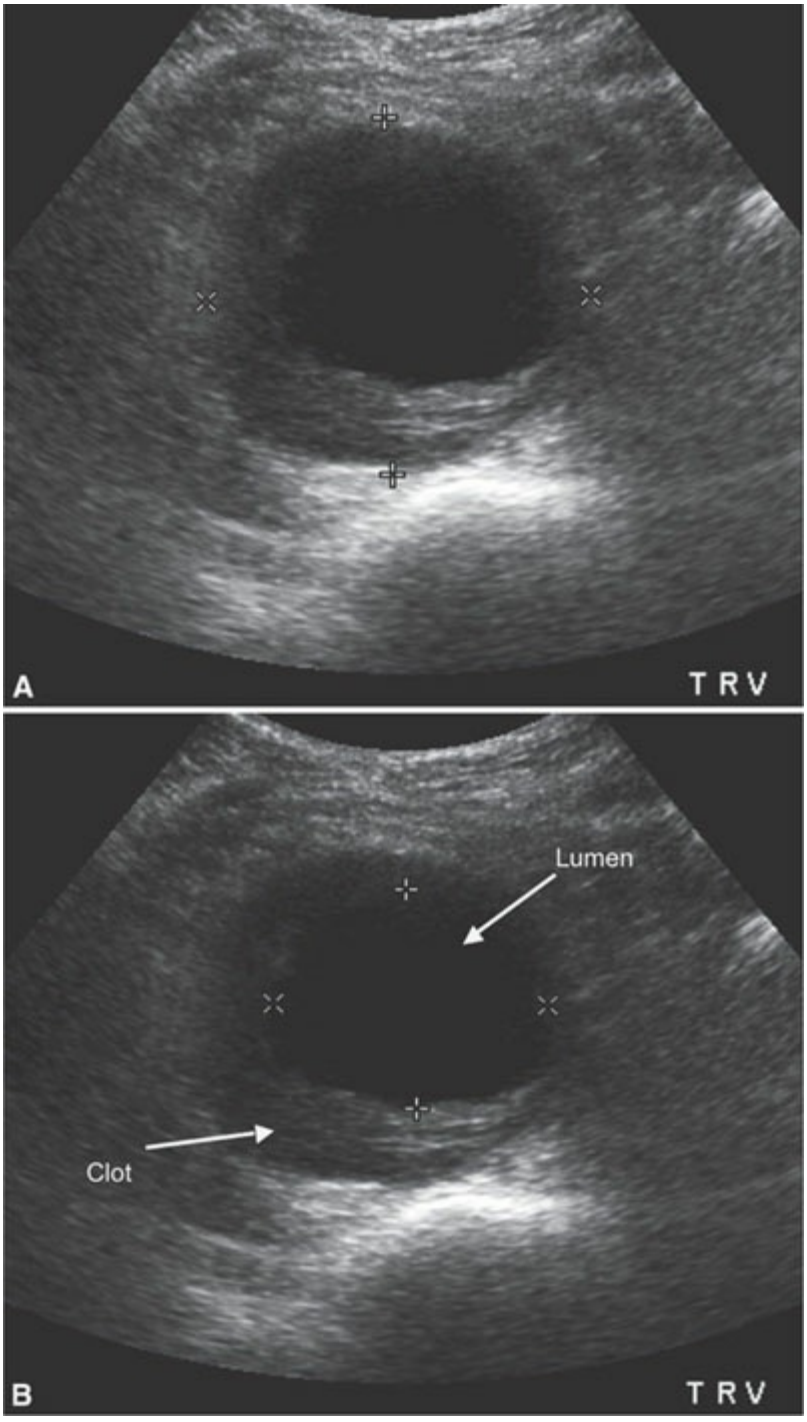


Figure 9-15 True lumen verses false lumen. **A.** Transverse abdominal aneurysm demonstrates the measurement of the entire abdominal aorta that contains notable clot within its borders (true lumen). **B.** The false lumen (*between calipers*) excludes the clot, and is therefore the residual lumen.

CLINICAL FINDINGS OF AN ABDOMINAL AORTIC ANEURYSM

1. Pulsatile abdominal mass
2. Abdominal bruit
3. Back pain
4. Abdominal pain
5. Lower extremity pain

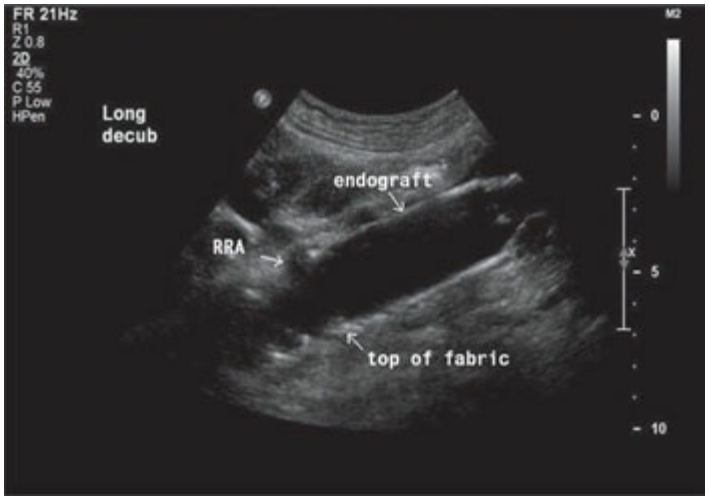


Figure 9-16 Aortic graft. The hyperechoic walls of the endograft can be seen in this image adjacent to the right renal artery (*RRA*).

SONOGRAPHIC FINDINGS OF AN ABDOMINAL AORTIC ANEURYSM

1. Diameter of the abdominal aorta measures greater than 3 cm
2. Thrombus within the lumen of the aorta
3. Calcifications, along with the thrombus, may produce acoustic shadowing

Aortic Dissection

Dissection of the abdominal aorta occurs when there is a separation of the layers of the arterial wall, predominantly disturbing the intima. Clinical findings of aortic dissection include intense chest pain, hypertension, abdominal pain, lower back pain, and some neurologic symptoms. Those who have Marfan syndrome are at an increased risk for dissection. Sonographically, a linear echo flap, termed an intimal flap, may be noted within the aortic lumen. This flap may be visualized swaying in the current of the passing blood (Fig. 9-17). Color Doppler can be used to demonstrate flow within the layers of the dissection.

SOUND OFF

The sonographic visualization of an intimal flap is indicative of aortic dissection.

CLINICAL FINDINGS OF AN AORTIC DISSECTION

1. Intense chest pain
2. Hypertension
3. Abdominal pain
4. Lower back pain
5. Neurologic symptoms

6. Marfan syndrome

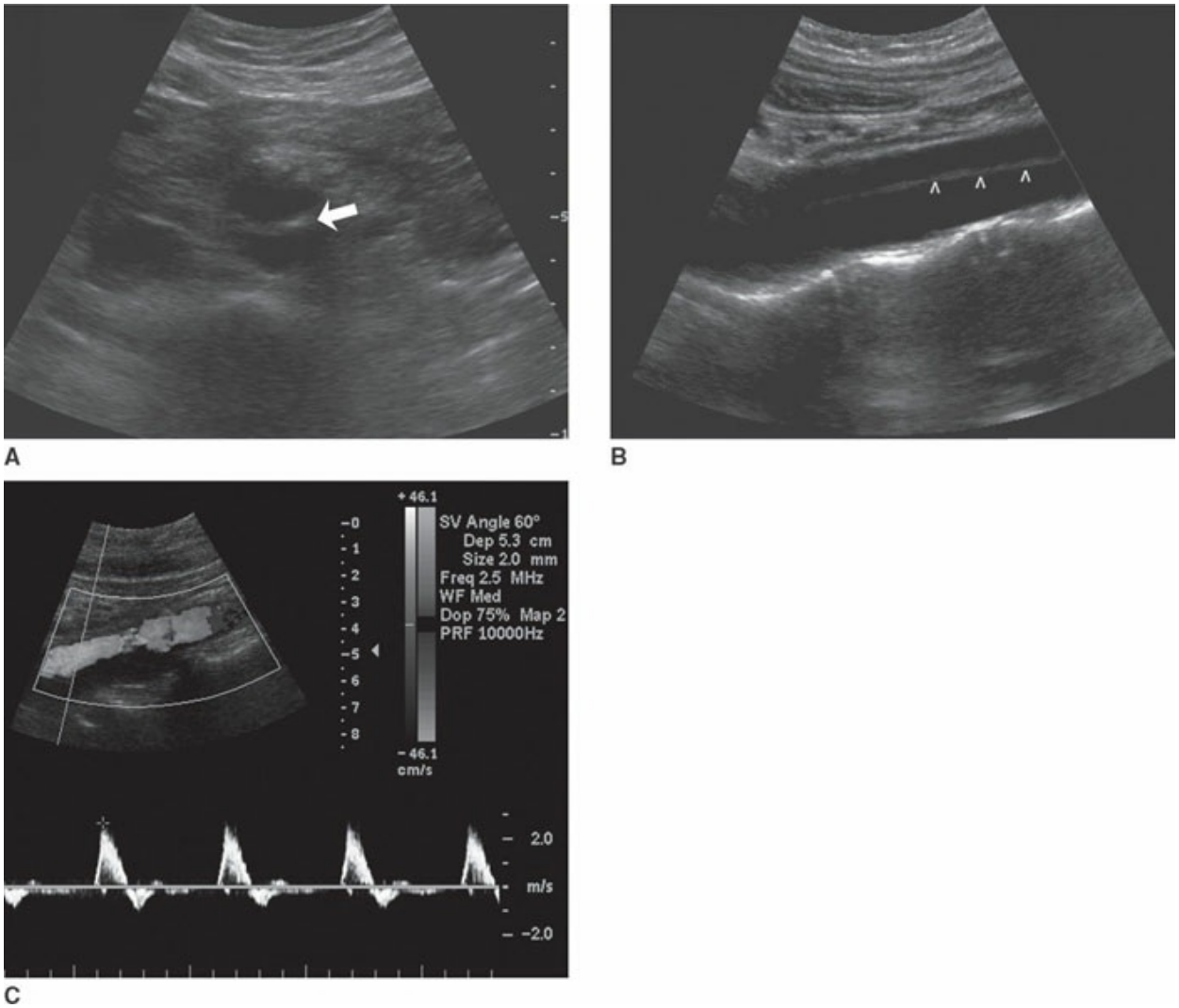


Figure 9-17 Dissecting aneurysm. **A.** Transverse image of a dissecting aneurysm demonstrating an intimal flap (*arrow*). **B.** Longitudinal image of a dissecting aneurysm. The intimal flap is identified by the *arrowheads*. **C.** Narrowing of the aortic flow and increase speed is demonstrated in this image. Color image provided online.

SONOGRAPHIC FINDINGS OF AN AORTIC DISSECTION

1. Possible AAA
2. Intimal flap may be noted within the aortic lumen

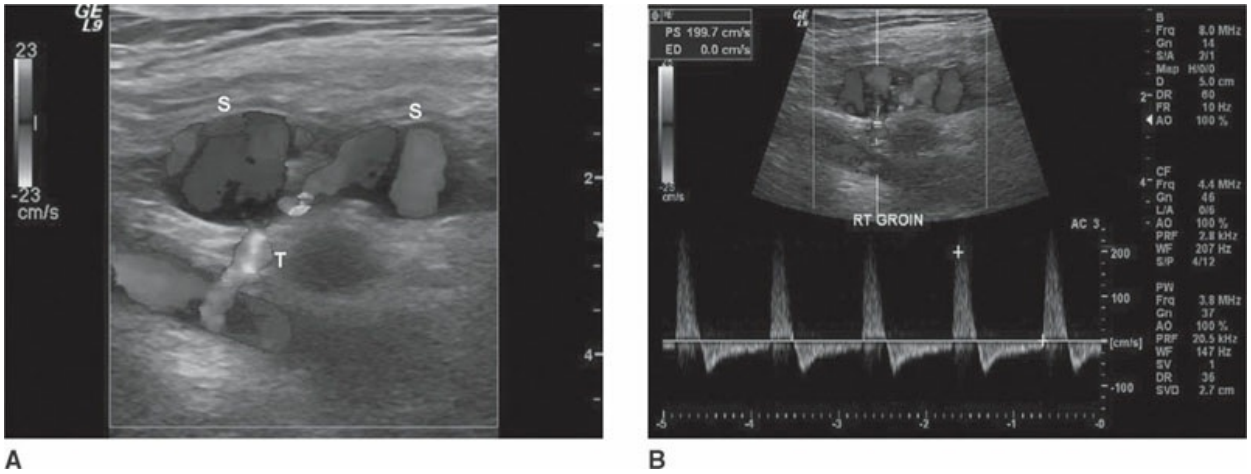
Abdominal Aortic Rupture

Rupture of the abdominal aorta has a high mortality and high morbidity rate. Specifically, aneurysms that measure greater than 7 cm in diameter are more prone to rupture. Clinical symptoms of aortic rupture include symptoms consistent with aortic aneurysms, with the addition of decreased hematocrit

and hypotension. The patient may also complain of back pain, abdominal pain, lower extremity pain, and have a pulsatile abdominal mass. Sonographically, an abdominal aneurysm with an adjacent hematoma is diagnostic for aortic rupture.

CLINICAL FINDINGS OF AN AORTIC RUPTURE

1. Decreased hematocrit
2. Hypotension
3. Pulsatile abdominal mass
4. Abdominal bruit
5. Back pain
6. Abdominal pain
7. Lower extremity pain



A B

Figure 9-18 Pseudoaneurysm. **A.** A color image of a pseudoaneurysm with the neck or tract (*T*) connecting from the vessel into two pseudoaneurysm sacs (*S*). **B.** Spectral Doppler patterns within the neck of a pseudoaneurysm with a classic to-and-fro pattern. Color image provided online.

SONOGRAPHIC FINDINGS OF AN AORTIC RUPTURE

1. Abdominal aneurysm with an adjacent hematoma

Pseudoaneurysms

A false aneurysm may also be called a pseudoaneurysm. A pseudoaneurysm is a contained rupture of a blood vessel that is most likely secondary to the disruption of one or more layers of that vessel's wall. False aneurysms typically result from some type of injury to an artery, as seen with interventional procedures, surgery, or trauma. Pseudoaneurysms may also be associated with infection.

A common site for pseudoaneurysm development is within the groin at the

level of the femoral artery following a heart catheterization. Clinical findings include a pulsatile mass in the area of the puncture location. Sonographic findings of a pseudoaneurysm include a perivascular hematoma that contains swirling blood and has a neck connecting it to the vessel. Color Doppler demonstration of turbulent flow within the mass can be seen as well (Fig. 9-18). The historical treatment for pseudoaneurysms consisted of prolonged compression. However, ultrasound-guided thrombin injections can also be used to treat pseudoaneurysms.



SOUND OFF

A common site for pseudoaneurysm development is within the groin at the level of the femoral artery following a heart catheterization.

CLINICAL FINDINGS OF A PSEUDOANEURYSM

1. Recent catheterization, surgical procedure, or trauma
2. Pulsatile mass in the area of the puncture location

SONOGRAPHIC FINDINGS OF A PSEUDOANEURYSM

1. Perivascular hematoma containing swirling blood and has a neck connecting it to the vessel
2. Color Doppler demonstration of turbulent flow within the mass

ANATOMY AND PHYSIOLOGY OF THE INFERIOR VENA CAVA

The IVC is the largest vein in the body. It is created by the union of the common iliac veins, usually near the level of the umbilicus. The wall of the IVC consists of three layers. Just like the abdominal aorta, the IVC has a tunica intima, tunica media, and tunica adventitia. However, the IVC has a smaller amount of smooth muscle within its tunica media compared with the abdominal aorta.

The IVC travels superiorly through the abdomen. It is considered retroperitoneal and located anterior to the spine and right lateral to the abdominal aorta (see Fig. 9-2). The IVC travels through the vena caval foramen of the diaphragm and ultimately terminates in the right atrium of the heart. The IVC can be separated into four sections from superior to inferior: hepatic, prerenal, renal, and postrenal. The primary function of the IVC is to bring deoxygenated blood from the lower extremities, pelvis, and abdominal organs back to the heart.

Hepatic Veins

The most superior portion of the IVC, the segment just below the diaphragm, courses posterior to the caudate lobe of the liver and through the bare area. Within the liver, the three hepatic veins—right, middle, and left—can be seen connecting to the IVC. Variants of the hepatic veins include duplication and branching anomalies. With pulsed Doppler analysis, the hepatic veins will have a pulsatile, triphasic blood flow pattern secondary to their association with the right atrium.

The hepatic veins may become narrowed with Budd–Chiari syndrome. Budd–Chiari syndrome, which is further discussed in Chapter 2, is described as the occlusion of the hepatic veins with possible coexisting occlusion of the IVC. Budd–Chiari syndrome can be seen secondary to a congenital webbing disorder, coagulation abnormalities, tumor invasion from hepatocellular carcinoma, thrombosis, oral contraceptive use, pregnancy, and trauma. Enlargement of the hepatic veins and IVC is often seen with right-sided heart failure.

Renal Veins

The next main venous connections to the IVC, just below the hepatic veins, are the paired renal veins. They are derived from the termination of the smaller venous branches within the kidney and travel to the lateral aspect of the IVC. The left renal vein is much longer than the right renal vein. Its course takes it from the left renal hilum, anterior to the left renal artery and abdominal aorta, and posterior to the SMA, before entering the left side of the IVC. The left renal vein can also travel posterior to the aorta in some persons, which is termed a retroaortic left renal vein. The right renal vein is much shorter than the left renal vein, secondary to its proximity to the IVC. The renal veins characteristically have low-velocity, continuous flow. Pathology of the renal veins is discussed in Chapter 7.

Gonadal Veins

The gonadal veins are referred to as testicular veins in the male and ovarian veins in the female. These paired veins are different in their orientation to the IVC. The right gonadal vein connects to the anterior aspect of the IVC. Conversely, the left gonadal vein drains into the left renal vein, and is therefore much longer than the right gonadal vein.



SOUND OFF

The left gonadal vein drains into the left renal vein, whereas right renal vein drains directly into the IVC.

Common Iliac Veins

The right and left common iliac veins combine to form the IVC near the umbilicus, typically just right of the midline.

SONOGRAPHY OF THE INFERIOR VENA CAVA

The hepatic section of the IVC can be recognized as an anechoic tube in the sagittal plane, marking the posterior border of the caudate lobe of the liver. In the transverse plane, the prerenal and renal IVC will be oval in shape and be seen to the right of the abdominal aorta. The postrenal segment of the IVC may be difficult to visualize. The size of the IVC is variable. Although its diameter should never exceed 2.5 cm, respiratory changes can alter the size of the IVC. Deep inspiration, sniffing, and the Valsalva maneuver will initially cause the IVC to collapse, whereas sustained inspiration will eventually lead to an enlargement of the IVC as blood begins to build up. The Doppler waveform of the IVC is pulsatile near the heart and more phasic near the common iliac veins.



SOUND OFF
The diameter of the IVC should not exceed 2.5 cm.

PATHOLOGY OF THE INFERIOR VENA CAVA

Inferior Vena Cava Thrombosis and Inferior Vena Cava Filter

Thrombus may be seen within the IVC. The most common findings of IVC thrombosis are IVC enlargement, absence of flow, and material noted within the IVC lumen. Acute thrombus may be completely anechoic, and therefore may be overlooked initially. With time, thrombus will become more echogenic and may even calcify and produce acoustic shadowing (Fig. 9-19). Patients with the likelihood of having a pulmonary embolus often require the placement of an IVC filter, also referred to as the Greenfield inferior vena cava filter. This filter is used to trap emboli that could be traveling upstream, potentially preventing a pulmonary embolus. Sonography can be used to evaluate the filter for proper placement and to assess for complications such as IVC perforation (Fig. 9-20).

Tumor Invasion of the Inferior Vena Cava

Tumor invasion of the IVC is often associated with renal cell carcinoma. The pediatric renal Wilms tumor and renal transitional cell carcinoma may also

attack the IVC. Tumors occupy the renal vein initially, move into the IVC, and may advance into the heart. This occurs more commonly on the right side, secondary to the short length of the right renal vein.

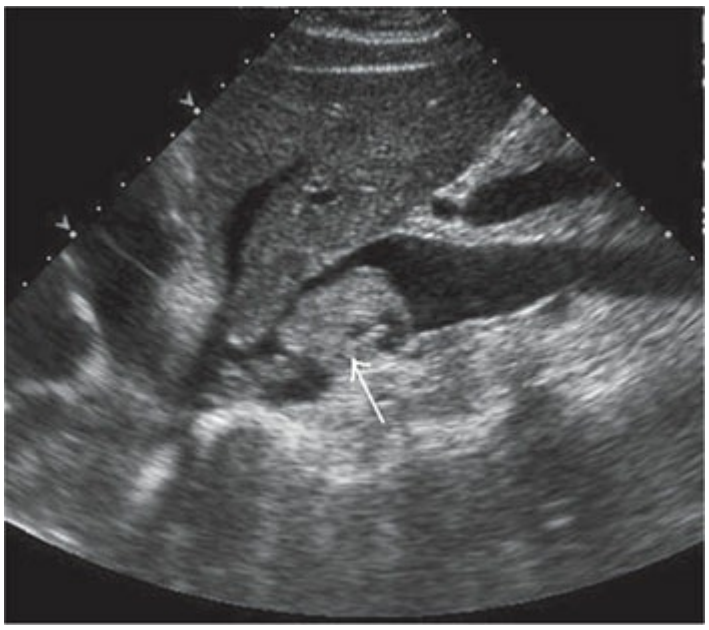


Figure 9-19 Inferior vena cava (IVC) thrombus. Longitudinal image of the IVC demonstrating echogenic clot (*white arrow*) within its walls.

Enlargement of the Inferior Vena Cava

As stated earlier, the diameter of the IVC does not normally exceed 2.5 cm. Enlargement of the IVC, with subsequent enlargement of the hepatic veins, is seen in cases of right-sided heart failure. In fact, right-sided heart failure is the most common cause of IVC obstruction that leads to enlargement.

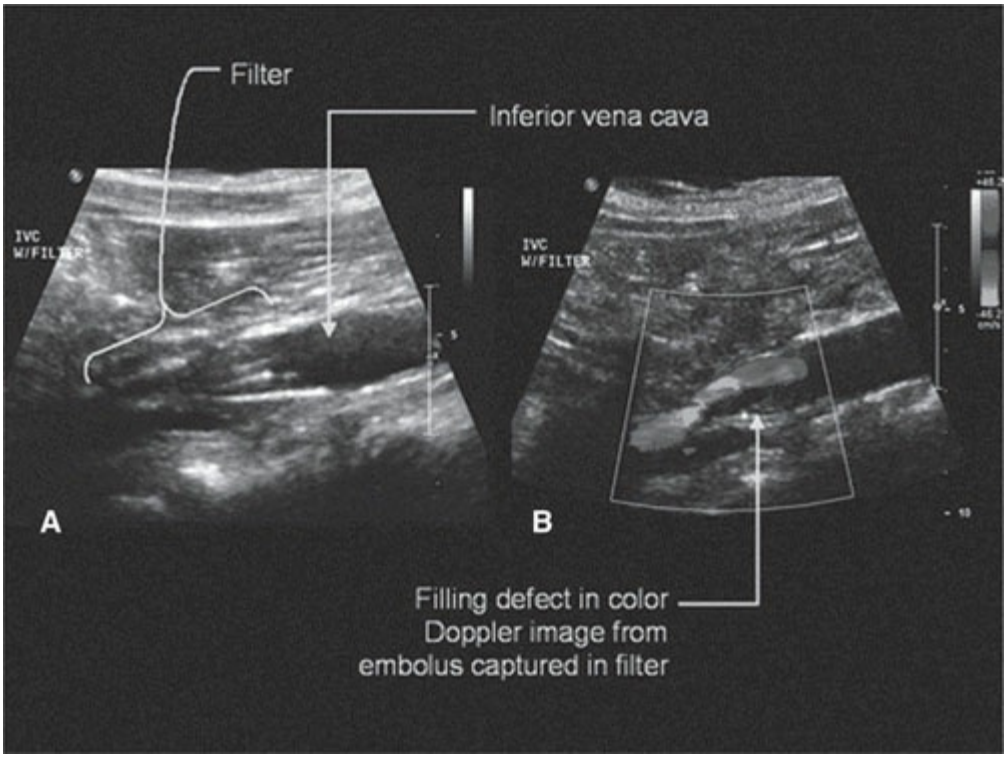


Figure 9-20 Inferior vena cava filter.

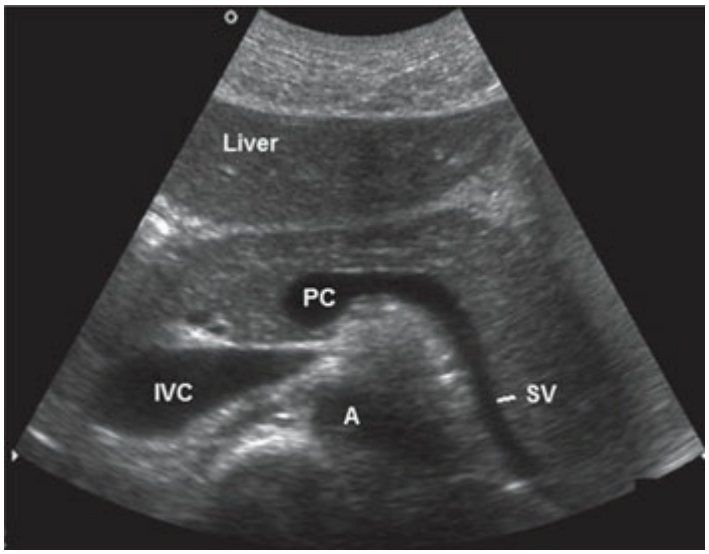


Figure 9-21 Portal system. Transverse pancreas image demonstrating the portal confluence (*PC*), splenic vein (*SV*), the liver, abdominal aorta (*A*), and inferior vena cava (*IVC*).

SOUND OFF
Right-sided heart failure is the most common cause of IVC enlargement.

ANATOMY AND PHYSIOLOGY OF THE PORTAL VENOUS SYSTEM

The main portal vein is created by the union of the superior mesenteric vein and splenic vein. A junction referred to as the portal splenic confluence or portal confluence is located posterior to the pancreatic neck. It consists of the splenic vein, superior mesenteric vein, and possibly the inferior mesenteric vein, although in some individuals the inferior mesenteric vein drains into the splenic vein (Fig. 9-21). The confluence lies within the midabdomen and collects blood from the intestines and spleen. It is not connected directly to the IVC.

The main portal vein travels right lateral to the liver and enters the liver at the porta hepatis. From there, it branches into right and left portal veins, supplying blood to the respective lobes of the liver. Normal flow within the portal veins should be hepatopetal and monophasic, with some variation noted with respiratory changes and after meals. The diameter of the portal vein can vary with respiration, although typically it is less than 13 mm.

SOUND OFF
The normal flow pattern in the main portal vein is hepatopetal and monophasic, and it should not exceed 13 mm in diameter.

The splenic vein is located posterior to the pancreatic body and tail. Flow within it should be toward the midline. Other smaller vessels that contribute to the portal venous system include the inferior mesenteric vein and the coronary vein, although these are not typically seen with sonography. Pathology of the portal venous system is discussed in Chapter 2.

Arteriovenous Fistulas and Arteriovenous Malformations

The abnormal connection between arteries and veins is referred to as arteriovenous fistulas. These may result from a simultaneous puncture of a vein and an artery. A connection between the vein and artery may be noted with color Doppler sonography. Arteriovenous fistulas can result from trauma or biopsy. Arteriovenous malformations (AVM) are direct communications between arteries and veins as well. An AVM may be congenital or caused by surgery, malignancy, biopsy, or trauma. Turbulent flow and focal accumulation of vascular structures will often be noted in the area of an AVM.

REVIEW QUESTIONS

1. In the sagittal plane, you recognize a circular, anechoic vascular structure

posterior to the IVC. Which of the following would this structure be most likely?
a. Abdominal aorta
b. Left renal vein
c. Right renal artery
d. SMA

2. A disorder of the connective tissue characterized by tall stature and aortic and mitral valve insufficiency is:
a. Wilms syndrome
b. Meckel–Gruber syndrome
c. Marfan syndrome
d. Kleinman syndrome

3. The inner wall layer of a vessel, closest to the passing blood, is the:
a. Tunica media
b. Tunica intima
c. Tunica rugae
d. Tunica adventitia

4. What vessel can be often noted coursing between the SMA and the abdominal aorta in the transverse scan plane?
a. Left renal vein
b. Left renal artery
c. Right renal vein
d. Right renal artery

5. The first main visceral branch of the abdominal aorta is the:
a. SMA
b. Celiac artery
c. Renal arteries
d. Hepatic artery

6. An aneurysm associated with infection is termed:
a. Recanalized
b. Saccular
c. Fusiform
d. Mycotic

7. Which of the following is not true about the abdominal aorta?
a. The abdominal bifurcates into the common iliac arteries.
b. The proximal aorta is situated more anterior than the distal aorta.
c. The aorta has a thicker tunica media than the IVC.

d. The third major branches of the abdominal aorta are the renal arteries.

8. All of the following are branches of the celiac axis except:
   a. Right gastric artery
   b. Hepatic artery
   c. Splenic artery
   d. Left gastric artery

9. The outer wall layer of a vessel is the:
   a. Tunica media
   b. Tunica intima
   c. Tunica rugae
   d. Tunica adventitia

10. What should the postprandial flow pattern be within the SMA?
    a. High resistance
    b. Low resistance

11. The second main branch of the abdominal aorta is the:
    a. SMA
    b. Celiac artery
    c. Renal arteries
    d. Hepatic artery

12. Which of the following vessels show a different flow pattern after eating?
    a. Celiac artery
    b. Splenic artery
    c. Renal artery
    d. SMA

13. Which of the following vessels would most likely yield a high-resistance flow pattern?
    a. Celiac artery
    b. Common hepatic artery
    c. Renal artery
    d. Fasting SMA

14. What flow pattern would the postprandial SMA yield in small bowel ischemia?
    a. High resistance
    b. Low resistance

15. An AAA is present when the diameter of the abdominal aorta exceeds:

a. 10 mm
b. 2.5 mm
c. 3 cm
d. 2 mm

16. Occlusion of the hepatic veins describes:
    a. Marfan syndrome
    b. Klinefelter syndrome
    c. Morrison syndrome
    d. Budd–Chiari syndrome

17. The most common shape of an AAA is:
    a. Saccular
    b. Bulbous
    c. True
    d. Fusiform

18. What branch and its tributaries of the abdominal aorta appears as a "seagull" in the transverse plane?
    a. SMA
    b. Hepatic artery
    c. Celiac artery
    d. Common iliac artery

19. Which vascular structure may be confused for the main pancreatic duct?
    a. Hepatic artery
    b. Left gastric artery
    c. SMA
    d. Splenic artery

20. The IVC terminates at the:
    a. Common iliac veins
    b. Right atrium
    c. Left atrium
    d. Left ventricle

21. A patient presents with unexplained abdominal pain for a vascular assessment of the SMA. Sonographically, you note that the patient's SMA yields a persistent high-resistive flow pattern. This is indicative of:
    a. Crohn disease
    b. Intussusception
    c. Bowel obstruction
    d. Small bowel ischemia

22. The main portal vein is created by the union of the:
    a. Splenic vein and superior mesenteric vein
    b. Superior mesenteric vein and inferior mesenteric vein
    c. Splenic vein and inferior mesenteric vein
    d. Splenic vein and gastroduodenal vein

23. The veins seen attaching to the IVC just below the diaphragm are the:
    a. Renal veins
    b. Superior mesenteric vein
    c. Hepatic veins
    d. Celiac axis

24. The aorta originates at the:
    a. Left atrium
    b. Right atrium
    c. Left ventricle
    d. Right ventricle

25. Which of the following is not a section of the IVC?
    a. Postrenal
    b. Pancreatic
    c. Prerenal
    d. Hepatic

26. The hepatic artery should demonstrate:
    a. High-resistance flow
    b. Low-resistance flow

27. Clinical findings of an AAA include all of the following except:
    a. Lower extremity pain
    b. Back pain
    c. Abdominal bruit
    d. Elevated hematocrit

28. An outpatient with a history of back pain and hypertension presents to the ultrasound department for an abdominal aortic sonogram. Sonographically, you visualize a 6 cm infrarenal aortic aneurysm with an echogenic linear structure noted gently swaying in the aortic lumen. What is the most likely diagnosis?
    a. Aortic rupture
    b. Chronic aortic aneurysm
    c. Aortic dissection

d. Aortic rupture

29. The left gonadal vein drains directly into the:
    a. IVC
    b. Superior mesenteric vein
    c. Left renal vein
    d. Left iliac vein

30. Which of the following would most likely yield a high-resistance flow pattern?
    a. Celiac artery
    b. Common iliac artery
    c. Splenic artery
    d. Right renal artery

31. What vessel may attach to the splenic vein before reaching the portal confluence?
    a. Left renal vein
    b. Inferior mesenteric vein
    c. Right renal vein
    d. Celiac vein

32. What vessel travels directly anterior to the left renal artery?
    a. Left renal vein
    b. Hepatic artery
    c. Right renal vein
    d. Superior mesenteric vein

33. What abnormality would the failure of an EVAR to isolate an aneurysm from circulation most likely results in?
    a. Endoleak
    b. Aortic dissection
    c. Pulmonary embolism
    d. Deep venous thrombosis

34. A patient presents to the sonography department with a history of Marfan syndrome. The sonographic evaluation reveals a linear echo within the aortic lumen that extends from the celiac axis to the iliac arteries. Color Doppler reveals flow throughout the aorta on both sides of the linear echo. The patient has had no surgeries, and there is no AAA. What does the linear echo most likely represent?
    a. Calcific thrombus
    b. Intimal flap

c. EVAR
d. Aortic filter

35. Which vessel would be the shortest in length?
    a. Right renal vein
    b. Right renal artery
    c. Left renal vein
    d. Left renal artery

36. Enlargement of the IVC, with subsequent enlargement of the hepatic veins, is seen in cases of:
    a. Budd–Chiari syndrome
    b. Marfan syndrome
    c. Left-sided heart failure
    d. Right-sided heart failure

37. Which of the following would have a pulsatile, triphasic blood flow pattern?
    a. Renal veins
    b. Hepatic veins
    c. Gonadal veins
    d. Common iliac veins

38. The diameter of the IVC should never exceed:
    a. 1.5 cm
    b. 2.5 cm
    c. 3.5 cm
    d. 8 mm

39. Which of the following statements about the IVC is not true?
    a. The diameter of the IVC is variable.
    b. Respiration can affect the size of the IVC.
    c. The IVC is located to the left of the abdominal aorta.
    d. The IVC is considered retroperitoneal in location.

40. Which of the following statements about the abdominal aorta is not true?
    a. Most aneurysms located within the abdominal aorta are false aneurysms.
    b. The abdominal aorta is located just left of the midline.
    c. The most common location of an AAA is infrarenal.
    d. The abdominal aorta is considered to be retroperitoneal in location.

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10

The Gastrointestinal Tract and Abdominal Wall

Introduction

Although sonography may not always be the modality of choice for the detection of all gastrointestinal abnormalities, it does provide a noninvasive, nonionizing diagnostic instrument. This chapter provides an overview of gastrointestinal structures often analyzed with sonography. It also discusses abnormalities of the abdominal wall.

Key Terms

acute appendicitis—inflammation of the appendix

adenocarcinoma—cancer originating in glandular tissue

appendicolith—a dense, calcified stone within the appendix

autoimmune disorder—a disorder in which the immune system attacks normal tissue

bezoars—masses of various ingested materials that may cause an intestinal obstruction

cervix sign—a sonographic sign associated with pyloric stenosis in the long axis

cinnamon bun sign—a sonographic sign associated with the appearance of intussusception

compression sonography—operator-applied transducer pressure on a structure during a sonographic examination

Crohn disease—an autoimmune disease characterized by periods of inflammation of the gastrointestinal tract

diverticulitis—the inflammation of diverticuli within the digestive tract, most often in the sigmoid colon

diverticulosis—the development of small outpouchings termed diverticuli in the digestive tract, most often in the sigmoid colon

doughnut sign—a sonographic sign associated with pyloric stenosis in the short axis

duodenal bulb—the proximal portion of the duodenum closest to the stomach

endometriosis—functional endometrial tissue located outside the uterus

fecalith—a stone that consists of feces

gastroesophageal junction—the junction between the stomach and the esophagus

gastroesophageal reflux—an abnormality in which fluid is allowed to reflux out of the stomach back into the esophagus

hypertrophic pyloric stenosis—a defect in the relaxation of the pyloric sphincter that leads to the enlargement of the pyloric muscles and closure of the pyloric sphincter

intussusception—the telescoping of one segment of bowel into another; most often the proximal segment of the bowel inserts into the distal segment

intussusceptum—the proximal segment of the bowel with intussusception

intussuscipiens—the distal segment of the bowel with intussusception

invaginate—to insert

lactobezoar—a bezoar that consists of powdered milk

leukocytosis—an elevated white blood cell count

McBurney point—a point halfway between the anterior superior iliac spine and the umbilicus; the area of pain and rebound tenderness in patients suffering from acute appendicitis

mechanical obstruction—a situation in which bowel is physically blocked by something

Meckel diverticulum—a common congenital outpouching of the wall of the small intestine

melanoma—a malignant form of cancer found most often on the skin

midgut malrotation—abnormal rotation of the bowel that leads to a proximal small bowel obstruction

nonbilious—not containing bile

nonmechanical obstruction—a situation in which bowel is blocked because

of the lack of normal peristalsis of a bowel segment or segments; also referred to as a paralytic ileus

olive sign—when the pyloric sphincter muscle is enlarged and palpable on physical examination of the abdomen; often indicative of pyloric stenosis

paralytic ileus—see key term nonmechanical obstruction

perienteric fat—fat around the intestines

peristalsis—contractions that move in a wavelike pattern to propel a substance

phytobezoars—a bezoar that consists of vegetable matter

pseudomyxoma peritonei—an intraperitoneal extension of mucin-secreting cells that result from the rupture of a malignant mucinous ovarian tumor or possibly a malignant tumor of the appendix

pylorospasm—a temporary spasm and thickening of the pyloric sphincter that can replicate the sonographic appearance of pyloric stenosis

rebound tenderness—pain encountered after the removal of pressure; a common clinical finding in patients suffering from acute appendicitis

red currant jelly stool—feces that contains a mixture of mucus and blood; a common clinical finding in patients suffering from intussusception

thyroid in the belly sign—the sonographic appearance of the hyperechoic edematous connective tissue that surrounds the inflamed appendix

trichobezoars—a bezoar that consists of matted hair

Valsalva technique—performed by attempting to forcibly exhale while keeping the mouth and nose closed

vermiform appendix—a blind-ended tube that is connected to the cecum of the colon

volvulus—a situation in which a loop of bowel twists upon itself

ANATOMY OF THE GASTROINTESTINAL TRACT

The gastrointestinal tract, or alimentary canal, consists of the mouth, pharynx, esophagus, stomach, the small intestines, and colon (Fig. 10-1). The mouth is the most proximal portion of the gastrointestinal tract. The pharynx lies distal to the mouth and unites it to the esophagus. The esophagus travels inferiorly within the thorax and through an opening in the diaphragm called the esophageal hiatus. The distal esophagus attaches to the stomach. This area, the gastroesophageal junction, can be identified with sonography and will appear as a bulls-eye structure between the left lobe of the liver and abdominal aorta in the sagittal imaging plane (Fig. 10-2).

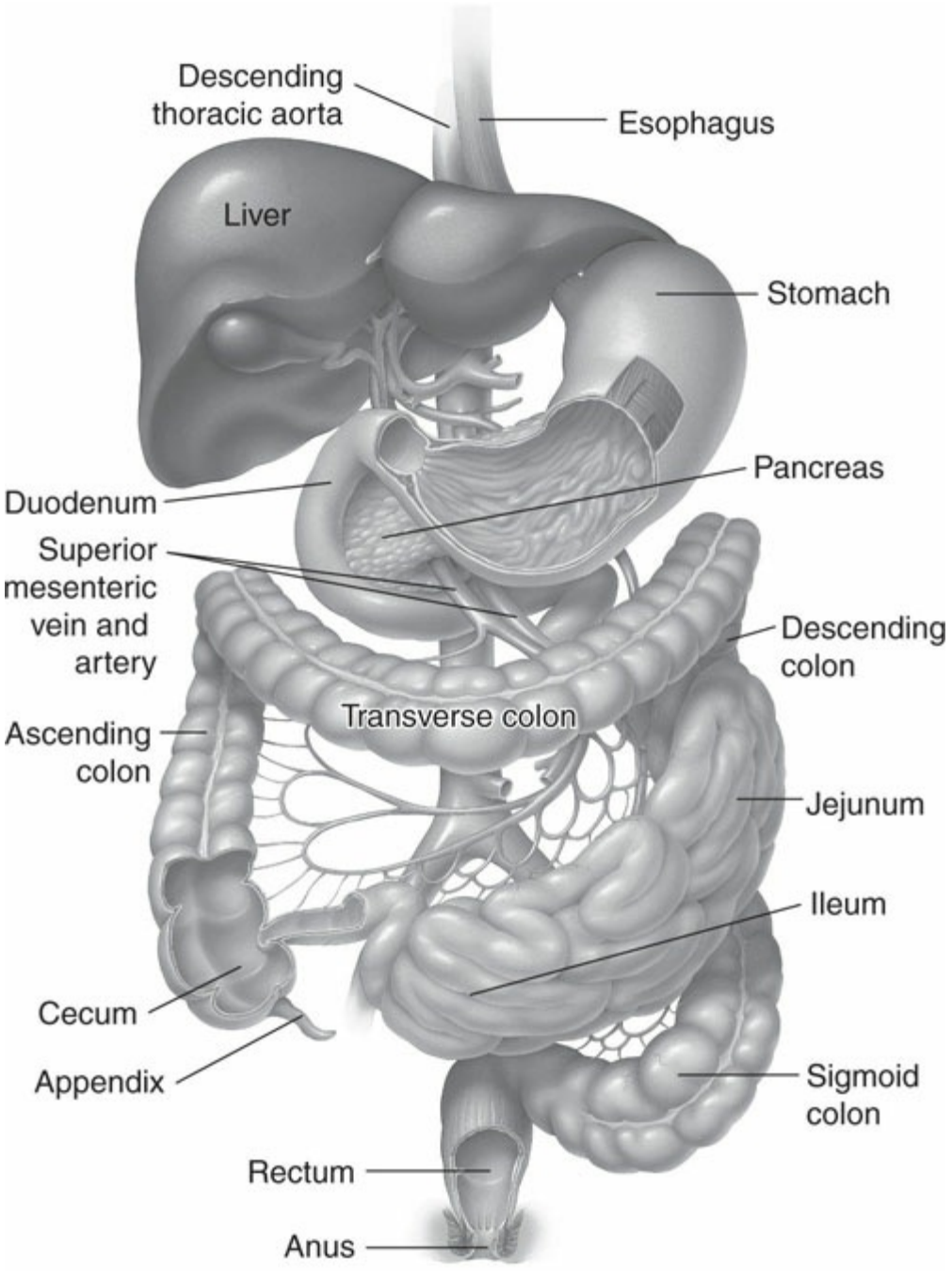


Figure 10-1 Gastrointestinal tract.

The stomach consists of a fundus, body, and pyloric region. Within the distal stomach lies the pyloric sphincter, a muscle that controls the emptying of the contents of the stomach into the duodenum. The proximal duodenum is C-shaped, and thus it is referred to as the C-loop of the duodenum. Distal to the duodenum are the jejunum and ileum of the small intestines. The ileum meets the cecum, or proximal colon, at the ileocecal valve within the right lower quadrant of the abdomen. At this level, a blind-ended tube, the vermiform appendix, is connected to the cecum.

After the cecum, the colon is termed the ascending colon as it travels superiorly toward the liver, within the right side of the abdomen. A bend in

the colon, the hepatic flexure or right colic flexure, marks the beginning of the transverse colon, which travels across the abdomen. Another bend, the splenic flexure or left colic flexure, located inferior to the spleen, marks the beginning of the descending colon, which is located within the left side of the abdomen. The colon travels inferiorly and becomes the sigmoid colon and subsequently the rectum. The anus, the external opening of the rectum, marks the termination point of the alimentary canal. Most gastrointestinal tract parts are considered intraperitoneal, with the exception of the duodenum and ascending and descending colon, which are regarded as retroperitoneal in location.

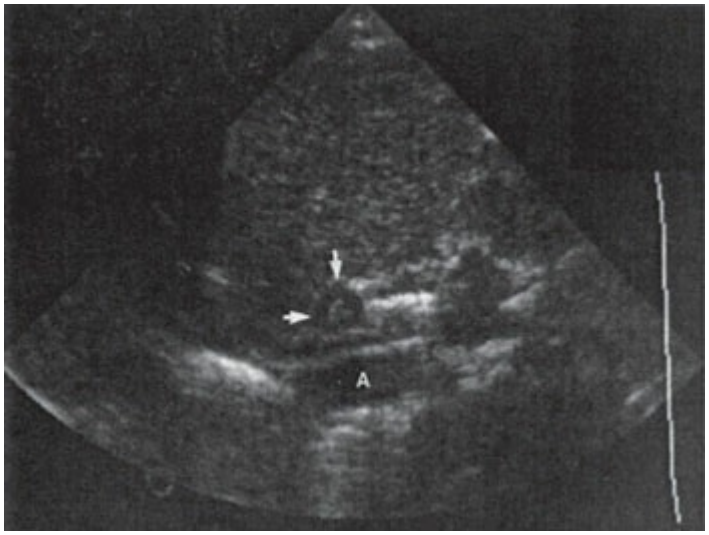


Figure 10-2 Gastroesophageal junction. Sagittal image of the left lobe and abdominal aorta (*A*) revealing the gastroesophageal junction (*arrows*).

SONOGRAPHY OF THE GASTROINTESTINAL TRACT

Sonography of the gastrointestinal tract may be indicated in the setting of several clinical conditions, including hypertrophic pyloric stenosis (HPS), intussusception, and acute appendicitis. Most gastrointestinal tract sonographic studies are performed using a high-frequency linear array transducer, although some studies may require a curved array transducer. During the examination, normal "gut signature" should be noted with sonography. The gastrointestinal tract consists of five histologic layers that sonographically appear as alternating echogenic and hypoechoic segments (Table 10-1; Fig. 10-3). However, not all of these are consistently identified with sonography. The alternating echogenicities of the bowel wall layers should produce the classic "target" or "bulls-eye" appearance.

A sonographic examination of the gastrointestinal tract should include graded-compression or compression sonography to differentiate normal from

anomalous bowel. Specifically, normal bowel should be compressible and should have observable peristalsis. Compression of the bowel will also move intraluminal fluid and/or gas out of the area of interest, which aids in the visualization of pathology. In addition, the wall of the involved bowel segment(s) should be closely analyzed. Generally, the normal intestinal wall should measure less than 5 mm in thickness.

A normal bowel wall segment produces little to no color Doppler. Consequently, color Doppler can be beneficial because inflammatory changes and neoplasms within the gastrointestinal tract will often reveal evidence of hyperemia. Additionally, transvaginal imaging has proven to be useful in identifying the inflamed appendix in some women, and may also prove valuable for analyzing the rectum and sigmoid colon for irregularities. Although rarely used, a water enema technique can be integrated during the examination to assess the rectum and sigmoid colon for suspected pathology.



SOUND OFF

Sonography utilizes compression to analyze bowel. In many situations, normal bowel is compressible, whereas abnormal bowel is noncompressible.

TABLE 10-1 Layers of the gut identified with sonography and their associated echogenicities

Layers of Gut Identified with Sonography	Echogenicity
Superficial mucosa (innermost layer)	Echogenic
Deep mucosa	Hypoechoic
Submucosa (muscularis propria interface)	Echogenic
Muscularis propria	Hypoechoic
Serosa (outermost layer)	Echogenic

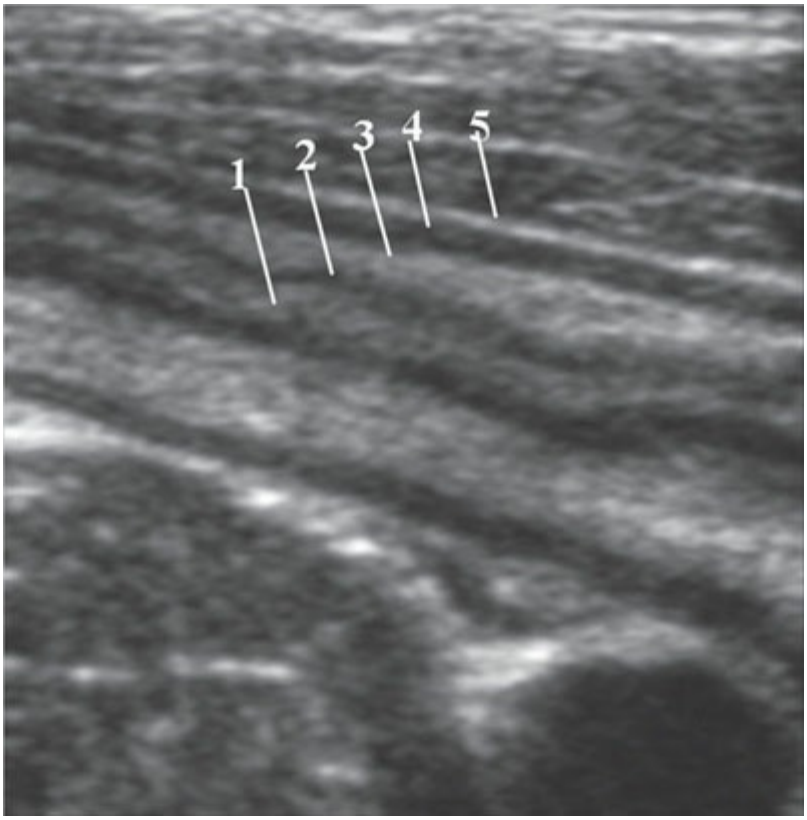


Figure 10-3 Gut signature. **1.** Echogenic superficial mucosal layer. **2.** Hypoechoic deep mucosal layer. **3.** Echogenic submucosal layer. **4.** Hypoechoic muscularis layer. **5.** Echogenic serosa.

GASTROINTESTINAL PATHOLOGY

Acute Appendicitis

The appendix, or vermiform appendix, is a long, narrow, blind-ended tube. Although its location may be variable, it is commonly located within the right lower quadrant, at the level of the cecum. Appendicitis, inflammation of the appendix, has been cited as the most common cause of acute abdominal pain resulting in surgery.

Acute appendicitis may be the result of some form of obstructive process such as an appendicolith, fecalith, lymph node, tumor, foreign body, seeds, or parasite. Clinically, patients may present with a history of epigastric pain, periumbilical pain, or general abdominal pain that, with time, is eventually restricted to the right lower quadrant. Patients will also suffer from rebound tenderness over the McBurney point in the right lower quadrant. Therefore, if possible, it is helpful to have the patient point to the most painful region. Laboratory tests, such as white blood cell count, are helpful as well because many patients with acute appendicitis will have evidence of leukocytosis.

Graded compression is used to sonographically investigate the abdomen for signs of appendicitis. The inflamed appendix will appear as a

noncompressible, blind-ended tube that measures more than 6 mm in diameter (Fig. 10-4). This measurement is taken from outer wall to outer wall. Careful exploration is further warranted for the presence of an obstructive etiology such as an appendicolith. An appendicolith will appear as an echogenic, shadowing structure within the lumen of the appendix (Fig. 10-5). There may also be evidence of a periappendiceal fluid collection, fat stranding around the appendix, and hyperemic flow within the wall of the irritated appendix. The thyroid in the belly sign has been used to describe the sonographic appearance of the hyperechoic edematous connective tissue that surrounds the inflamed appendix because the echogenicity of this tissue appears much like that of the normal thyroid. Complications of appendicitis include perforation, peritonitis, abscess formation, and possibly even death. A normal appendix may be perceived sonographically, and therefore, a comprehensive assessment, which includes both clinical findings and sonographic criteria, should be performed.

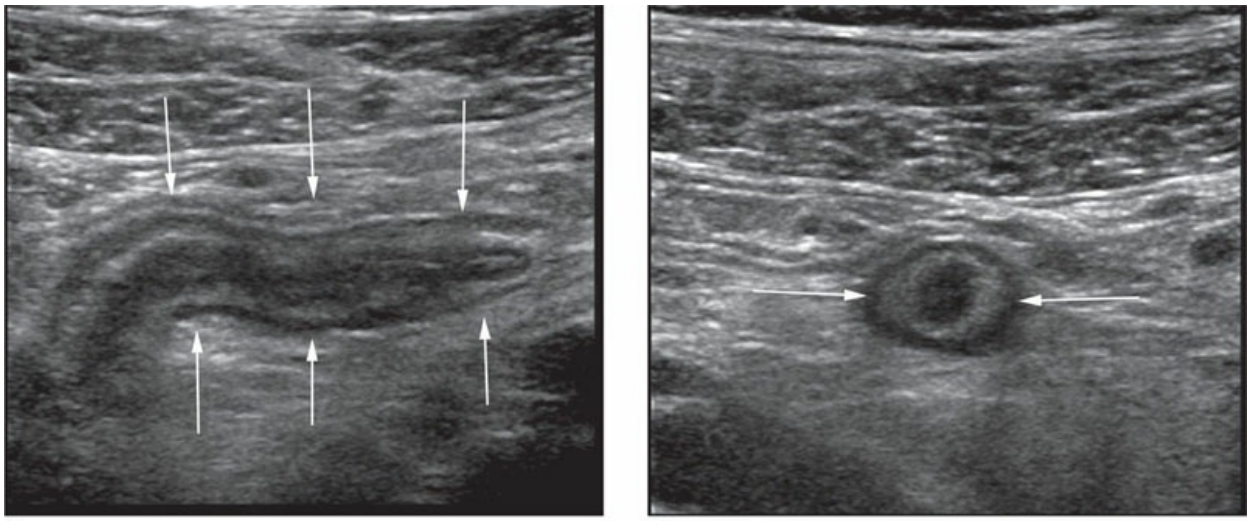


Figure 10-4 Appendicitis. **A.** Longitudinal image of an inflamed appendix (*arrows*). **B.** Transverse image of an inflamed appendix (*between arrows*).

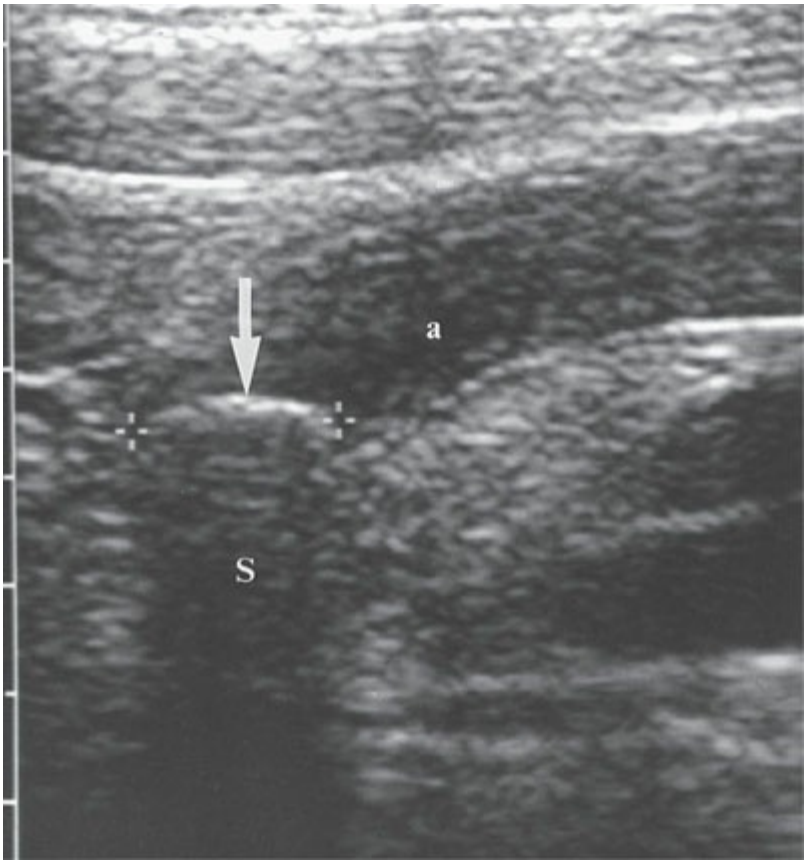


Figure 10-5 Appendicolith. An obstructing appendicolith (*white arrow*) that produces posterior shadowing (*S*) is seen within this inflamed appendix (*a*).

SOUND OFF
Appendicitis is indicative when inflamed appendix is noncompressible and measures greater than 6 mm.

CLINICAL FINDINGS OF ACUTE APPENDICITIS

1. Initial epigastric or general abdominal pain that, with time, is eventually restricted to the right lower quadrant
2. Acute abdominal pain
3. Rebound tenderness
4. Nausea and vomiting
5. Possible leukocytosis
6. High fever (with abscess formation)

SONOGRAPHIC FINDINGS OF ACUTE APPENDICITIS

1. Noncompressible, blind-ended tube that measures more than 6 mm in diameter from outer wall to outer wall
2. Echogenic structure within the lumen of the appendix (appendicolith)
3. Hyperemic flow within the wall of the inflamed appendix
4. Periappendiceal fluid collection

Hypertrophic Pyloric Stenosis

The pylorus is the distal region of the stomach. The pyloric channel is located at the distal portion of the pylorus, between the stomach and the proximal duodenal bulb. In this region, a group of muscles, called the pyloric sphincter, controls gastric emptying and prevents undigested food products, or chyme, from refluxing back into the stomach from the duodenum. HPS is a defect in the relaxation of the pyloric sphincter. This leads to the enlargement, or hypertrophy, of the pyloric muscles, effectively causing a persistent closure of the pyloric sphincter. Ultimately, HPS causes a gastric outlet obstruction.

Although HPS can occur in adults, it is most commonly encountered in infants between 2 and 6 weeks old. First-born, white male infants are more likely to suffer from HPS. The patient with HPS often presents clinically with nonbilious, projectile vomiting, dehydration, weight loss, constipation, and an insatiable appetite. The enlarged pyloric muscle may be palpable during a physical examination of an infant with pyloric stenosis. This is referred to as the "olive sign."



SOUND OFF

The clinical finding where the enlarged pyloric muscle can be palpated is referred to as the olive sign.

In the past, the customary diagnostic modality used to evaluate infants with clinical findings consistent with pyloric stenosis was radiography. Now, sonography has become the modality of choice. To examine the pyloric region of the stomach, the infant is placed in the right lateral decubitus position. If the stomach is completely empty, a small amount of water or glucose solution may be given to the infant to drink to better visualize the pylorus. However, care should be taken to not overdistend the stomach with fluid, because this may prevent adequate visualization of the pylorus.

In the longitudinal plane, the pylorus will be noted within the epigastrium, slightly right of the midline, near the gallbladder. The pylorus is normally positioned transversely in the abdomen. Thus, a longitudinal image of the abdomen will often yield a short-axis image of the stenosis, while a transverse image of the abdomen will often yield a long-axis image of the stenosis. The abnormal pylorus appears as a "target" or "doughnut" (doughnut sign) in the short axis, and as a cervix (cervix sign) in the long axis (Figs. 10-6 and 10-7). If pyloric stenosis is present, the wall of the pyloric muscle will measure 3 mm or greater in thickness, while the length of the abnormal pyloric channel will measure 17 mm or greater. It is important to note that the thickness of the muscle appears to be the more specific

sonographic measurement. Furthermore, fluid must be observed traveling from the pylorus into the duodenum to eliminate the diagnosis of pyloric stenosis.



Figure 10-6 Pyloric stenosis. Pyloric stenosis (*arrows*) in the transverse often revealing the "doughnut" or "target" appearance of the enlarged sphincter muscle.

SOUND OFF
The pylorus is transversely oriented within the abdomen. Therefore, pyloric stenosis yields a cervix appearance when the transducer is placed transverse to the abdomen, while in the longitudinal plane to the abdomen, the enlarged pylorus yields a doughnut appearance.

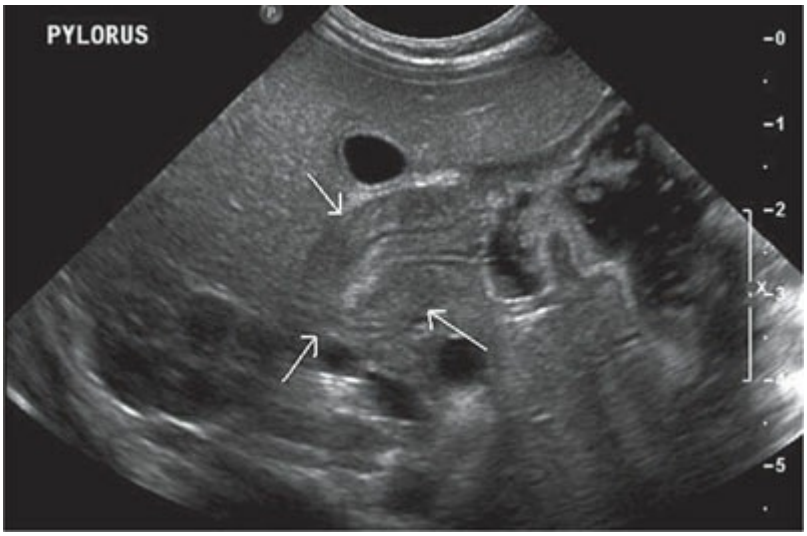


Figure 10-7 Pyloric stenosis. Longitudinal image of pyloric stenosis (*arrows*) revealing the "cervix" appearance of the enlarged sphincter muscle.

Three additional causes of nonbilious vomiting in the infant are pylorospasm, gastroesophageal reflux, and malrotation of the midgut. These

abnormalities should be excluded in those patients who present with clinical findings consistent with pyloric stenosis.

Pylorospasm is a common cause of delayed gastric opening as well. Unlike HPS, the measurements tend to be within normal limits, and eventually, during follow-up examinations some fluid is noted traveling through the pyloric channel.

SOUND OFF

The abnormal pyloric channel will measure greater than 17 mm in length, and the muscle will measure greater than 3 mm.

Gastroesophageal reflux is another cause of nonbilious projectile vomiting in the infant. Sonography can be used to evaluate infants for gastroesophageal reflux. For this examination, a transverse section of the gastroesophageal junction can be obtained in most persons posterior to the left lobe of the liver and anterior to the abdominal aorta in the sagittal scan plane of the abdomen. After identifying the gastroesophageal junction, the transducer is manipulated to obtain a longitudinal image of the esophagus. Fluid mixed with gas bubbles can be observed traveling retrograde up the esophagus in cases of gastroesophageal reflux.

Midgut malrotation, with or without volvulus, has a presentation that is clinically similar to that of HPS, although patients most often suffer from bilious vomiting rather than nonbilious vomiting as seen with HPS. With malrotation, the small bowel mesentery rotates around the superior mesenteric artery (SMA). The sonographic diagnosis of malrotation is confirmed by identifying the relationship of the SMA with the superior mesenteric vein (SMV). The SMA is typically located to the left of the SMV. With malrotation, the position of the two vessels will be reversed. An upper gastrointestinal radiographic series is typically used to verify the diagnosis of malrotation.

CLINICAL FINDINGS OF PYLORIC STENOSIS

1. First-born (white) male infant (most often)
2. Nonbilious, projectile vomiting
3. Weight loss
4. Constipation
5. Dehydration
6. Insatiable appetite
7. Palpable olive sign

SONOGRAPHIC FINDINGS OF PYLORIC STENOSIS

1. Abnormal pylorus appears as a target or doughnut in the short-axis view
2. Abnormal pylorus appears as a cervix in the long-axis view
3. Wall of pylorus will measure greater than or equal to 3 mm in thickness
4. Length of pyloric channel will measure greater than or equal to 17 mm

Intussusception

Sonography has become the modality of choice for evaluating pediatric patients with clinical symptoms suggestive of intussusception. Intussusception is the telescoping of one segment of bowel into another. Specifically, the intussusceptum, the proximal portion of the bowel, is allowed to invaginate into the next distal segment, the intussuscipiens. The most common type of intussusception, the ileocolic intussusception, occurs within the right lower quadrant at the level of the ileocecal valve. Intussusception, which is often idiopathic, occurs more often in male patients, and it has been cited as the most common cause of intestinal obstructions in children less than 2 years of age. Conversely, it rarely occurs in those under 3 months and over 3 years of age. In patients older than 2 years, there may be a lead point. This lead point may be an intestinal polyp, Meckel diverticulum, lymphoma, or intraluminal hematoma. In adults, intussusception can be caused by a neoplasm.

Clinically, patients present with intermittent, severe abdominal pain, vomiting, and a palpable abdominal mass. Their stool often contains a mixture of blood and mucus. This is referred to as a red currant jelly stool, and it is a hallmark clinical finding of intussusception. Laboratory tests may reveal anemia, dehydration, and/or leukocytosis as well.



SOUND OFF
A key clinical finding of intussusception is red currant jelly stool.

Graded-compression sonography should be used to evaluate the pediatric patient who has clinical findings suspicious for intussusception. With sonography, an intussusception will appear as a “target” mass in the transverse plane or a “pseudokidney” in the longitudinal plane to the mass (Fig. 10-8). The intussusception will have alternating rings of echogenicity representing the edematous layers of the bowel wall. Therefore, intusscusception may also resemble a cinnamon bun sign in the transverse plane as a result of the alternating echogenicity and the elliptical shape of the mass. The intussusception will also maintain its shape when compression is applied. The diameter of the intussuscepted bowel will exceed 3 cm.

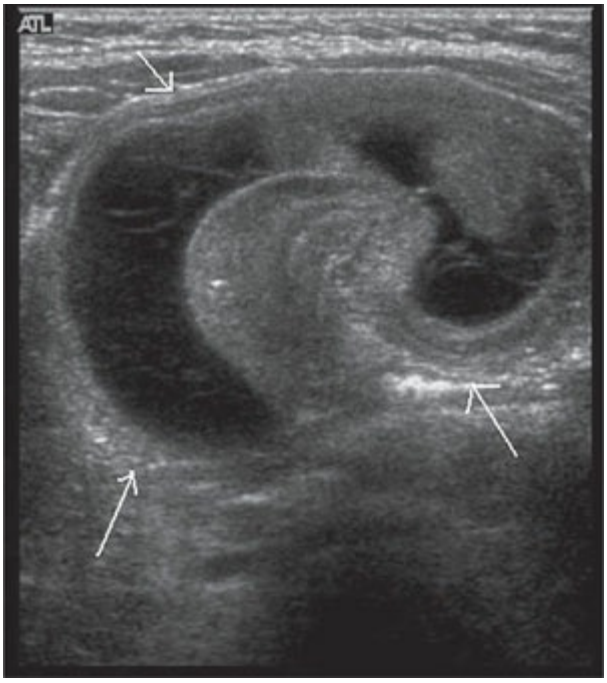


Figure 10-8 Intussusception. Transverse image through the right lower quadrant revealing intussusception (*arrows*).

This condition can lead to ischemia and gangrene of the bowel. Consequently, color Doppler may be utilized to determine whether blood flow is present within the intussusception. Flow is often present within the bowel wall with higher gain settings. If gangrene is suspected, surgical intervention is warranted. However, treatment for intussusception is typically by means of a therapeutic enema via radiography or hydrostatic reduction. Sonographic reduction has been performed with some success.

CLINICAL FINDINGS OF INTUSSUSCEPTION

1. Intermittent, severe abdominal pain
2. Vomiting
3. Palpable abdominal mass
4. Red currant jelly stools
5. Leukocytosis

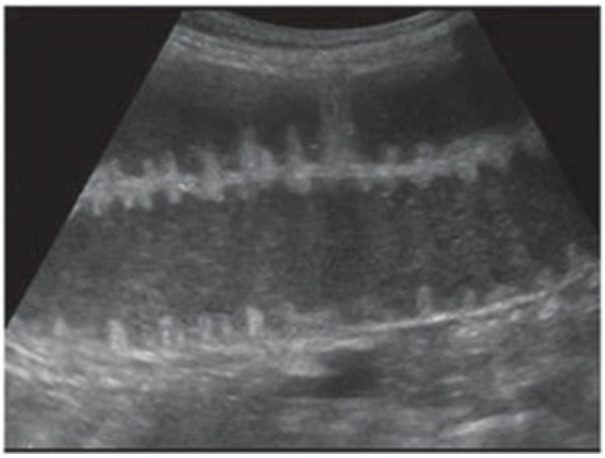


Figure 10-9 Bowel obstruction. Distended, fluid-filled loops of bowel are noted in this image.

SONOGRAPHIC FINDINGS OF INTUSSUSCEPTION

1. Noncompressible, target-shaped or pseudokidney-shaped mass that consists of alternating rings of echogenicity (cinnamon bun sign)
2. The diameter of the intussuscepted bowel will exceed 3 cm

Intestinal Obstruction

Although sonography is not typically the diagnostic modality of choice, an intestinal or a bowel obstruction may be incidentally noted during a sonographic examination of the abdomen. Patients with bowel obstructions can present with abdominal distention, intermittent abdominal pain, constipation, and nausea and vomiting. There are two types of intestinal obstructions: mechanical and nonmechanical. A mechanical obstruction results from the bowel being physically blocked by something. A nonmechanical obstruction or paralytic ileus is when the bowel lacks normal peristalsis. Sonographically, an intestinal obstruction appears as distended fluid-filled loops of bowel (Fig. 10-9). Occasionally, an abrupt termination point of the distended bowel may be identified with sonography, although bowel gas may inhibit this finding. Peristaltic motion may also be increased in cases of mechanical obstruction, with signs of to-and-fro motion of the intraluminal contents.

Although rarely identified sonographically, masses of various ingested materials may cause intestinal obstructions. These are referred to as bezoars. Bezoars that are more often found in pediatric patients, trichobezoars, consist of ingested hair. Pediatric patients may also suffer from lactobezoars, which are bezoars that consist of powdered milk that has not been adequately mixed with water. Bezoars that consist of vegetable material are called phytobezoars and are more often found in older patients. Sonographically, bezoars will appear as complex masses with varying degrees of acoustic

enhancement and posterior shadowing, depending on their structure.

Clinical Findings of an Intestinal Obstruction

1. Abdominal distention
2. Intermittent abdominal pain
3. Constipation
4. Nausea and vomiting

Sonographic Findings of an Intestinal Obstruction

1. Distended fluid-filled loops of bowel
2. An abrupt termination point of the distended bowel may be identified
3. Increased peristaltic motion with to-and-fro motion of intraluminal contents (mechanical obstruction only)

Crohn Disease

Crohn disease is an autoimmune disorder characterized by periods of inflammation of the gastrointestinal tract. Although it is the most common inflammatory disease of the small intestine, its cause is unknown. This disease usually involves the terminal ileum or proximal colon, although it can affect any part of the gastrointestinal tract. Patients can present with episodes of diarrhea, abdominal pain, weight loss, and rectal bleeding. Once more, like other bowel abnormalities discussed in this chapter, the sonographic appearance of Crohn disease resembles a target and will not be compressible. Sonographically, the affected bowel wall will measure greater than 5 mm and will reveal hyperemia with color Doppler interrogation.

Clinical Findings of Crohn Disease

1. Episodes of diarrhea
2. Abdominal pain
3. Weight loss
4. Rectal bleeding

Sonographic Findings of Crohn Disease

1. Bowel wall thickening
2. Affected bowel will be noncompressible and have a target appearance
3. Hyperemic wall

Diverticulitis

Diverticulosis is the development of small outpouchings termed diverticuli in

the digestive tract, most often the sigmoid colon. Inflammation resulting from infection of those outpouching is termed diverticulitis. Clinically, patients with diverticulitis can present with constipation or diarrhea, fever, nausea and vomiting, and cramping abdominal pain, especially in the left lower quadrant, where the sigmoid colon is found.

Sonographically, diverticulitis appears as segmentally thickened bowel with evidence of an inflamed diverticula and inflamed perienteric fat. The bowel segment will typically reveal hyperemia, and the inflamed diverticula may appear as echogenic projections from the bowel that produce shadowing or ring-down artifact (Fig. 10-10). A close evaluation of the quadrant should also ensue for signs of fistula or abscess formation.

CLINICAL FINDINGS OF DIVERTICULITIS

1. Constipation or diarrhea
2. Fever
3. Nausea and vomiting
4. Cramping, left lower quadrant pain

SONOGRAPHIC FINDINGS OF DIVERTICULITIS

1. Segmentally thickened bowel with evidence of an inflamed diverticula and inflamed perienteric fat
2. Affected bowel segment will typically reveal hyperemia
3. Inflamed diverticula may appear as echogenic projections from the bowel that produce shadowing or ring-down artifact

Colitis

Colitis is the inflammation of the colon. There are several different forms of colitis, including pseudomembranous, ulcerative, ischemic, and infectious. Watery and/or bloody diarrhea is a common feature of colitis. Pain and fever also occur. Pseudomembranous colitis, which is more often associated with watery diarrhea, can result from the use of antibiotic therapy that destroys the healthy flora of the intestines and leads to the subsequent proliferation of Clostridium difficile (C. difficile). Sonographically, colitis will yield bowel thickening of the colon wall with an increase in echogenicity and, especially with infectious colitis, hyperemia can be represented with color Doppler.



Figure 10-10 Diverticulitis. An inflamed outpouching (*arrow*) of the intestine is noted in this image.

CLINICAL FINDINGS OF COLITIS

1. Bloody or watery diarrhea
2. Fever
3. Abdominal pain
4. Previous use of antibiotic therapy

SONOGRAPHIC FINDINGS OF COLITIS

1. Thickened, hypoechoic colon wall
2. Hyperemia within the colon wall

Gastric Carcinoma and Metastatic Disease of the Bowel

Gastric cancer is most often in the form of adenocarcinoma. Patients typically present with weight loss, abdominal pain, anorexia, and vomiting. Occasionally, gastric carcinoma may be identified with sonography. Most often, a malignancy of the alimentary tract will appear as a hypoechoic, irregular-shaped, bulky mass that can measure up to 10 cm in size. The mass may have a “target” or “pseudokidney” appearance as well. Adenocarcinoma of the appendix can lead to rupture with the subsequent development of a gelatinous ascites referred to as pseudomyxoma peritonei. Sonographically, this form of ascites may appear as a multiseptated cystic mass within the pelvis. Lastly, malignant melanoma and primary tumors of the lungs and breast are the most commonly encountered metastatic tumors to the bowel. Their sonographic appearance may be similar to that of primary adenocarcinoma.

CLINICAL FINDINGS OF GASTRIC CARCINOMA

1. Weight loss
2. Abdominal pain
3. Anorexia
4. Vomiting

SONOGRAPHIC FINDINGS OF GASTRIC CARCINOMA

1. Hypoechoic, irregular-shaped, bulky mass

ANTERIOR ABDOMINAL WALL PATHOLOGY

Rectus Sheath Hematoma

The rectus sheath forms a covering for the paired rectus abdominis muscles. The rectus abdominis muscles are found on both sides of the midline of the anterior abdomen. They are divided by a band of connective tissue, the linea alba, which is located in the midline of the abdomen. A rupture in the muscle or associated vasculature can lead to a rectus sheath hematoma. Blood accumulation within the muscle or under the sheath can be the result of abdominal trauma or may occur spontaneously. Abdominal contractions that result from child birth, sneezing, coughing, defecation, urination, and intercourse have been shown to result in a rectus sheath hematoma. Clinically, patients present with abdominal pain, palpable abdominal mass, discoloration of the skin in the area of the hematoma, and a decreased hematocrit. Sonographically, a rectus sheath hematoma can appear anechoic, hypoechoic, complex, or hyperechoic depending on the stage of development.

CLINICAL FINDINGS OF A RECTUS SHEATH HEMATOMA

1. Abdominal pain
2. Palpable abdominal mass
3. Discoloration of the skin in the area of the hematoma
4. Decreased hematocrit

SONOGRAPHIC FINDINGS OF A RECTUS SHEATH HEMATOMA

1. Blood can appear hypoechoic, hyperechoic, complex, and/or anechoic depending on the stage of development.

Endometriosis of the Abdominal Wall

The most common site for endometriosis outside the female pelvis region is the anterior abdominal wall. Endometriosis is ectopic, functional endometrial tissue. The ectopic tissue is typically located within the scar of a previous cesarean section, and is thus termed scar endometriosis. The mass may be palpable. And because the endometrial tissue is reactive to the hormones of the menstrual cycle, patients may complain of cyclical pain in the region. Sonographically, a linear transducer should be utilized. Scar endometriosis within the abdominal wall can be well defined, lobulated, or infiltrative and will most likely appear hypoechoic or heterogeneous. Cystic changes may be seen within the mass as well. A biopsy is typically warranted.

CLINICAL FINDINGS OF ENDOMETRIOSIS OF THE ABDOMINAL WALL

1. History of endometriosis
2. Prior cesarean section
3. Pain on the area of the cesarean section scar (possible pain that correlates with the menstrual cycle)
4. Palpable mass

SONOGRAPHIC FINDINGS OF ENDOMETRIOSIS OF THE ABDOMINAL WALL

1. Well-defined, lobulated, or infiltrative mass
2. Hypoechoic to the adjacent tissue

Abdominal Wall Hernias

The abdominal wall can be sonographically interrogated for various abdominal wall hernias. There are several different types of hernias (Table 10-2). Inguinal hernias are further discussed in Chapter 13. A high-frequency linear transducer and standoff pad should be utilized during the examination. Sonography of abdominal wall hernias can be difficult. Often, the Valsalva technique is utilized to show movement and the change in size of the hernia. Hernias should be carefully examined for bowel content and the peristaltic motion of the potentially trapped bowel. Abdominal wall hernias can have different sonographic appearances because the contents of the hernia can vary. Complications of abdominal wall hernias include incarceration, strangulation, and ischemia of the affected bowel.

TABLE 10-2 Types of abdominal hernias

Type of

Hernia	Description	Location
Inguinal hernia	Can be further described as direct or indirect Bowel protrudes into the groin	Groin Scrotum or labia
Incisional hernia	Bowel protrudes into a surgical incision site	A surgical incision site
Linea alba hernia	Bowel protrudes through the fascia of the linea alba	Midline of the abdomen
Umbilical hernia	Bowel protrudes into the umbilicus	Umbilicus
Spigelian hernia	Bowel protrudes into a weakened area in the lower one-fourth of the rectus muscle	Midline of the abdomen Between the umbilicus and symphysis pubis

REVIEW QUESTIONS

1. A patient presents to the sonography department with bilious vomiting. While investigating the pediatric patient for pyloric stenosis, you note that while the pyloric sphincter appears normal, the SMA is abnormally located to the right of the SMV. What is the most likely diagnosis?
   a. Pylorospasm
   b. Intussusception
   c. Crohn disease
   d. Midgut malrotation

2. What anatomic structure may be noted as a bulls-eye structure anterior to the abdominal aorta and posterior to the left lobe of the liver in the sagittal scan plane?
   a. Pyloric sphincter
   b. Duodenal antrum
   c. Gastroesophageal junction
   d. Distal jejunum

3. Which of the following is not a layer of gut identified with sonography?
   a. Visceral
   b. Serosa
   c. Submucosa
   d. Mucosa

4. All of the following are true of normal intestinal findings with

sonography except:
a. Normal bowel does not compress
b. Normal bowel should have observable peristalsis
c. Intestinal wall should measure less than 5 mm
d. Normal bowel has little to no color Doppler signals

5. Upon sonographic evaluation of the right lower quadrant in a patient complaining of focal abdominal pain in that area, you visualize a hyperemic blind-ended, tubular structure that contains a shadowing focus. What is the most likely etiology of the shadowing focus?
a. Ureteral stone
b. Appendicolith
c. Gallstone
d. Herniated omentum

6. All of the following are sonographic criteria in the diagnosis of pyloric stenosis except:
a. Wall of the pylorus is focally thinned
b. Length of the pylorus measures more than 17 mm
c. Doughnut appearance in transverse
d. Cervix appearance in longitudinal

7. All of the following are sonographic findings of acute appendicitis except:
a. Appendicolith
b. Compressible, blind-ended tube
c. Periappendiceal fluid collection
d. Hyperemic flow

8. Clinical findings of acute appendicitis include all of the following except:
a. Leukocytosis
b. Right lower quadrant pain
c. Constipation
d. Rebound tenderness

9. All of the following are common clinical findings in infants who present with pyloric stenosis except:
a. Weight loss
b. Dehydration
c. Olive sign
d. First-born female

10. Pseudomyxoma peritonei can result from:

a. Intussusception
b. Pyloric stenosis
c. Crohn disease
d. Appendix cancer

11. A patient presents to the sonography department with a painful, superficial abdominal mass located within a prior cesarean scar. What clinical feature would be most consistent with scar endometriosis?
a. Hematuria
b. Chronic headaches
c. Cyclical pain
d. Bloody diarrhea

12. What abnormality associates red currant jelly stools?
a. Diverticulosis
b. Appendicitis
c. Intussusception
d. Pyloric stenosis

13. Other abnormalities that can present much like pyloric stenosis include all of the following except:
a. Midgut malrotation
b. Pylorospasm
c. Gastroesophageal reflux disease
d. Intussusception

14. Which of the following would be the most likely clinical feature of colitis?
a. Inguinal herniation of the bowel
b. Right shoulder pain
c. Watery diarrhea
d. Midline hematoma

15. Gastric cancer is most often in the form of:
a. Cystadenocarcinoma
b. Adenocarcinoma
c. Rhabdomyocarcinoma
d. Angiosarcoma

16. Pediatric patients could suffer from bowel obstructions that are caused by a buildup of ingested hair. The mass associated with this type of obstruction is termed a:
a. Phytobezoar

b. Lactobezoar
c. Trichobezoar
d. Permabezoar

17. An autoimmune disease characterized by periods of inflammation of the gastrointestinal tract describes:
    a. Crohn disease
    b. Intussusception
    c. Pyloric stenosis
    d. Meckel diverticulitis

18. The telescoping of one segment of bowel into another is referred to as:
    a. Volvulus
    b. Crohn disease
    c. Intussusception
    d. Pyloric stenosis

19. Which of the following types of obstruction refers to the bowel being physically blocked by something?
    a. Mechanical
    b. Nonmechanical
    c. Obstreperous
    d. Bezoarine

20. Which of the following would be useful to employ during a sonographic evaluation of a suspected abdominal wall hernia?
    a. Upright positioning
    b. Prone positioning
    c. Graded compression
    d. Valsalva

21. The situation when bowel protrudes into the groin is referred to as a(n):
    a. Inguinal hernia
    b. Linea alba hernia
    c. Umbilical hernia
    d. Spigelian hernia

22. The situation when bowel protrudes into a weakened area in the lower one-fourth of the rectus muscle is referred to as a(n):
    a. Inguinal hernia
    b. Linea alba hernia
    c. Umbilical hernia
    d. Spigelian hernia

23. The area of pain and rebound tenderness with acute appendicitis is most likely at:
    a. Meckel point
    b. McBurney point
    c. Murphy point
    d. Olive point

24. Which of the following best describes the location of McBurney point?
    a. Left lateral to the umbilicus and medial to the left iliac crest
    b. Halfway between the anterior superior iliac spine and the umbilicus
    c. Midway between the umbilicus and the symphysis pubis
    d. Medial to the superior iliac spine

25. The olive sign is best described as:
    a. The palpation of the inflamed appendix with rebound tenderness
    b. An area of pain halfway between the anterior superior iliac spine and the umbilicus
    c. An enlarged palpable pyloric sphincter
    d. The sonographic appearance of pyloric stenosis

26. Rebound tenderness is associated with:
    a. Appendicitis
    b. Intussusception
    c. Diverticulitis
    d. Gastric carcinoma

27. The most common location of the vermiform appendix is in the area of the:
    a. Jejunum
    b. Descending colon
    c. Cecum
    d. Sigmoid colon

28. Which of the following is the development of small outpouchings within the sigmoid colon?
    a. Diverticulitis
    b. Crohn disease
    c. Diverticulosis
    d. Midgut malrotation

29. Which of the following is not associated with a rectus sheath hematoma?
    a. Palpable abdominal mass

b. Increased hematocrit
c. Child birth
d. Sneezing

30. Which of the following is not a sonographic finding consistent with Crohn disease?
a. Bowel wall thickening
b. Noncompressible bowel that has a target appearance
c. Increased peristalsis
d. Hyperemic wall

31. All of the following are common clinical findings in infants who present with intussusception except:
a. Vomiting
b. First-born male infant
c. Red currant jelly stools
d. Leukocytosis

32. The sonographic finding of fluid-filled, distended loops of bowel is consistent with:
a. Meckel diverticulum
b. Diverticulitis
c. Gastroesophageal reflux disease
d. Intestinal obstruction

33. Traditionally, treatment for intussusception is by means of:
a. Surgery
b. External manipulation
c. Compression sonography
d. Therapeutic enema

34. The most common cause of intestinal obstruction in children less than 2 years of age is:
a. Intussusception
b. Midgut malrotation
c. Pyloric stenosis
d. Acute appendicitis

35. HPS is most often found in infants between:
a. 1 and 10 days of age
b. 2 and 6 weeks of age
c. 10 and 24 weeks of age
d. 2 and 4 years of age

36. In what position is the infant often placed for better sonographic visualization of the pyloric sphincter?
    a. Right lateral decubitus
    b. Left lateral decubitus
    c. Prone
    d. Upright

37. An adult patient presents to the sonography department with left lower quadrant pain, fever, and bouts of both constipation and diarrhea. Which of the following would be the most likely etiology?
    a. Diverticulitis
    b. Intussusception
    c. Midgut malrotation
    d. Appendicitis

38. What are the diagnostic criteria for pyloric stenosis?
    a. 17 mm in thickness and 2 mm in length
    b. 17 mm in thickness and 3 mm in length
    c. 3 mm in thickness and 10 mm in length
    d. 3 mm in thickness and 17 mm in length

39. Clinical findings of a patient with Crohn disease include all of following except:
    a. Palpable abdominal mass
    b. Rectal bleeding
    c. Abdominal pain
    d. Weight loss

40. Which of the following would be most likely a cause of colitis?
    a. Gastroesophageal reflux disease
    b. Antibiotic therapy
    c. Dehydration
    d. Rectus sheath hematoma

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11

Noncardiac Chest and Retroperitoneum

Introduction

This brief chapter provides a summary of relevant material pertaining to sonographic analysis of the noncardiac chest and retroperitoneum.

Key Terms

congenital cystic adenomatoid malformation—a mass consisting of abnormal bronchial and lung tissue that develops within the fetal chest

crura of the diaphragm—paired linear muscular sections of the diaphragm that attach to the anterolateral surfaces of the upper lumbar vertebrae

hemophiliac—an inherited bleeding disorder that inhibits the control of blood clotting

lung consolidation—the replacement of normal air-filled alveoli with fluid, inflammation, blood, or neoplastic cells

mediastinum—the central portion of the chest cavity between the pleural sacs of the lungs that contains all of the chest organs but the lungs, including the heart, thymus gland, part of the trachea, esophagus, and many lymph nodes

pericardial effusion—the accumulation of fluid around the heart in the pericardial cavity

pleural effusion—the abnormal accumulation of fluid in the pleural space

pneumothorax—free air within the chest outside of the lungs that can lead

to lung collapse

pulmonary sequestration—a separate mass of nonfunctioning lung tissue with its own blood supply

retroperitoneal fibrosis—a disease characterized by the buildup of fibrous tissue within the retroperitoneum; this mass may involve the abdominal aorta, inferior vena cava, ureters, and sacrum

retroperitoneal hematoma—a bloody tumor located within the retroperitoneum

retroperitoneal lymphadenopathy—the enlargement of the abdominal lymph nodes located within the abdomen

sandwich sign—the sign associated with abnormal abdominal lymph node enlargement that leads to the compression of the aorta and inferior vena cava

thoracentesis—a procedure that uses a needle to drain fluid from the pleural cavity for either diagnostic or therapeutic reasons

NONCARDIAC CHEST

Pleural and Pericardial Effusion

Fluid accumulation around the lung, referred to as a pleural effusion, may be noted during a sonographic examination of the abdomen (Fig. 11-1). Therefore, during abdominal sonogram studies, the lower chest should be evaluated for signs of pleural effusion. Simple pleural fluid tends to fall to the dependant side and is anechoic in appearance. The lungs will be noted floating in the pleural fluid. Complex fluid may indicate malignancy, infection, or blood. A thoracentesis is often performed to either determine the origin of the fluid (diagnostic thoracentesis) or for therapeutic reasons (therapeutic thoracentesis). The patient is typically placed in an upright position, and access to the fluid is obtained posteriorly. One complication of the thoracentesis is the development of a pneumothorax. This abnormality can be diagnosed with a chest radiograph. A pericardial effusion may also be noted during an abdominal sonogram. Fluid around the heart will most often appear anechoic.

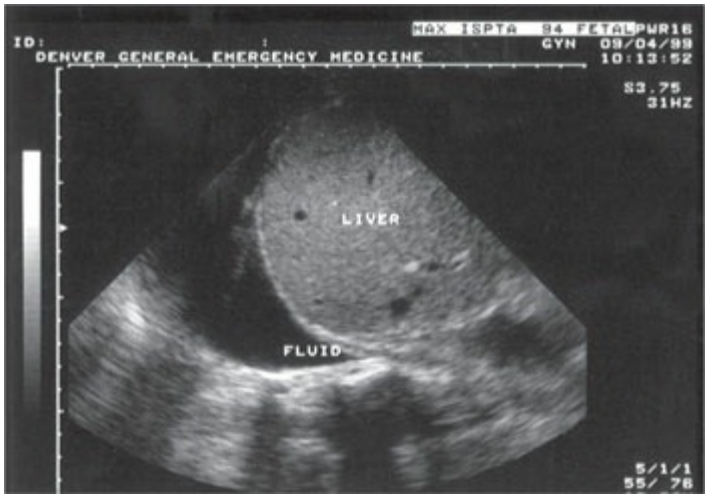


Figure 11-1 Pleural effusion. Anechoic fluid is noted superior to diaphragm and the liver.

Lung and Chest Masses

Superficial lung masses may be noted with sonography. Lung masses such as large lung cancers and surface irregularities may be further evaluated and biopsied with the assistance of sonography. Pediatric patients may be evaluated for pulmonary sequestration or congenital cystic adenomatoid malformation. Tumors of the mediastinum, such as lymphomas and thymomas, may be analyzed sonographically as well. The normal thymus may be noted in the pediatric patient posterior to the sternum, and will appear as an echogenic mass of tissue that contains linear and punctuate echogenicities. Before puberty, the thymus gland is vital for the development of T cells, which are specialized lymphocytes. Following puberty, the thymus slowly begins to atrophy, ultimately being replaced by fat in adults.

Lung Consolidation

Lung consolidation is the replacement of normal air-filled alveoli with fluid, inflammation, blood, or neoplastic cells. Causes include pneumonia, pulmonary edema, hemorrhage, and carcinoma. Sonographically, lung consolidation may appear similar to the liver or spleen tissue, but typically contains several internal echoes that radiate in a linear pattern because of air within the bronchi. Pleural effusion is often seen with lung consolidation.

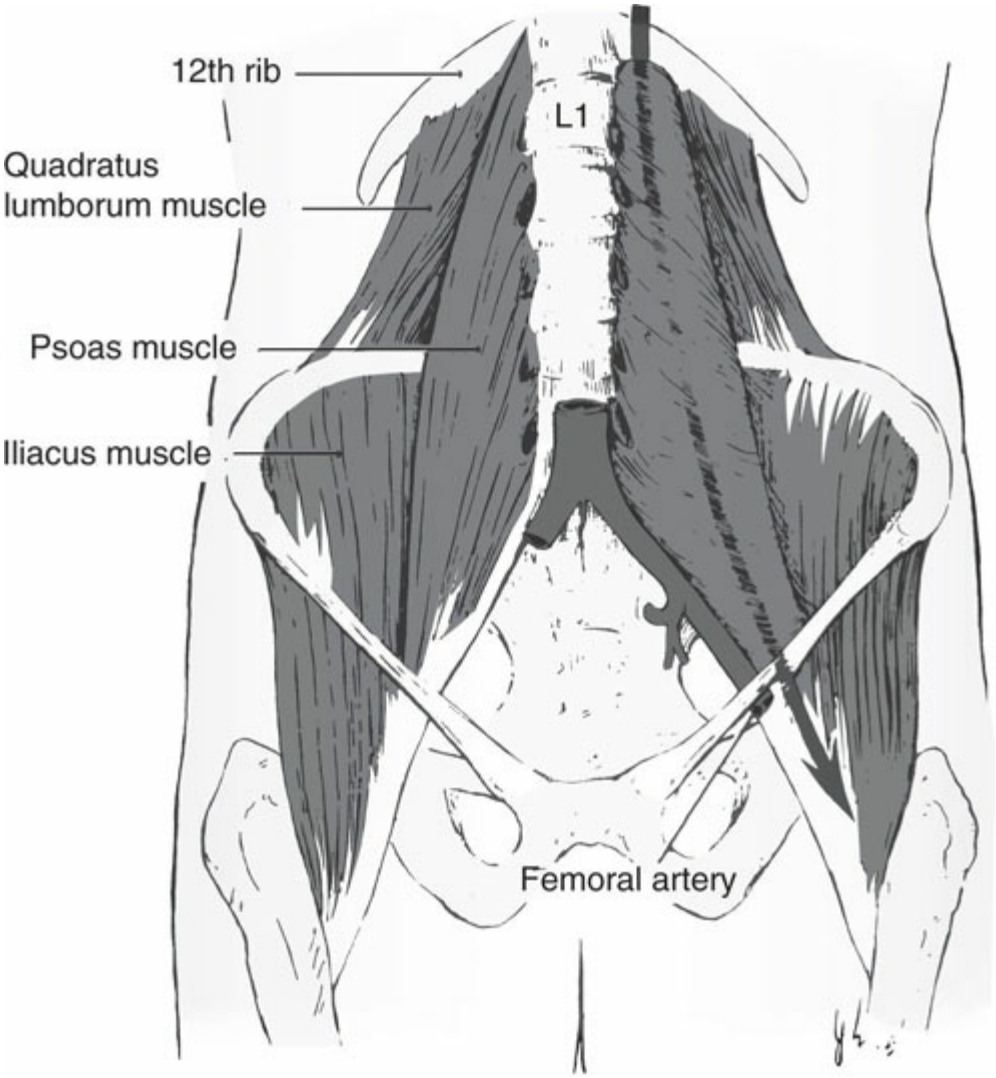


Figure 11-2 Coronal drawing depicting the location of the psoas, iliacus, and quadratus lumborum muscles.

RETROPERITONEUM

Retroperitoneal Muscles and the Crura of the Diaphragm

There are several prominent muscles that may be seen on an abdominal sonogram adjacent to the kidneys, including the psoas muscles and the quadratus lumborum (Figs. 11-2 and 11-3). On a transverse image of the kidney, the quadratus lumborum may be noted posterior to the kidney and lateral on the image, while the psoas muscle will be noted posterior to the kidney and closer to the spine. In addition, the paired crura (singular is crus) of the diaphragm, which are linear muscular sections of the diaphragm that attach to the anterolateral surfaces of the upper lumbar vertebrae, may be seen on sonography as hypoechoic structures in the longitudinal plane extending caudally into the abdomen anterior to the spine (Fig. 11-4).

Retroperitoneal Lymphadenopathy

Retroperitoneal lymphadenopathy is the enlargement of the abdominal lymph nodes located within the abdomen. Normal abdominal lymph nodes are typically not seen and measure less than 1 cm. Within the abdomen, lymph nodes are located in the mesentery, renal hilum, and along the length of the abdominal aorta. The enlargement of abdominal lymph nodes greater than 1 cm in diameter can indicate infection or malignancy such as lymphoma. The "sandwich" sign denotes abdominal nodes surrounding and compressing the aorta and inferior vena cava (Fig. 11-5). Enlarged nodes will also deviate from their normal sonographic appearance and become more hypoechoic or possibly anechoic.

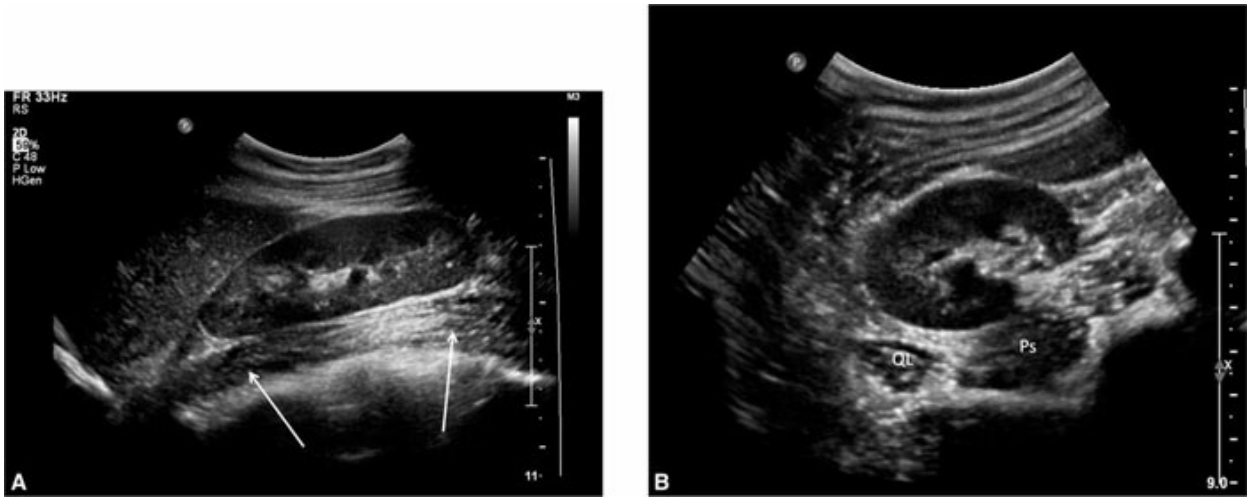


Figure 11-3 Psoas muscle with the patient in a posterior oblique position. **A.** Longitudinal view of the psoas muscle (*arrows*). **B.** Transverse view of the psoas (*Ps*) and quadratus lumborum (*QL*) muscles.

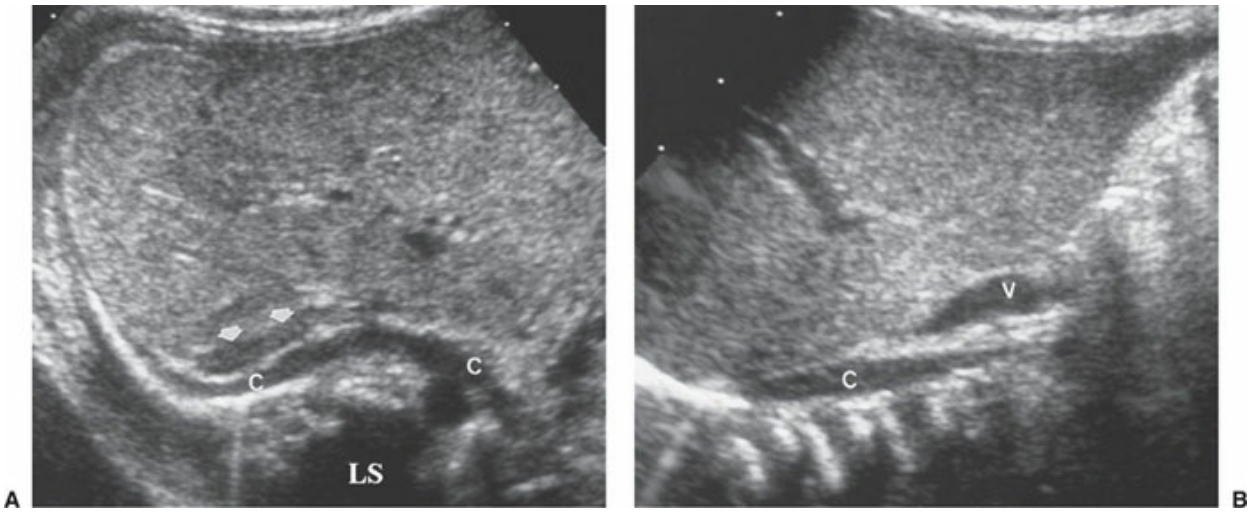


Figure 11-4 Crus of the diaphragm. **A.** Transverse view of the crura (*C*) of the diaphragm seen anterior to the lumbar spine (LS) and posterior to the adrenal gland (arrowheads). **B.** Longitudinal image of the right crus of the diaphragm (*C*) appearing as a linear, hypoechoic structure anterior to the spine and posterior to the inferior

vena cava (*V*).

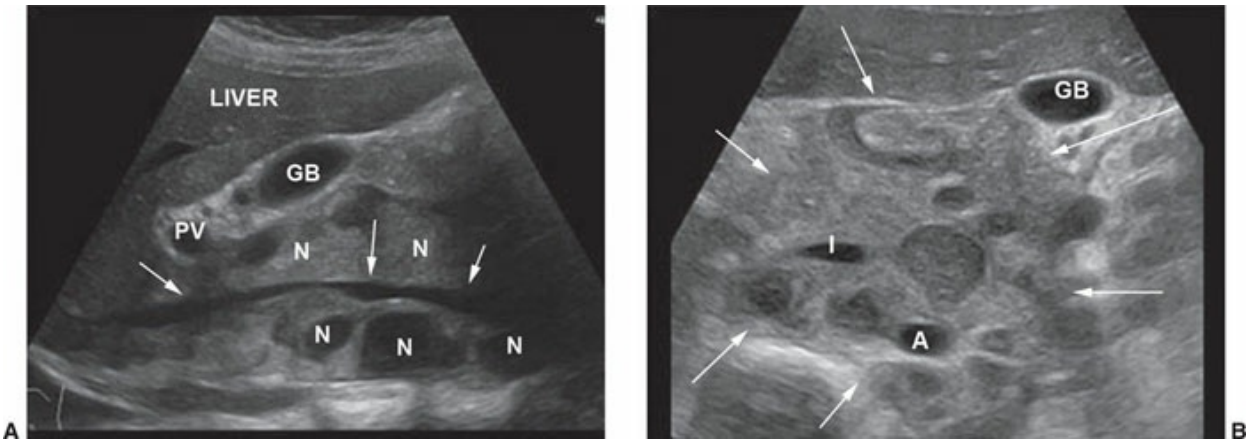


Figure 11-5 Retroperitoneal lymphadenopathy. **A.** Longitudinal image of the abdomen demonstrating compression of the inferior vena cava (*arrows*) by lymphadenopathy (*N*) seen anterior and posterior to the vessel. PV, portal vein, GB, gallbladder**B.** Transverse midline image demonstrating an echogenic mass (arrows) encompassing and compressing the aorta (*A*) and inferior vena cava (*I*). GB, gallbladder

Retroperitoneal Fibrosis

The development of a fibrous mass that covers the abdominal aorta, inferior vena cava, ureters, and sacrum is referred to as retroperitoneal fibrosis. Its cause is typically unknown. However, it has been linked with infections, migraine headache medication, malignant disease, and aneurysm rupture or leakage. Clinical symptoms include back or flank pain, weight loss, nausea, vomiting, and malaise. Sonographically, retroperitoneal fibrosis appears as a large, hypoechoic mass surrounding the abdominal aorta.

Clinical Findings of Retroperitoneal Fibrosis

1. Migraine medication use
2. Back pain
3. Flank pain
4. Weight loss
5. Nausea
6. Vomiting
7. Malaise

Sonographic Findings of Retroperitoneal Fibrosis

1. Large, hypoechoic mass surrounding the abdominal aorta

Retroperitoneal Hematoma

The most common location for a retroperitoneal hematoma, especially in the hemophiliac patient, is within the psoas muscles. Clinical findings include hemophilia, trauma, and surgery. Laboratory findings include a drop in hematocrit and pain. Depending on the stage of the blood, hematomas may appear hypoechoic, complex, or hyperechoic.

CLINICAL FINDINGS OF A RETROPERITONEAL HEMATOMA

1. Hemophilia
2. Trauma
3. Recent surgery
4. Low hematocrit

SONOGRAPHIC FINDINGS OF A RETROPERITONEAL HEMATOMA

1. Depending on the stage of the blood, hematomas may appear hypoechoic, complex, or hyperechoic

REVIEW QUESTIONS

1. Which of the following muscles would be situated closest to the spine?
   a. Rectus abdominis
   b. Psoas muscle
   c. Quadratus lumborum
   d. Iliacus

2. Which of the following is included in the clinical findings of retroperitoneal fibrosis?
   a. Hematuria
   b. Migraine medication use
   c. Diabetes mellitus
   d. Diarrhea

3. A 45-year-old patient presents to the sonography department with chest pain and shortness of breath. During the sonographic examination of the abdomen, an anechoic fluid collection is noted superior to the diaphragm. This most likely represents:
   a. Congenital cystic adenomatoid malformation of the lung
   b. Pulmonary sequestration
   c. Pleural effusion
   d. Cystic adenomatoid malformation

4. The “sandwich” sign denotes:
   a. Pyloric stenosis
   b. Intussusception
   c. Retroperitoneal fibrosis
   d. Abdominal lymphadenopathy

5. Abnormal lymph nodes typically measure more than:
   a. 10 mm
   b. 7 mm
   c. 8 mm
   d. 1 mm

6. Where is the thymus located?
   a. Within the neck
   b. Within the mediastinum
   c. Superior to rectum
   d. Anterior to the abdominal aorta

7. Fluid located around the lungs is termed:
   a. Ascites
   b. Pleural effusion
   c. Lung consolidation
   d. Pericardial effusion

8. What is the most common location of a retroperitoneal hematoma in hemophiliac patients?
   a. Rectum
   b. Anterior abdominal wall
   c. Psoas muscle
   d. Rectus abdominis muscle

9. Which of the following is not located within the mediastinum?
   a. Heart
   b. Thymus
   c. Esophagus
   d. Lungs

10. The replacement of normal air-filled alveoli with fluid, inflammation, blood, or neoplastic cells is referred to as:
   a. Pneumothorax
   b. Congenital cystic adenomatoid malformation
   c. Pulmonary sequestration
   d. Lung consolidation

11. Free air within the chest outside the lungs is referred to as:
    a. Pneumothorax
    b. Congenital cystic adenomatoid malformation
    c. Pulmonary sequestration
    d. Lung consolidation

12. A separate mass of nonfunctioning lung tissue with its own blood supply describes:
    a. Pneumothorax
    b. Congenital cystic adenomatoid malformation
    c. Pulmonary sequestration
    d. Lung consolidation

13. A mass consisting of abnormal bronchial and lung tissue that develops within the fetal chest best describes:
    a. Pneumothorax
    b. Congenital cystic adenomatoid malformation
    c. Pulmonary sequestration
    d. Lung consolidation

14. The diagnostic or therapeutic procedure where fluid is removed from the pleural space is referred to as:
    a. Thoracentesis
    b. Pneumothorax
    c. Paracentesis
    d. Pericardial centesis

15. Which of the following could result from undergoing a thoracentesis?
    a. Deep venous thrombosis
    b. Pneumothorax
    c. Pericardial effusion
    d. Ascites

16. Typically, a hematoma appears:
    a. Hyperechoic
    b. Hypoechoic
    c. Complex
    d. All of the above have been encountered

17. The diagnosis of a pneumothorax is typically via a(n):
    a. Upright sonogram
    b. Thoracentesis

c. Chest radiograph
d. Nuclear medicine chest perfusion study

18. Fluid located around the heart is termed:
    a. Ascites
    b. Pleural effusion
    c. Lung consolidation
    d. Pericardial effusion

19. Which of the following is the most likely sonographic appearance of the thymus?
    a. Echogenic mass that contains linear and punctuate echogenicities
    b. Anechoic structure anterior to the sternum
    c. Complex mass anterior to the iliac crest
    d. Homogeneous mass with posterior shadowing containing anechoic cystic structures

20. Which of the following is the most common sonographic appearance of retroperitoneal fibrosis?
    a. Hypoechoic mass surrounding the aorta
    b. Multiple small lymph nodes anterior to the abdominal aorta
    c. Anechoic mass in the lower abdomen
    d. Echogenic mass posterior to the kidneys

21. Which of the following can be seen posterior and lateral to the kidney?
    a. Rectus abdominis
    b. Psoas muscle
    c. Quadratus lumborum
    d. Iliacus

22. Which of the following would not be a typical clinical finding of a patient with retroperitoneal hematoma?
    a. Low hematocrit
    b. Trauma
    c. Weight loss
    d. Hemophilia

23. Enlargement of the abdominal lymph nodes is referred to as:
    a. Retroperitoneal fibrosis
    b. Retroperitoneal lymphadenopathy
    c. Abdominal consolidation
    d. Retroperitoneal sequestration

24. Which of the following is a linear muscular section of the diaphragm that attaches to the anterolateral surfaces of the upper lumbar vertebrae?
    a. Crus of the diaphragm
    b. Psoas muscle
    c. Iliacus
    d. Quadratus lumborum

25. All of the following are potential causes of lung consolidation except:
    a. Pneumonia
    b. Hemorrhage
    c. Carcinoma
    d. Pulmonary sequestration

26. One complication of a thoracentesis that may require a chest radiograph for diagnosis is the development of a:
    a. Pneumothorax
    b. Sequestration
    c. Cystic adenomatoid malformation
    d. Rib fracture

27. Common locations for abdominal lymph nodes include all of the following except:
    a. Mesentery
    b. Renal hilum
    c. Along the length of the abdominal aorta
    d. Within the subhepatic space

28. Lung consolidation typically appears sonographically as:
    a. Several internal echoes that radiate in a linear pattern because of air within the bronchi
    b. An anechoic mass with posterior enhancement
    c. An echogenic mass with posterior shadowing
    d. A large, hypoechoic mass surrounding the pericardial space

29. A 65-year-old patient presents to the sonography department with a history of abdominal pain and weight loss. Sonographically, you visualize multiple hypoechoic masses that extend along the anterior border of the abdominal aorta. Which of the following would be most likely?
    a. Pulmonary sequestration
    b. Retroperitoneal hematoma
    c. Retroperitoneal lymphadenopathy

d. Encapsulated ascites

30. What patient position is typically required for a thoracentesis?
    a. Upright
    b. Prone
    c. Supine
    d. Trendelenburg

31. A 35-year-old female patient presents to the sonography department with a history of migraine headache medication use, weight loss, nausea, and malaise. Sonographically, you visualize a 15-cm hypoechoic mass within the abdomen. Which of the following would be most likely?
    a. Volvulus
    b. Retroperitoneal fibrosis
    c. Intussusception
    d. Retroperitoneal lymphadenopathy

32. All of the following are true of abnormal lymph nodes except:
    a. They tend to lose their echogenic hilum.
    b. Enlargement may be associated with infection or malignancy.
    c. They tend to measure less than 1 cm.
    d. The “sandwich” sign denotes abdominal nodes surrounding and compressing the aorta and inferior vena cava.

33. Which of the following most often accompanies lung consolidation?
    a. Ascites
    b. Retroperitoneal fibrosis
    c. Retroperitoneal hematoma
    d. Pleural effusion

34. A 63-year-old male patient presents to the sonography department for an examination of the abdomen. He has a history of lung cancer and is suffering from shortness of breath. Sonographically, the liver and gallbladder appear normal. However, you visualize a heterogenous fluid collection superior to the right hemidiaphragm. What is the most likely diagnosis?
    a. Pulmonary sequestration
    b. Complex pleural effusion
    c. Pneumothorax
    d. Cystic adenomatoid malformation

35. A 38-year-old female patient presents to the sonography department with a history of femoral artery puncture and back pain. What laboratory value

would be helpful to assess the patient for active bleeding?
a. Hematocrit
b. Blood urea nitrogen
c. Alkaline phosphatase
d. Creatinine

36. A pleural effusion that is associated with infection will sonographically appear:
a. Complex
b. Anechoic
c. Septated
d. Varying sonographic appearances have been noted

37. Which of the following best describes a hemophiliac?
a. A person who lacks hemoglobin and hematocrit clotting factors.
b. A person who has an inherited bleeding disorder that inhibits the control of blood clotting.
c. A person who has an inherited breathing disorder that causes the development of pulmonary sequestrations.
d. A person who has abnormally shaped red blood cells.

38. The tissue comprising a lung consolidation can appear sonographically isoechoic to:
a. The liver
b. The inferior vena cava
c. The aorta
d. The rectus abdominis

39. Enlarged, abnormal lymph nodes tend to deviate from their normal sonographic appearance and become more:
a. Isoechoic
b. Anechoic
c. Hypoechoic
d. Anechoic or hypoechoic

40. All of the following may be discovered sonographically within the chest except:
a. Bronchial infections
b. Pleural effusion
c. Lymphomas
d. Thymomas

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12

The Face and Neck

Introduction

Sonography can provide a noninvasive image of the highly sensitive thyroid gland. This chapter presents anatomy, physiology, and sonography of the face and neck, including thyroid, parathyroid, the salivary glands, and lymph nodes. Pathology of these structures is also provided.

Key Terms

branchial cleft cysts—benign congenital neck cysts found most often near the angle of the mandible

cervical lymphadenopathy—enlargement of the cervical lymph nodes

cold nodules—the hypofunctioning thyroid nodules seen on a nuclear medicine study that have malignant potential

colloid—the fluid produced by the thyroid that contains thyroid hormones

dysphagia—difficulty swallowing

dyspnea—difficulty breathing

fibromatosis colli—a rare, pediatric fibrous tumor located within the sternocleidomastoid muscle

goiter—an enlarged, hyperplastic thyroid gland

Graves disease—the most common cause of hyperthyroidism that produces bulging eyes, heat intolerance, nervousness, weight loss, and hair loss

Hashimoto thyroiditis—the most common cause of hypothyroidism in the United States

hot nodules—the hyperfunctioning thyroid nodules seen on a nuclear medicine study that are almost always benign

hyperthyroidism—a condition that results from the overproduction of thyroid hormones

hypothyroidism—a condition that results from the underproduction of thyroid hormones

mucoepidermoid carcinoma—the most common malignancy of the salivary glands; typically starts in the parotid gland

papillary carcinoma—the most common form of thyroid cancer

pleomorphic adenoma—benign and most frequent tumor of the salivary glands; most commonly seen in the parotid gland

psammoma bodies—round, punctate calcific deposits

punctate—marked with dots

pyramidal lobe—a normal variant of the thyroid gland in which there is a superior extension of the isthmus

saliva—fluid produced by the salivary glands which aids in digestion

scintigraphy (thyroid)—nuclear medicine study in which a radiopharmaceutic is used to examine the thyroid gland

sialadenitis—inflammation of the salivary gland or glands

sialadenosis—benign, painless enlargement of a salivary gland or glands

sialolithiasis—salivary duct stones

Sjögren syndrome—an autoimmune disease that affects all glands that produce moisture, leading to dysfunction of the salivary glands and severe dryness of the eyes, nose, skin, and mouth

Stensen duct—the main duct of the parotid gland

thyroglossal duct cysts—benign congenital cysts located within the midline of the neck superior to the thyroid gland and near the hyoid bone

thyroglossal duct—the embryonic duct that is located from the base of the tongue to the midportion of the anterior neck

thyroid inferno—the sonographic appearance of hypervascularity demonstrated with color Doppler imaging of the thyroid gland

thyroidectomy—the surgical removal of the thyroid or part of the thyroid

torticollis—twisted neck

Wharton duct—the duct that drains the submandibular gland

THE FACE

Anatomy and Physiology of the Salivary Glands

Salivary glands are exocrine glands whose primary function is to produce saliva that is ultimately released into the oral cavity through ducts. Saliva, which aids in digestion, is mostly composed of water. However, it does contain electrolytes and digestive enzymes like amylase, which is also produced by the pancreas. There are three paired groups of salivary glands: the parotid glands, the submandibular glands, and the sublingual glands (Fig. 12-1).

The parotid glands are the largest of the salivary glands and are consequently the most likely to be analyzed with sonography. They are located bilaterally, anterior to the ears and extend inferiorly, where they are bounded anteriorly by the rami of the mandibles and posteriorly by the mastoid processes of the temporal bones. The paired, bilateral sternocleidomastoid muscles are also located posterior to the parotid glands. The parotid gland can be separated into three anatomic lobes, and its main duct is referred to as the Stensen duct. The bilateral submandibular glands are located beneath the floor of the mouth and are bordered laterally by the body of the mandible and superiorly by musculature. The submandibular gland is drained by the Wharton duct. The bilateral sublingual glands are located just under the tongue and anterior to the submandibular glands.

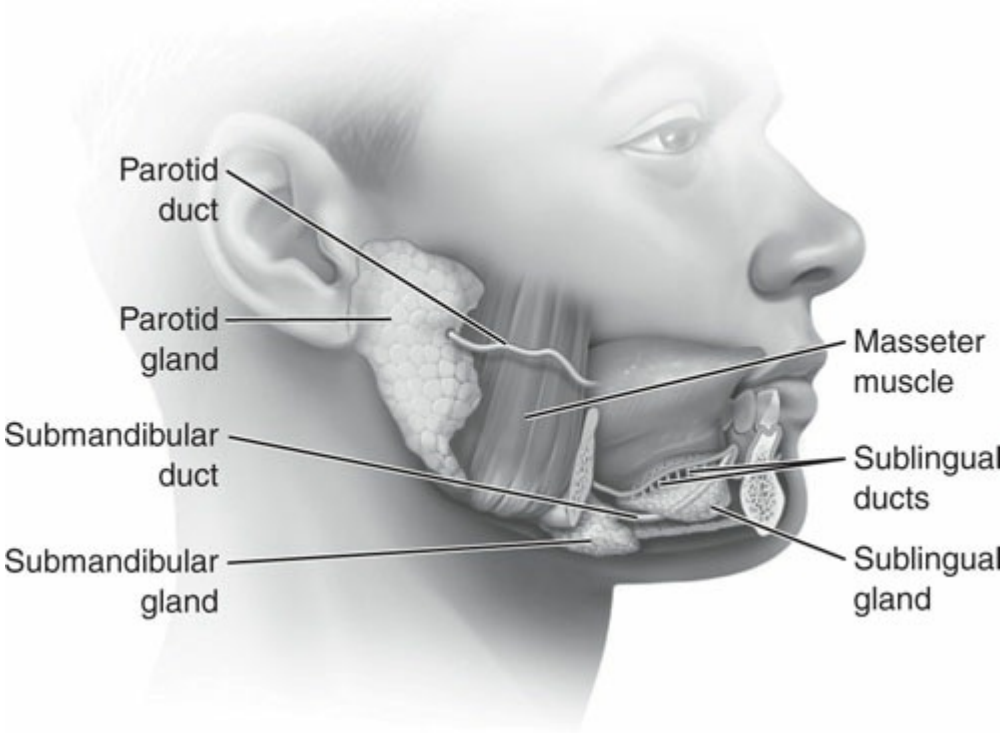


Figure 12-1 Salivary gland anatomy.

Sonography and Pathology of the Salivary Glands

The salivary glands are most often imaged with a high-frequency linear transducer, although when the glands are enlarged, a lower frequency may be required. For superficial masses, a stand-off device may be needed. When abnormalities of the salivary glands are suspected, it is best to image both sides for comparison because many diseases impact both glands.

The salivary glands are typically hyperechoic compared to the adjacent musculature (Fig. 12-2). Especially when dilated, the ducts of the glands may be recognized as anechoic tubular structures. Color flow should be used to delineate ducts from vasculature. The salivary glands should be imaged in both sagittal and transverse planes. The parotid gland will appear elliptical in the sagittal plane and round in the transverse plane. The sublingual glands are round as well, whereas the submandibular glands are more of a triangular shape. Pathology of the salivary glands includes Sjögren syndrome, sialadenosis (sialoadenosis), sialolithiasis, and sialadenitis (sialoadenitis). A brief summary of these pathologies and others are provided in Table 12-1. Especially when malignancy is suspected, an evaluation of the cervical lymphatic chain should be performed.



SOUND OFF
The word part “sial(o)” means saliva.

THE NECK

Anatomy and Physiology of the Thyroid Gland

The thyroid gland is a crucial endocrine gland that develops within the third week of gestation. In the embryo, the thyroid begins its initial development at the base of the tongue. It descends down the thyroglossal duct to ultimately rest anterior to the trachea. It is fully functional by the end of the first trimester. The thyroid consists of a right and a left lobe. A bridge of tissue, the isthmus, crosses over the midline of the neck anterior to the trachea, providing a link between the two thyroid lobes. Occasionally, individuals may have a superior extension of the isthmus. This normal variant is termed a pyramidal lobe. Agenesis of a lobe may also occur.

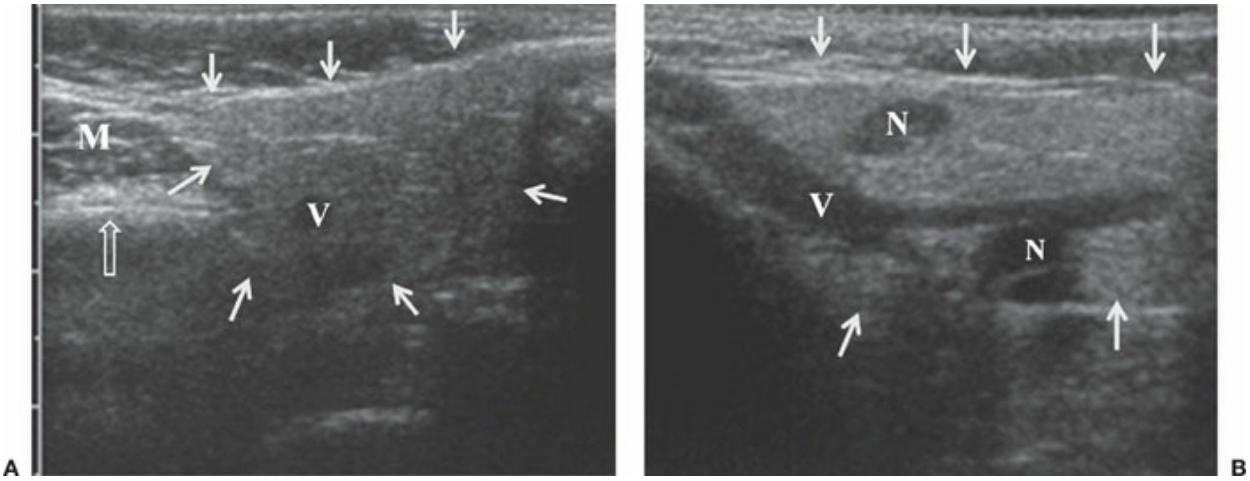


Figure 12-2 Normal parotid gland. **A.** In the transverse scan plane, which is perpendicular to the earlobe, the parotid gland (*arrows*) is ovoid in shape and hyperechoic to the adjacent muscle (*M*). **B.** In the longitudinal plane, the parotid gland is elliptical in shape. The mandibular vein (*V*) can be seen in both images, as well as several lymph nodes (*N*).

TABLE 12-1 Pathology of the salivary glands

Pathology	Explanation	Sonographic Appearance
Sjögren syndrome	An autoimmune disease that affects all glands that produce moisture; leads to dysfunction of the salivary glands and severe dryness of the eyes, nose, skin, and mouth.	Heterogeneous, hyperemic, visibly enlarged, and may contain diffuse hypoechoic regions.
Sialadenitis	Inflammation of the salivary gland(s).	Heterogeneous, hyperemic, visibly enlarged, and may contain diffuse hypoechoic regions.
Sialolithiasis	Salivary duct stones; most commonly located within the submandibular gland.	Dilated duct containing a shadowing, echogenic focus or foci.
Sialadenosis	Benign, painless enlargement of the salivary gland; usually affects both parotid glands.	Enlarged gland without hypervascularity
Pleomorphic adenoma (see Fig. 12-3)	Benign and most frequent tumor of the salivary glands; most commonly seen in the parotid gland.	Hypoechoic mass; biopsy is often warranted
Mucoepidermoid carcinoma (see Fig. 12-4)	Most common malignancy of the salivary glands; typically starts in the parotid gland.	Hypoechoic or heterogeneous mass with moderate to marked internal vascularity; biopsy is

The hypothalamus, located within the brain, produces thyroid-releasing hormone, which in turn controls the release of thyroid-stimulating hormone (TSH) by the anterior pituitary gland. The thyroid consists of multiple follicles that contain a fluid called colloid. Colloid is composed of proteins and thyroid hormones. As a result of the TSH released by the pituitary gland, the thyroid, in turn, releases the hormones contained within its cells. These hormones are thyroxine (T_4), triiodothyronine (T_3), and calcitonin (Table 12-2).

SOUND OFF
The thyroid uses iodine to produce its hormones.

The thyroid utilizes iodine to manufacture its hormones. Iodine is found in some vegetables, seafood, and within many processed foods that contain iodized salt. Accordingly, the subscripted numbers “3” and “4” found in the thyroid hormones denote the number of iodine atoms contained within each hormone. Thyroxine is the most abundant hormone produced by the thyroid. However, each hormone is vital, and they work together to regulate metabolism, growth and development, and the activity of the nervous system. A surplus of these hormones will produce hyperthyroidism and a reduction will cause hypothyroidism.

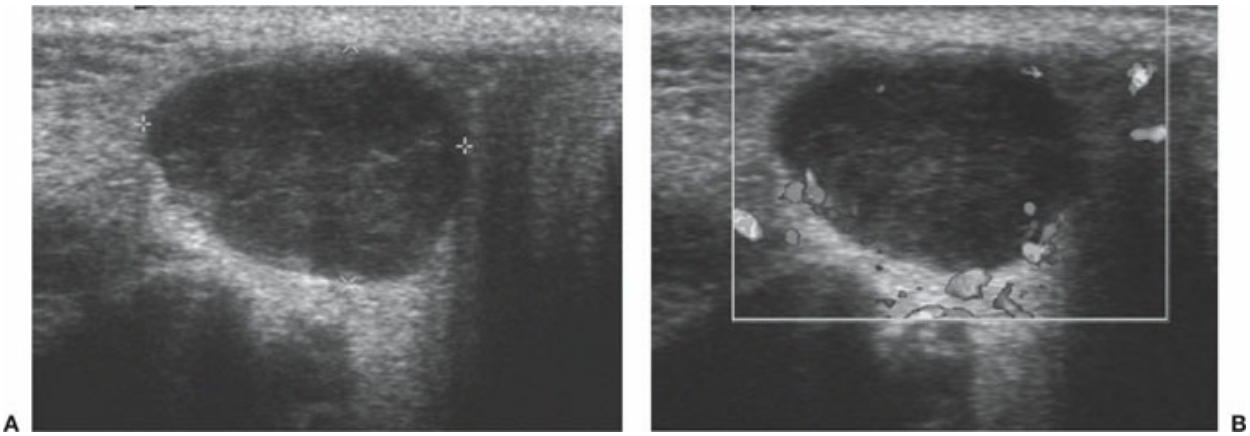


Figure 12-3 Pleomorphic adenoma. **A.** This hypoechoic mass (*between calipers*) was noted in the parotid gland and was diagnosed as a pleomorphic adenoma. **B.** Color Doppler image reveals flow around the mass, but not much within it. (Color image provided online.)

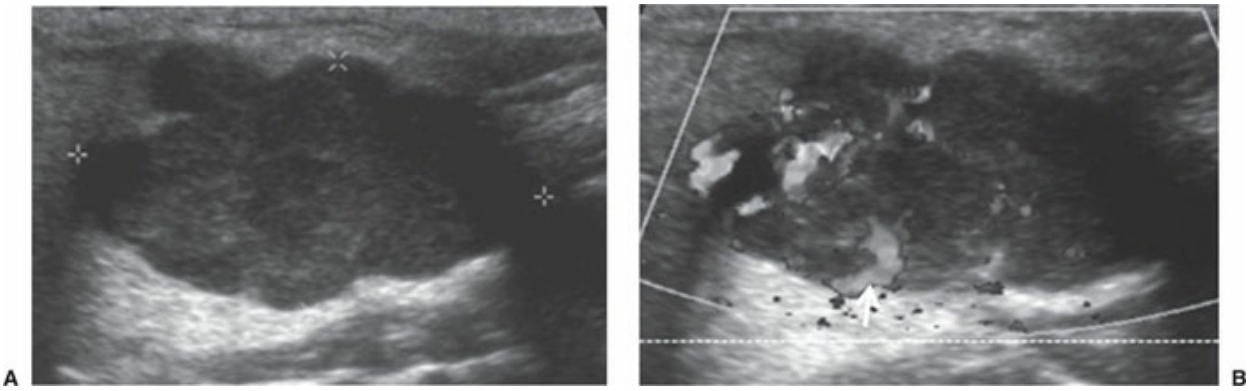


Figure 12-4 Salivary gland cancer. **A.** This hypoechoic mass has lobulated borders. It was identified as salivary gland cancer after biopsy. **B.** Color Doppler reveals extensive blood flow within the mass. (Color image provided online.)

TABLE 12-2 The three thyroid hormones and their functions

Thyroid Hormone	Function
Thyroxine (T_4)	Aids in the metabolism of fats, proteins, and carbohydrates
Triiodothyronine (T_3)	Aids in the metabolism of fats, proteins, and carbohydrates
Calcitonin	Responsible for removing calcium from the blood for storage in the bones

SOUND OFF
The most abundant hormone of the thyroid gland is thyroxine.

Vascular Anatomy of the Thyroid Gland and Neck

Two prominent vascular structures can be seen lateral to the thyroid gland: the common carotid artery and the internal jugular vein. The most medial vessel is the common carotid artery. The common carotid arteries branch into internal and external carotid arteries above the thyroid gland. The superior thyroid artery is the first branch of the external carotid artery. The inferior thyroid artery is a branch of the thyrocervical trunk of the subclavian artery. These arteries have corresponding thyroid veins that drain into the internal jugular vein. The jugular veins are located superior and lateral to the common carotid arteries.

TABLE 12-3 Surrounding structures of the thyroid gland

Structure	Relationship to Thyroid Gland
Strap muscles (sternohyoid, sternothyroid, thyrohyoid, and omohyoid)	Anterior to each lobe
Sternocleidomastoid muscles	Lateral to each lobe
Longus colli muscles	Posterior to each lobe
Common carotid artery	Lateral to each lobe
Internal jugular vein	Lateral to each lobe Superior and lateral to each common carotid artery
Esophagus	Most often seen on the left side posterior to the trachea and thyroid

Sonography of the Thyroid and Neck

A thyroid sonogram can be ordered for various clinical reasons, including a palpable mass found within the neck, abnormal laboratory findings, and as a follow-up examination from nuclear medicine studies and other diagnostic imaging studies. Before beginning the examination, the sonographer should determine whether there are any palpable nodules by standing behind the patient and palpating the thyroid gland. A thyroid and neck sonogram is performed with a high-frequency linear transducer. The patient should be in the supine position, with the neck extended. Normal thyroid tissue is homogenous and consists of medium- to high-level echogenicities similar to that of the testes.

Images are obtained in both the sagittal and transverse planes of each lobe and of the isthmus. Each adult pear-shaped lobe measures approximately 4 to 6 cm in length, 2 to 3 cm in width, and 1 to 2 cm in thickness, with the right lobe typically being the largest. The isthmus normally measures between 2 and 6 mm in the anteroposterior dimension. A thyroid volume can be calculated using the following formula: length × width × thickness × 0.529. A sonographic examination of the entire neck should also be performed for enlarged lymph nodes or masses. Some institutions may require an analysis of various regions of the neck for classification, as suggested by the American Institute of Ultrasound in Medicine (see “Cervical Lymph Nodes and the Postsurgical Neck” section).

There are several prominent muscles and vascular structures that delineate the margins of the thyroid gland (Table 12-3; Fig. 12-5). The neck muscles, which appear more hypoechoic than the normal thyroid tissue, are easily seen with sonography. The thin infrahyoid or strap muscles, which include the sternohyoid, sternothyroid, thyrohyoid, and omohyoid, are found anterior to

the thyroid gland. The much larger sternocleidomastoid muscles pass lateral to the thyroid lobes. The longus colli muscles are seen posterior to each lobe. The common carotid artery and internal jugular vein will be seen lateral to each lobe as anechoic tubes in the longitudinal plane and circles in the transverse plane. The esophagus lies posterior to the thyroid gland, most often on the left side, and can often resemble a mass. To differentiate the esophagus from a mass, one can have the patient swallow. Upon real-time observation of swallowing, the saliva can be visualized passing through the esophagus.

SOUND OFF
To differentiate the esophagus from a mass, have the patient swallow. Upon real-time observation of swallowing, the saliva can be visualized passing through the esophagus.

Each thyroid lobe should be evaluated using color Doppler because increase vascularity or hyperemia may be evident with Graves disease and Hashimoto thyroiditis, both of which are discussed further in this chapter. Identified thyroid lesions should be further analyzed with color Doppler. Also, when technically pertinent, elastography may be performed as an adjunct to grayscale imaging to further characterize thyroid lesions based on stiffness properties. With elastography, a relative stiffness is obtained in relationship to the surrounding tissue. Softer lesions tend to be more likely benign, whereas harder lesions tend to be more likely malignant. Fine needle aspiration (FNA) is a highly efficient way to determine the characteristics of clinically palpable and sonographically identifiable thyroid nodules. The use of sonographic guidance for FNA is especially beneficial. During this minimally invasive procedure, the tissue is identified with sonography, and a small needle is inserted into the nodule. A FNA is considered a low-risk procedure.

SOUND OFF
Both Graves disease and Hashimoto thyroiditis yield increased vascularity within the thyroid with color Doppler interrogation.

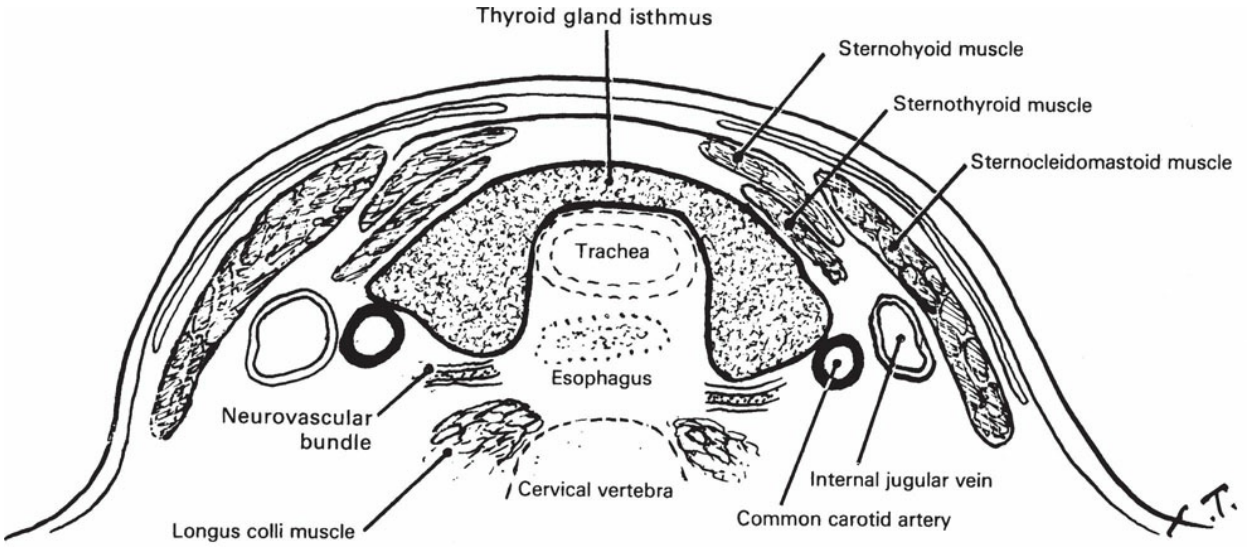


Figure 12-5 Neck anatomy. Transverse anatomy of the neck.

THYROID PATHOLOGY

Goiter

A goiter is defined as an enlarged, hyperplastic thyroid gland. It has many causes, including iodine deficiency, Graves disease, and thyroiditis. Clinically, patients with a goiter often have a palpable (and often visually) enlarged thyroid gland. The enlarged gland can cause a feeling of tightening in the throat, dysphagia, dyspnea, coughing, and hoarseness. Thyroid enlargement can be diagnosed by calculating volume measurements or by obtaining an anteroposterior thickness of the thyroid isthmus. An isthmus that measures greater than 1.0 cm may be indicative of thyroid enlargement (Fig. 12-6). Sonographically, the thyroid will appear enlarged and heterogeneous. The enlarged thyroid gland that contains multiple nodules with cystic and solid components may be referred to as a multinodular goiter or adenomatous goiter.

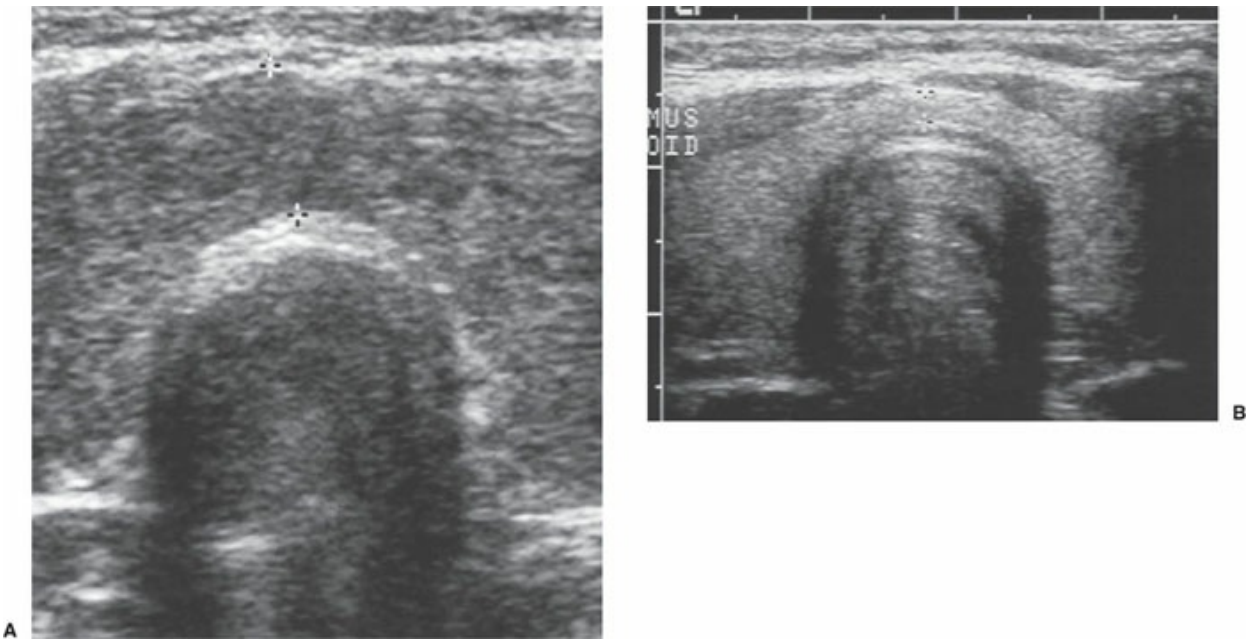


Figure 12-6 Thickened thyroid isthmus. **A.** The thyroid isthmus measured 13 mm (*between calipers*), which is indicative of a goiter. **B.** A normal thyroid gland and thyroid isthmus (2 mm) are shown in comparison (*between calipers*).

CLINICAL FINDINGS OF A GOITER

1. Palpable (and possibly visually) enlarged thyroid gland
2. Dyspnea
3. Dysphagia
4. Feeling of tightening in the throat
5. Coughing
6. Hoarseness

SONOGRAPHIC FINDINGS OF A GOITER

1. Enlarged thyroid gland (isthmus that exceeds 1 cm in the anteroposterior plane)
2. Diffusely heterogeneous echotexture
3. Multiple nodules with cystic and solid components

SOUND OFF

Goiter is the general term for thyroid enlargement that can result from inadequate iodine intake. However, there can be other underlying causes.

Graves Disease and Hyperthyroidism

Hyperthyroidism is a condition that results from the overproduction of thyroid hormones. Clinical findings in individuals suffering from hyperthyroidism include bulging eyes, heat intolerance, nervousness, weight loss, and hair loss (Fig. 12-7). Graves disease, which may also be referred to

as a diffuse toxic goiter, is the most common cause of hyperthyroidism. Sonographically, the thyroid may appear diffusely heterogeneous or hypoechoic (Fig. 12-8). Hypervascularity may be noted with color Doppler imaging within the thyroid gland. This is termed the "thyroid inferno."

CLINICAL FINDINGS OF GRAVES DISEASE

1. Bulging eyes
2. Heat intolerance
3. Nervousness
4. Weight loss
5. Hair loss

SONOGRAPHIC FINDINGS OF GRAVES DISEASE

1. Enlarged gland
2. Heterogeneous or diffusely hypoechoic echotexture
3. Thyroid inferno

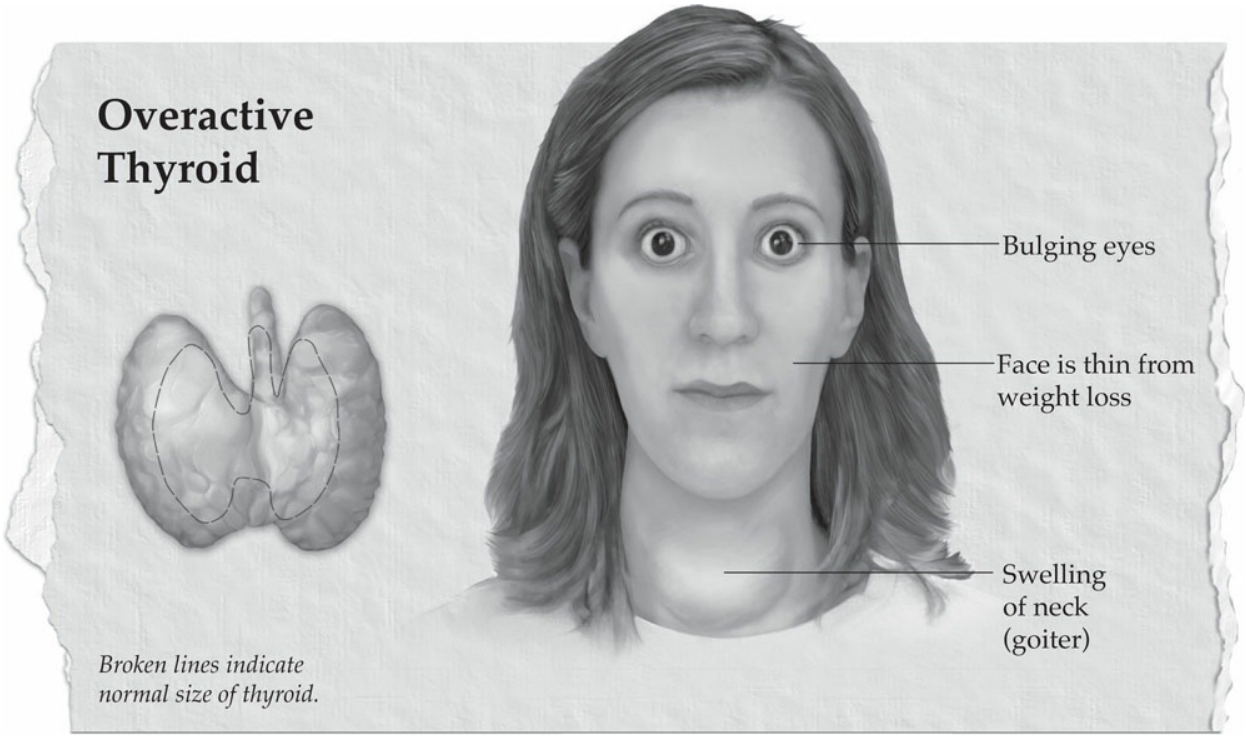


Figure 12-7 Several clinical findings of an overactive thyroid or hyperthyroidism.

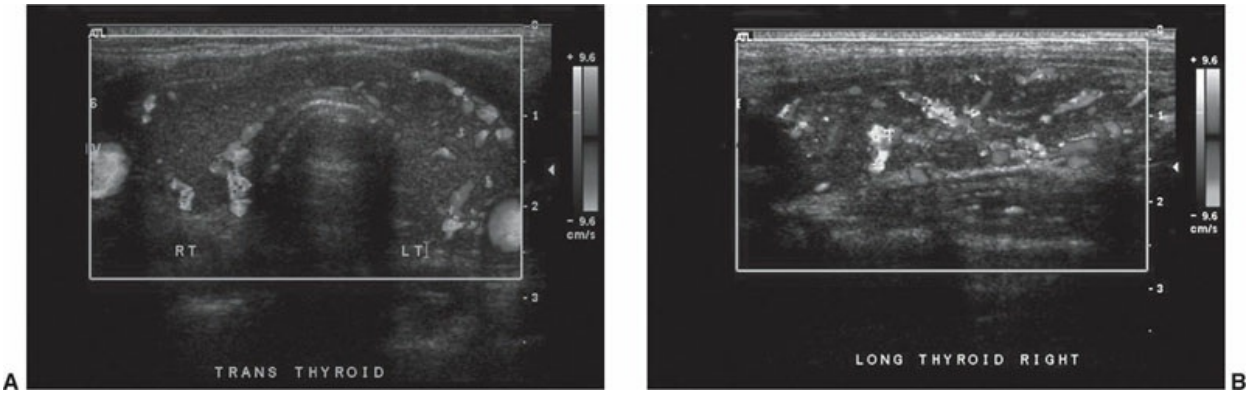


Figure 12-8 Hyperthyroidism. Transverse (**A**) and longitudinal (**B**) images with color Doppler in a patient with hyperthyroidism revealing hyperemia. (Color image provided online.)

SOUND OFF
Graves disease is the most common cause of hyperthyroidism. To recall this, remember that both Grav***e***s and hyp***e***rthyroidism both contain the letter "***e***."

Hashimoto Thyroiditis and Hypothyroidism

Hypothyroidism is a condition that results from the underproduction of thyroid hormones. Hashimoto thyroiditis is an autoimmune disease, which is the most common cause of hypothyroidism in the United States. It may also be referred to as chronic autoimmune lymphocytic thyroiditis. With Hashimoto disease, the thyroid becomes inflamed, and, as a result, the thyroid produces smaller amounts of thyroid hormones. In order to compensate, the pituitary gland releases more TSH, which causes the thyroid to become enlarged. Clinically, many patients are asymptomatic in the early stages of the disease. However, as the disease progresses, they may present with puffiness under the eyes, puffy face, dry skin, slight weight gain, depression, increased cold sensitivity, and elevated blood cholesterol levels (Fig. 12-9). The end-stage of the disease may actually lead to fibrosis and atrophy of the gland. Sonographically, the thyroid will appear diffusely heterogeneous, coarse, and mildly enlarged with increased vascularity within the gland (Fig. 12-10). Oftentimes, multiple, ill-defined hypoechoic regions separated by fibrous hyperechoic tissue will be demonstrated with Hashimoto thyroiditis.

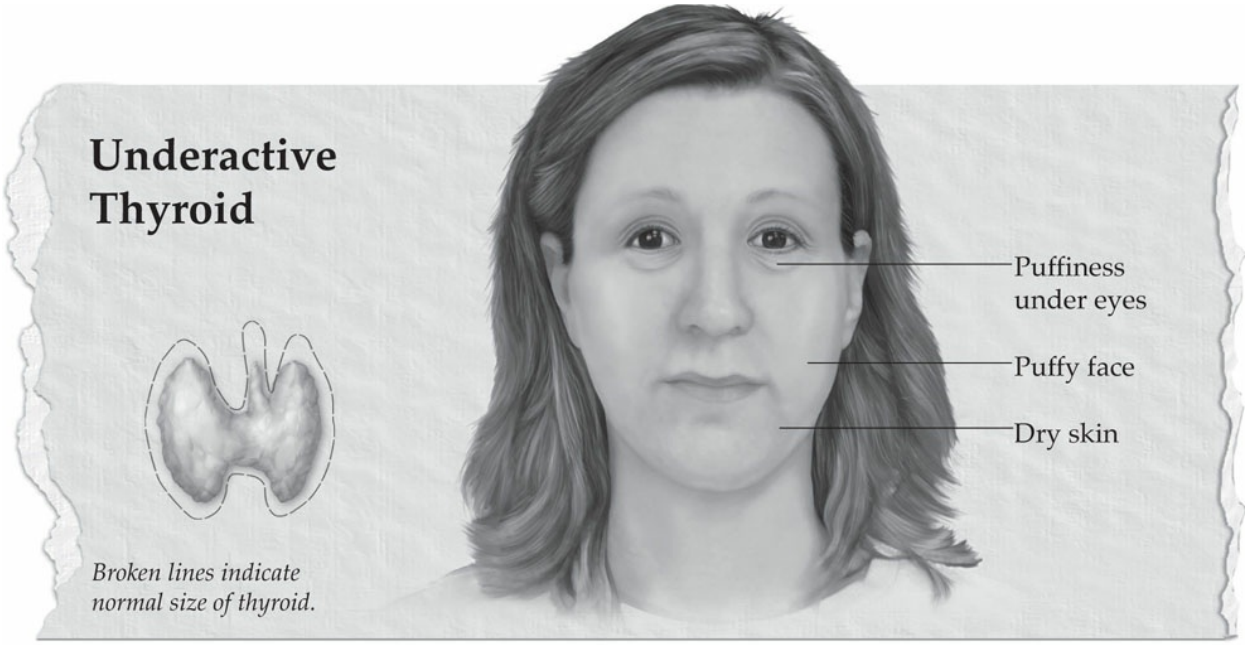


Figure 12-9 Hypothyroidism. Several clinical findings of an underactive thyroid or hypothyroidism. The end-stage of hypothyroidism may actually lead to atrophy of the gland as depicted in this figure.

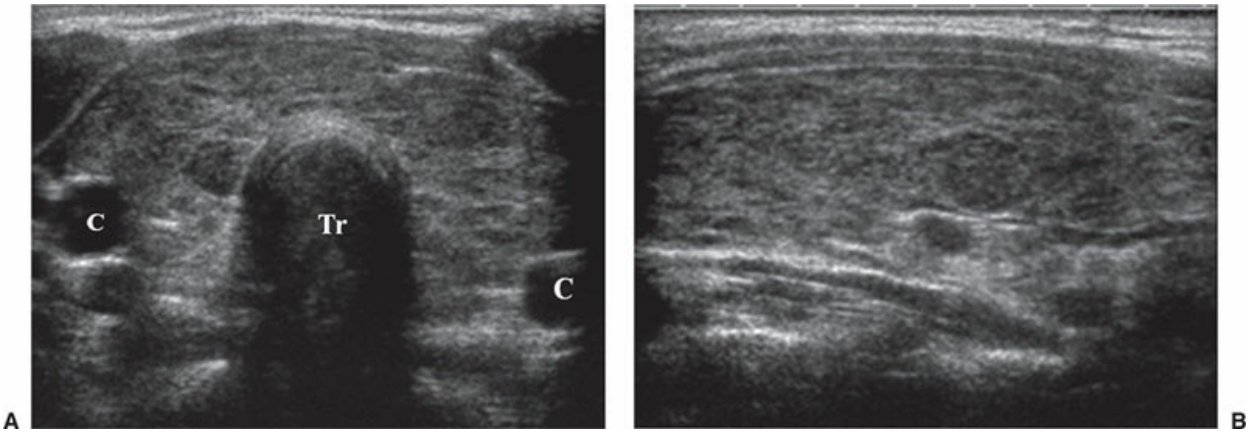


FIGURE 12-10 Hashimoto thyroiditis. **A.** Transverse image of the thyroid gland in a patient with hypothyroidism revealing a diffusely coarse, heterogeneous gland. The trachea (*Tr*) and carotid arteries (*C*) are also demonstrated. **B.** Longitudinal image of the same patient.

CLINICAL FINDINGS OF HASHIMOTO THYROIDITIS

1. Depression
2. Increased cold sensitivity
3. Elevated blood cholesterol levels
4. Slight weight gain may occur
5. Puffy face and puffiness under the eyes

SONOGRAPHIC FINDINGS OF HASHIMOTO THYROIDITIS

1. Mild enlargement of the thyroid gland (initially)
2. Heterogeneous echotexture
3. Multiple, ill-defined hypoechoic regions separated by fibrous hyperechoic tissue
4. Hypervascular gland

SOUND OFF
Hashimoto thyroiditis is the most common cause of hypothyroidism. To recall this, remember that both Hashim***o***t***o*** and hyp***o***thyroidism both contain the letter "***o***."

Benign Thyroid Nodules

Given that between 10% and 41% of all adults have sonographically identifiable thyroid nodules, they are very common. Benign thyroid nodules are the most common masses identified within the thyroid gland with sonography. They can be considered follicular adenomas, adenomatous or hyperplastic nodules, or colloid nodules. Follicular adenomas are most often small, round, and can have varying sonographic appearances, including completely anechoic, isoechoic, or hyperechoic (Fig. 12-11). They may also have a surrounding halo. Nodular hyperplasia is the most common cause of thyroid nodules. Hyperplastic nodules, also referred to as adenomatous nodules, are almost always multiple and also have varying sonographic appearances.

TABLE 12-4 Benign characteristics of thyroid nodules

Extensive cystic components
Cysts <5 mm
Hyperechoic mass
"Eggshell" calcifications
"Hot" nodule (nuclear medicine finding)

Many benign thyroid masses have cystic components. Within the cystic component of these masses, especially colloid cysts, a hyperechoic focus or foci may be seen, which may produce comet-tail artifact (Fig. 12-12). Sonographic features of benign thyroid nodules are listed in Table 12-4, although benign and malignant features can overlap and no single feature can be used to delineate benign versus malignant thyroid nodules. While many benign nodules are small and incidentally noted, large nodules may become palpable and impinge upon neighboring structures, consequently leading to

dysphagia or general neck discomfort.

Malignant Thyroid Nodules

Papillary carcinoma is the most common form of thyroid cancer. Other forms of thyroid malignancies include follicular carcinoma, medullary carcinoma, anaplastic carcinoma, lymphoma, and metastases of the thyroid. It is difficult to diagnose malignant thyroid nodules with sonography; however, there are some distinct features that increase the likelihood of the nodule being malignant (Table 12-5; Fig. 12-13). It is important to note that the presence of microcalcifications within a thyroid mass seems to increase the likelihood of a malignancy. These structures may be referred to as psammoma bodies, which are round calcific deposits that appear sonographically as punctate, hyperechoic foci without acoustic shadowing. A solitary, hypoechoic mass is also suspicious. Elastography can be used as an adjunct to grayscale imaging. With elastography, stiffer masses, in comparison to the tissue around them, in general have an increased risk for malignancy.

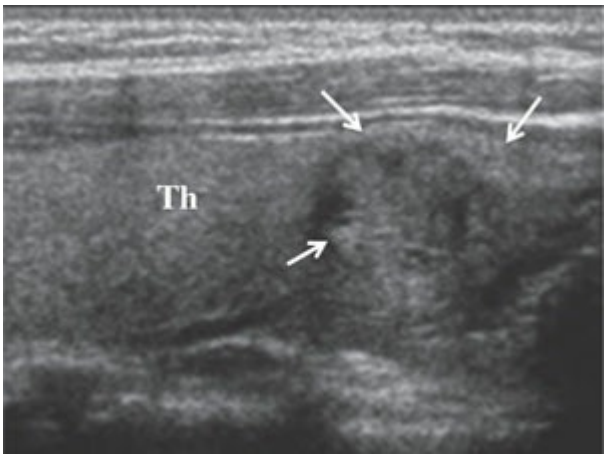


Figure 12-11 Benign thyroid nodule. Longitudinal image of a thyroid (*Th*) adenoma (*arrows*).

TABLE 12-5 Malignant characteristics of thyroid nodules

Hypoechoic mass
Taller-than-wide shape
Mass with internal microcalcifications (psammoma bodies)
Solitary mass
Marked vascularity within the central part of the nodule
Interrupted peripheral calcification
Extracapsular invasion
Lobulated margins
Enlargement of the cervical lymph nodes (metastasis)

Nuclear Medicine and Thyroid Nodules

Nuclear medicine utilizes scintigraphy to classify thyroid nodules as either hyperfunctioning or hypofunctioning. This examination includes the injection of a radiopharmaceutical that is high in iodine. Because the thyroid utilizes iodine to create its hormones, the drug is absorbed by the thyroid gland. Images are obtained with a camera that detects radioactivity within the neck. The thyroid tissue, along with thyroid nodules, is displayed on the image obtained. Hyperfunctioning or "hot nodules" yield dark areas on a thyroid scan, whereas hypofunctioning or "cold nodules" yield light or blank areas on the scan. Most cancers are hypofunctioning nodules and will therefore appear as cold nodules, although not all cold nodules are malignant (Fig. 12-14). Although sonography and nuclear medicine can work together to establish the characteristics of a nodule, in almost all situations, an FNA is needed to obtain the most definitive diagnosis.

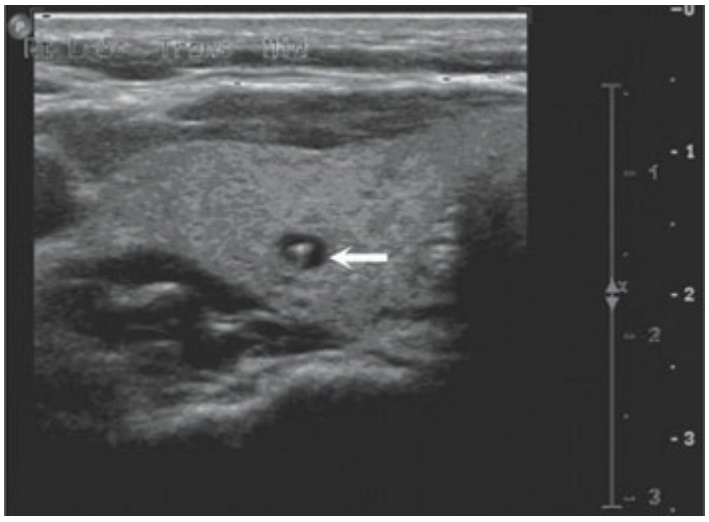


Figure 12-12 Colloid cyst. Transverse image of the thyroid revealing a small colloid cyst (*arrow*) with a small, hyperechoic focus contained within it that is producing comet-tail artifact.

ANATOMY, PHYSIOLOGY, AND PATHOLOGY OF THE PARATHYROID GLANDS

There are typically two pairs of parathyroid glands, although some individuals may have a fifth gland. Their locations are variable. However, commonly one is located near the posterior aspect of the midportion of each lobe, and one is often positioned inferior to each lobe. Normal parathyroid

glands will measure 5.0 mm × 3.0 mm × 1.0 mm, and their sonographic appearance is similar to the thyroid tissue. The parathyroid glands serve as calcium regulators for the body. The parathyroid glands control the release and absorption of calcium by producing parathyroid hormone (PTH). An elevated level of calcium is referred to as hypercalcemia, whereas a low level is hypocalcemia. Thus, hyperparathyroidism can cause hypercalcemia, and hypoparathyroidism can cause hypocalcemia.

Parathyroid Adenoma

A parathyroid adenoma is the most common cause of enlargement of a parathyroid gland. Patients with a parathyroid adenoma will present with elevated serum calcium levels and PTH (hyperparathyroidism). Sonographically, a parathyroid adenoma appears as a solid mass that will most likely be hypoechoic to the adjacent thyroid gland.

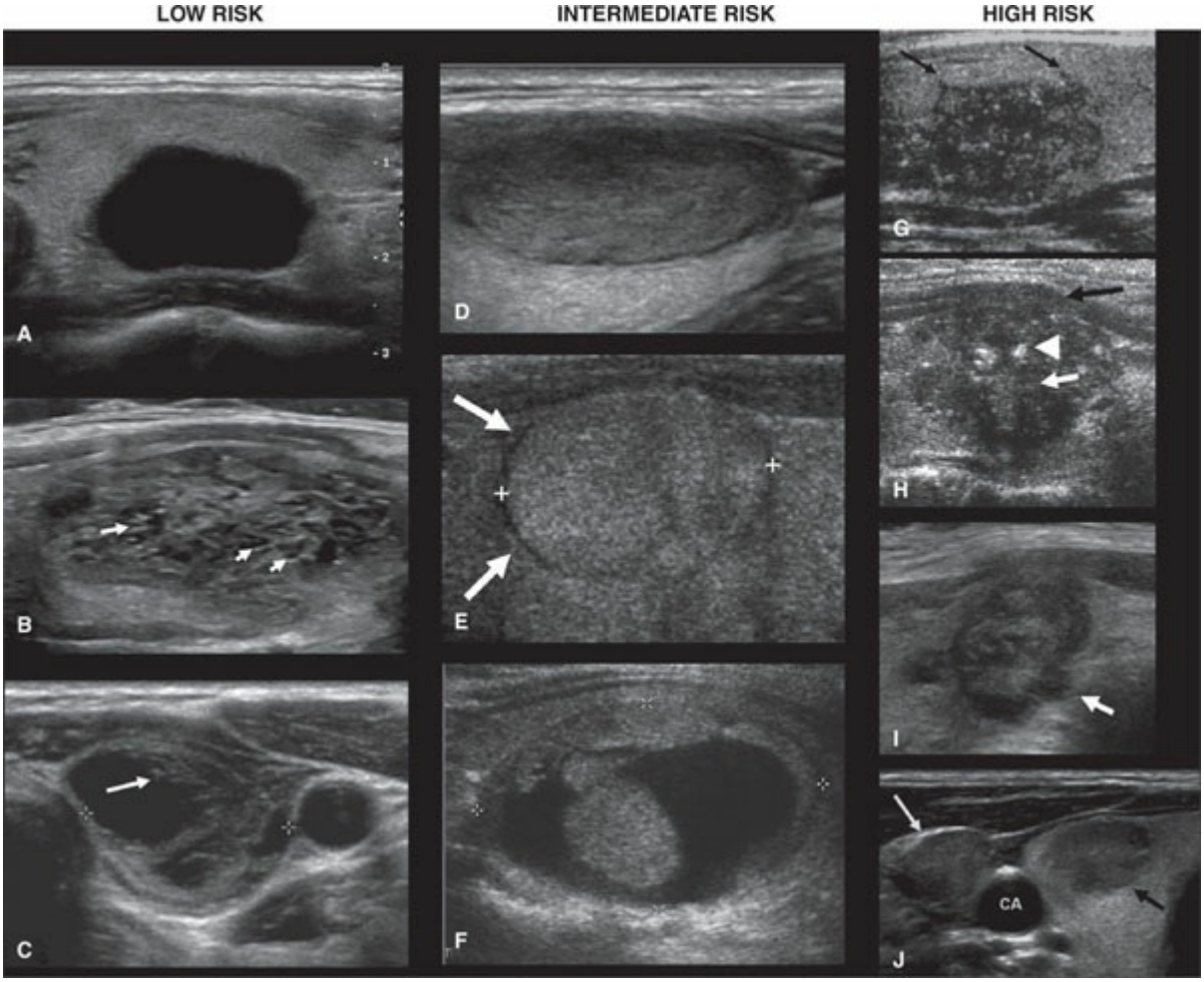


Figure 12-13 Nodules with low-, intermediate-, and high-risk sonographic appearances of thyroid cancer. **A.** A completely anechoic nodule. **B.** A nodule with both solid tissue and cystic areas (*arrows*). **C.** A complex cyst with echogenic foci that produce comet-tail artifact (*arrow*). **D.** A large hypoechoic mass. **E.** An isoechoic nodule with a hypoechoic halo (*arrows*). **F.** A large cystic nodule with solid mural or

wall elements. **G.** A hypoechoic nodule that contains small echogenic foci and that is invading the surrounding tissue (*black arrows*). **H.** An invasive, hypoechoic nodule with varying size calcifications (*arrowhead*) that can produce acoustic shadows (*arrow*). **I.** A hypoechoic nodule that is taller-than-wide and has irregular borders (*arrow*). **J.** Hypoechoic nodule (*black arrow*) with metastasis to an area lymph node (*white arrow*).

SOUND OFF

If the patient has elevated serum calcium (hypercalcemia), analyze the neck carefully for signs of a parathyroid adenoma.

CLINICAL FINDINGS OF A PARATHYROID ADENOMA

1. Elevated serum calcium
2. Elevated PTH

SONOGRAPHIC FINDINGS OF A PARATHYROID ADENOMA

1. Hypoechoic mass adjacent to the thyroid

OTHER NECK PATHOLOGY

Cervical Lymph Nodes and the Postsurgical Neck

Enlargement of the cervical lymph nodes, or cervical lymphadenopathy, can be established sonographically. These structures, which normally measure less than 1 cm, are often recognized during a routine sonographic examination of the neck. They are typically oblong-shaped hypoechoic structures with a distinguishable echogenic hilum. Abnormal lymph nodes can result from infections and malignancy. Sonographically, abnormal lymph nodes will appear enlarged, measuring greater than 1 cm. They may also be more rounded in shape, lose their normal hilar feature, contain calcifications, or demonstrate abnormal vascular patterns (Fig. 12-15). The postsurgical neck sonogram—especially in those who require imaging following a thyroidectomy because of cancer—should include a thorough examination of the neck for lymphadenopathy (i.e., metastatic disease to the nodes). An analysis of the nodal regions of the neck for classification may be required by some institutions (Fig. 12-16).

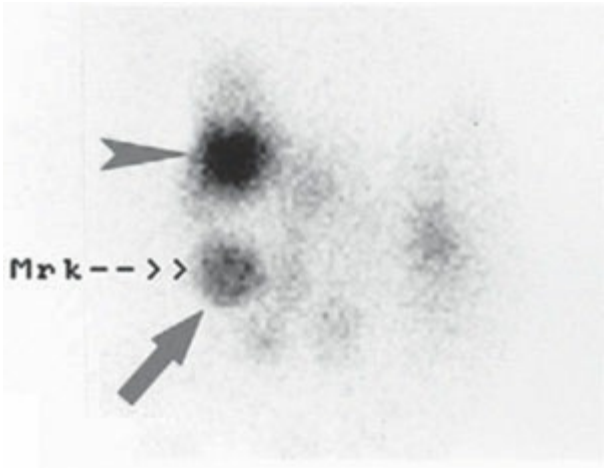


Figure 12-14 Nuclear medicine images of thyroid nodules. A radioactive marker (*Mrk*) was placed over a 2-cm palplable nodule (*arrow*) in the right thyroid lobe. This nodule represents a “hot” nodule, which is most likely benign.

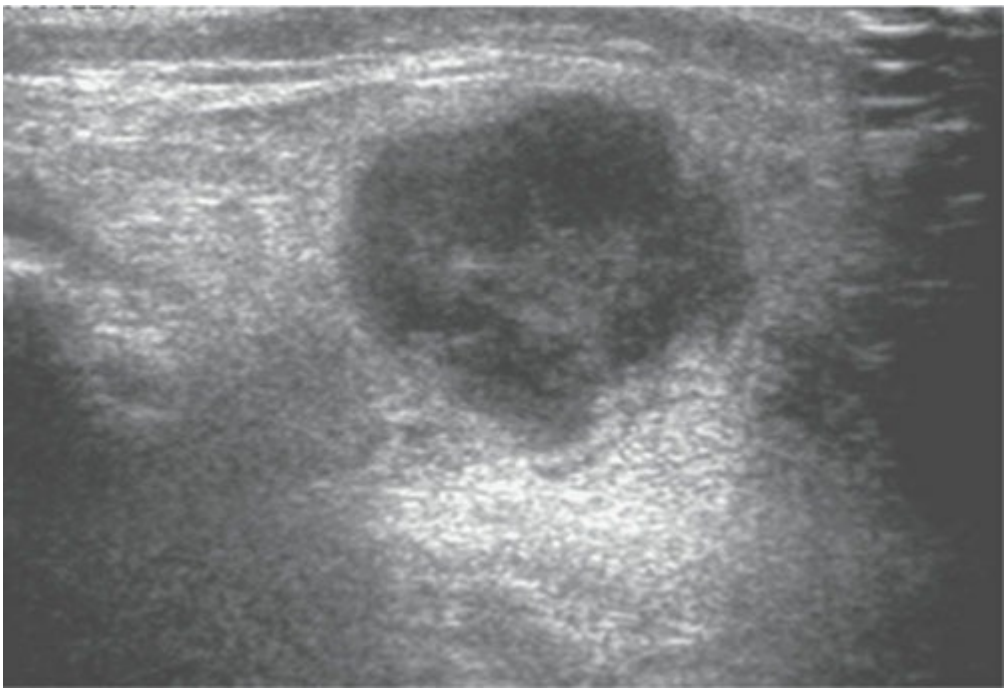


Figure 12-15 Abnormal lymph node. This lymph node is enlarged, hypoechoic, and has lost its echogenic hilum.

CLINICAL FINDINGS OF ABNORMAL LYMPH NODES

1. Palpable neck mass (possibly)
2. Enlarged nodes may be painful

SONOGRAPHIC FINDINGS OF ABNORMAL LYMPH NODES

1. Enlargement of the node >1 cm
2. Rounded shape
3. Loss of the echogenic hilum

4. Calcifications
5. May be hyperemic or demonstrate abnormal vascular patterns with color Doppler

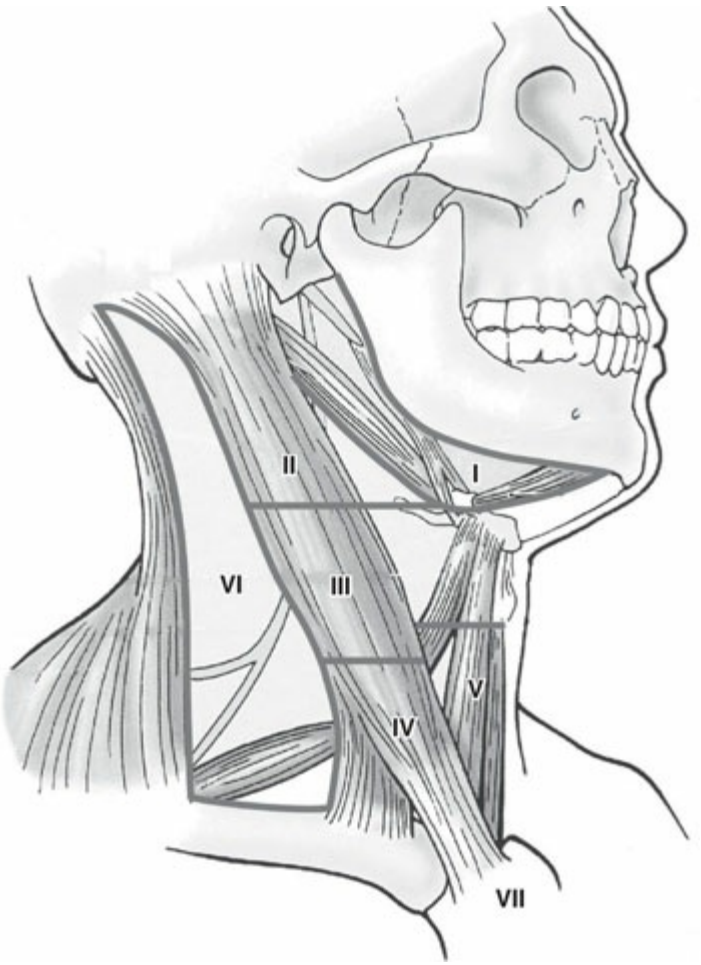


Figure 12-16 Lymph node regions.

Other Neck Masses

Thyroglossal duct cysts are benign congenital cysts located within the midline of the neck superior to the thyroid gland and are typically located below the level the hyoid bone. They are most often asymptomatic, although they may become painful when inflamed. Sonographically, a simple thyroglossal duct cyst will appear as an anechoic, well-defined, and unilocular cyst with posterior enhancement. Complicated thyroglossal duct cysts will appear more complex. Branchial cleft cysts are congenital neck cysts as well. They are found most often near the angle of the mandible and appear as an anechoic mass with posterior enhancement.

Fibromatosis colli is a rare, pediatric fibrous tumor located within the sternocleidomastoid muscle. Although the cause is unknown, it is speculated that perhaps malposition in utero or a traumatic birth leads to the development of fibrosis (scar tissue) within the muscle. Because of the mass within the sternocleidomastoid muscle, the muscle shortens, resulting in the

twisting of the infant's chin toward the nonaffected side—termed congenital muscular torticollis. Sonographically, the mass will distort the normal shape of the muscle, often in a fusiform pattern, and may appear hypoechoic, hyperechoic, or even isoechoic to the adjacent tissue. It may also contain calcifications and yield a hyperemic blood flow pattern with color Doppler.

CLINICAL FINDINGS OF A THYROGLOSSAL DUCT CYST

1. Palpable mass within the midline of the neck superior to the thyroid gland
2. Infected cysts may be painful

SONOGRAPHIC FINDINGS OF A THYROGLOSSAL DUCT CYST

1. Anechoic, well-defined, and unilocular cyst with posterior enhancement
2. May have internal components

CLINICAL FINDINGS OF A BRANCHIAL CLEFT CYST

1. Palpable neck mass located near the angle of the mandible
2. Infected cysts may be painful

SONOGRAPHIC FINDINGS OF A BRACHIAL CLEFT CYST

1. Anechoic mass near the angle of the mandible

CLINICAL FINDINGS OF FIBROMATOSIS COLLI

1. Pediatric palpable neck mass
2. Torticollis (twisted neck with the chin angled to the nonaffected side)

SONOGRAPHIC FINDINGS OF FIBROMATOSIS COLLI

1. Fusiform-shaped mass within the sternocleidomastoid muscle that is hypoechoic, hyperechoic, or even isoechoic to the adjacent tissue
2. May also contain calcifications that shadow
3. May yield a hyperemic pattern with color Doppler

REVIEW QUESTIONS

1. A patient with hypercalcemia presents to the sonography department for a neck sonogram. What abnormality in the neck should be suspected?
   a. Parathyroid adenoma
   b. Parotid gland enlargement

c. Thyroid papillary carcinoma
d. Hashimoto thyroiditis

2. Benign congenital cysts located superior to the thyroid gland near the hyoid bone are referred to as:
a. Branchial cleft cysts
b. Follicular adenomas
c. Thyroglossal duct cysts
d. Parathyroid adenomas

3. Normally, how many parathyroid glands are found within the adult neck?
a. 3
b. 4
c. 6
d. 8

4. A cystic mass noted at the mandibular angle is most likely a:
a. Branchial cleft cyst
b. Follicular adenoma
c. Thyroglossal duct cyst
d. Parathyroid adenoma

5. Which of the following would more likely be a malignant thyroid nodule?
a. Cold nodule
b. Hot nodule

6. Parathyroid glands control the release and absorption of which nutrient?
a. Thyroxine (T_4)
b. Triiodothyronine (T_3)
c. Calcitonin
d. Calcium

7. A normal lymph node will not measure greater than:
a. 8 mm
b. 5 mm
c. 12 mm
d. 10 mm

8. With which of the following is elevated serum calcium associated?
a. Graves disease
b. Thyroglossal duct cyst

c. Parathyroid adenoma
d. Thyroid adenoma

9. Which of the following best describes the normal appearance of a cervical lymph node?
   a. A hypoechoic, oblong structure with a distinct echogenic hilum
   b. A rounded, echogenic structure with small calcifications
   c. A solid, hypoechoic mass that measures greater than 1 cm
   d. A solid, echogenic mass that measures less than 1 cm

10. Which abnormality is associated with the sonographic findings of a thyroid inferno?
   a. Hashimoto thyroiditis
   b. Graves disease
   c. Hyperparathyroidism
   d. Cervical lymphadenopathy

11. All of the following are sonographic findings of malignant thyroid nodules except:
   a. Internal calcifications
   b. Hyperechoic mass
   c. Cervical node involvement
   d. Solitary mass

12. All of the following are diagnostic findings of a likely benign thyroid nodule except:
   a. Anechoic nodule
   b. Eggshell calcification
   c. Hyperechoic nodule
   d. Cold nodule

13. Which of the following is the most common form of thyroid cancer?
   a. Follicular
   b. Anaplastic
   c. Lymphoma
   d. Papillary

14. What is the most common cause of hypothyroidism?
   a. Graves disease
   b. Hashimoto thyroiditis
   c. Papillary carcinoma
   d. Parathyroid adenoma

15. All of the following are sonographic findings of an abnormal lymph node except:
    a. Rounded shape
    b. Echogenic hilum
    c. Calcifications
    d. Enlargement

16. What is the most common cause of hyperthyroidism?
    a. Graves disease
    b. Hashimoto thyroiditis
    c. Papillary carcinoma
    d. Parathyroid adenoma

17. Which gland is located immediately anterior to the ear?
    a. Submandibular gland
    b. Sublingual gland
    c. Thyroid gland
    d. Parotid gland

18. Which muscle does fibromatosis colli mostly affect?
    a. Omohyoid
    b. Longus colli
    c. Sternocleidomastoid
    d. Infrahyoid

19. A 30-year-old patient presents to the sonography department for a thyroid sonogram with a history of weight loss, hair loss, and hyperthyroidism. You note that the patient has bulging eyes. What is the most likely diagnosis?
    a. Hashimoto thyroiditis
    b. Graves disease
    c. Hyperparathyroidism
    d. Cervical lymphadenopathy

20. The fluid produced by the thyroid gland that contains thyroid hormones is referred to as:
    a. Thyroxine
    b. Calcitonin
    c. Colloid
    d. Triiodothyronine

21. In the presence of Hashimoto thyroiditis, the thyroid produces:
    a. Too many thyroid hormones

b. Too much calcium
c. Too few thyroid hormones
d. Too much iodine

22. A 45-year-old female patient presents to the sonography department with a palpable neck mass 6 months following a thyroidectomy for papillary carcinoma. Which of the following would be the most likely etiology of the palpable mass?
a. Torticollis
b. Lymphadenopathy
c. Sialadenitis
d. Graves disease

23. Which of the following is the duct that drains the submandibular gland?
a. Stensen duct
b. Wharton duct
c. Seigel duct
d. Partridge duct

24. Which of the following does the thyroid gland utilize to produce its hormones?
a. Colloid
b. Iodine
c. Iron
d. Calcium

25. Which muscles are located posterior to each thyroid lobe?
a. Sternocleidomastoid
b. Longus colli
c. Sternohyoid
d. Omohyoid

26. Which muscles are located lateral to each thyroid lobe?
a. Sternocleidomastoid
b. Longus colli
c. Sternohyoid
d. Omohyoid

27. Which of the following is associated with congenital muscular torticollis?
a. Fibromatosis colli
b. Branchial cleft cyst
c. Pleomorphic adenoma
d. Sialadenosis

28. What structure may be confused for a thyroid or parathyroid mass because of its relationship to the trachea and the posterior aspect of the left thyroid gland?
    a. Esophagus
    b. Common carotid artery
    c. Internal jugular vein
    d. Sternothyroid

29. Which vascular structure is located closest to the thyroid lobes?
    a. External carotid vein
    b. External carotid artery
    c. Internal jugular vein
    d. Common carotid artery

30. A thyroid isthmus that measures greater than _____is indicative of thyroid enlargement.
    a. 8 mm
    b. 5 mm
    c. 12 mm
    d. 10 mm

31. Which of the following is the term for stones within the salivary duct?
    a. Sjögren syndrome
    b. Torticollis
    c. Cervical lymphadenopathy
    d. Sialolithiasis

32. Which muscles are located anterior to the thyroid gland?
    a. Sternocleidomastoid
    b. Longus colli
    c. Thyrocervical trunk
    d. Strap

33. What is the first branch of the external carotid artery?
    a. Internal carotid artery
    b. Optic artery
    c. Superior thyroid artery
    d. Inferior thyroid artery

34. Psammoma bodies are
    a. Hypoechoic structures
    b. Comet-tail artifacts emanating from inside a colloid mass

c. Punctate calcific deposits
d. Mural or wall nodules within a solid mass

35. All of the following are hormones produced by the thyroid except:
a. Thyroxine
b. Iodine
c. Triiodothyronine
d. Calcitonin

36. Which of the following is the hormone that is the most abundantly produced by the thyroid?
a. Thyroxine
b. Iodine
c. Triiodothyronine
d. Calcitonin

37. Which of the following is an autoimmune disease that affects the glands that produce moisture, leading to dysfunction of the salivary glands, and dryness of the eyes, nose, skin, and mouth?
a. Wharton syndrome
b. Sjögren syndrome
c. Stenson syndrome
d. Sialadenosis syndrome

38. What type of gland is the thyroid gland?
a. Endocrine
b. Exocrine
c. Both A and B
d. Neither A nor B

39. The superior extension of the thyroid isthmus is referred to as the:
a. Thyroglossal duct
b. Branchial cleft
c. Yodeler’s lobe
d. Pyramidal lobe

40. Which of the following is the most common form of salivary gland cancer?
a. Mucoepidermoid carcinoma
b. Papillary carcinoma
c. Ancillary carcinoma
d. Medullary carcinoma

SUGGESTED READINGS

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13 The Male Pelvis

Introduction

The male pelvis and relevant pathology, including that of the penis, testicles, scrotum, prostate, and seminal vesicles, are discussed in this chapter. Reviewers should especially have a thorough understanding of the vastly different sonographic features of testicular torsion and epididymitis.

Key Terms

adrenal rest—mass of ectopic adrenal tissue within the testicle; are associated with congenital adrenal hyperplasia or Cushing syndrome

alpha-Fetoprotein—a protein produced by the fetal yolk sac, fetal gastrointestinal tract, and the fetal liver; may also be produced by some malignant tumors

appendix epididymis—the testicular appendage located at the head of the epididymis

appendix testis—the testicular appendage located between the head of the epididymis and the superior pole of the testis

appendix vas—the testicular appendage located between the body and tail of the epididymis

"bell-clapper" deformity—the condition in which the patient lacks the normal posterior fixation of the testis and epididymis to the scrotal wall

benign prostatic hypertrophy—the benign enlargement of the prostate

gland

“blue dot” sign—the appearance of a torsed testicular appendage that can be observed as a blue dot just under the skin surface

Buck fascia—deep layer of fascia that covers the corpus cavernosa and corpus spongiosum of the penis

bulbourethral gland—gland that secretes pre-ejaculate fluid that lubricates the penile urethra prior to ejaculation; also referred to as the Cowper gland

chlamydia—a sexually transmitted disease that can lead to infection of the genitals

corpus cavernosa—paired erectile tissues of the penis

corpus spongiosum—component of erectile tissue of the penis that contains the urethra

Cowper gland—see key term bulbourethral gland

cremaster muscle—the muscle that raises the testicle

cryptorchidism—the condition of having an undescended testis or testicles

digital rectal examination—the medical procedure that requires the insertion of the finger into the rectum to palpate the prostate gland and lower gastrointestinal tract

ductus (vas) deferens—the tube that connects the epididymis to the seminal vesicles

ecchymosis—subcutaneous spot of bleeding

epidermoid cyst—small benign mass within the testicle that contains keratin

epididymal cyst—a cyst located anywhere along the length of the epididymis

epididymis—a coiled structure that is attached to the testicle and the posterior scrotal wall that is responsible for storing sperm

epididymitis—inflammation of all or part of the epididymis

epididymo-orchitis—inflammation of the epididymis and testis

germ cell tumor—a type of neoplasm derived from germ cells of the gonads; may be found outside of the reproductive tract

gonorrhea—sexually transmitted disease that leads to infection of the genitals

hematocele—a collection of blood within the scrotum

hematospermia—the presence of blood within the semen

human chorionic gonadotropin—hormone produced by the trophoblastic cells of the early placenta; may also be used as a tumor marker in nongravid patients and males

hydrocele—a fluid collection within the scrotum; most often found between

the two layers of the tunica vaginalis

idiopathic—from an unknown origin

inguinal canal—normal passageway in the lower anterior abdominal wall that allows for the passage of the spermatic cord into the scrotum

inguinal hernia—the protrusion of bowel or abdominal contents through the inguinal canal

Klinefelter syndrome—a condition in which a male has an extra X chromosome; characteristic features include small testicles, infertility, gynecomastia, long legs, and abnormally low intelligence

median raphe—the structure that separates the scrotum into two compartments externally

mediastinum testis—the structure that is formed by the tunica albuginea and contains the rete testis

nocturia—frequent urination at night

nutcracker syndrome—an anomaly where left renal vein entrapment occurs between the superior mesenteric artery and abdominal aorta

omentum—a fold of peritoneum

orchiopexy—the surgery that moves an undescended testis into the scrotum

orchitis—inflammation of the testis or testicles

pampiniform plexus—the group of veins in the spermatic cord

peripheral zone—the largest zone of the prostate and most common location for prostatic cancer

Peyronie disease—the buildup of fibrous plaque (scar tissue) and calcifications within the penis that results in a painful curvature

prostate-specific antigen—a protein produced by the prostate gland

prostatitis—inflammation of the prostate gland

pyocele—a pus collection within the scrotum

rete testis—a network of tubules that carry sperm from the seminiferous tubules to the epididymis

scrotal pearl—an extratesticular calculus

scrotum—sac of cutaneous tissue that holds the testicles

semen—a fluid that contains secretions from the testicles, seminal vesicles, and prostate gland

seminal vesicles—small glands located superior to the prostate gland and posterior to the base of the bladder, which secrete an alkaline-based fluid

seminiferous tubules—the location of spermatogenesis within the testicles

seminoma—the most common malignant neoplasm of the testicles

spermatic cord—the structure that travels through the inguinal canal and contains blood vessels, nerves, lymph nodes, and the cremaster muscle

spermatocele—a common cyst found most often in the head of the epididymis that is composed of nonviable sperm, fat, cellular debris, and lymphocytes

spermatogenesis—the production of sperm

testicular torsion—a condition that results from the arterial blood supply to the testicle being cut off secondary to the twisting of the testicular axis

transitional zone—the prostatic zone that is the most common site for benign prostatic hypertrophy

transurethral resection of the prostate—surgical procedure performed to treat benign prostatic hypertrophy in which prostatic tissue is removed to relieve urinary complications

tubular ectasia of the rete testis—the cystic dilation and formation of cysts within the rete testis

tunica albuginea—the dense connective tissue that is closely applied to each testicle; it is also located within the penis

tunica albuginea cysts—cysts located within the tunica albuginea surrounding the testis

tunica dartos—the structure that separates the scrotum into two separate compartments internally

tunica vaginalis—the paired serous coatings of the testis; hydroceles are most often found between the two layers of the tunica vaginalis

undescended testis—testicles that do not descend into the scrotum; also referred to as cryptorchidism

Valsalva maneuver—performed by attempting to forcibly exhale while keeping the mouth and nose closed

varicocele—a dilated group of veins found within the scrotum

vasectomy—a form of male contraception in which the vas deferens is surgically interrupted to prohibit the flow of sperm from the testicles

verumontanum—an elevated area within the prostatic urethra at which the ejaculatory ducts meet the urethra

Zinner syndrome—syndrome that consists of unilateral renal agenesis, ipsilateral seminal vesicle cyst, and ejaculatory duct obstruction

ANATOMY AND PHYSIOLOGY OF THE SCROTUM, TESTICLES, AND EPIDIDYMIS

The testicles begin to develop in the upper abdomen in the fetus near the kidneys and do not descend into the pelvis until the fourth week of gestation. By 28 weeks, the testicles descend into the scrotum. They may become trapped anywhere along this path and consequently never completely descend into the scrotum. This condition is known as cryptorchidism.

The normal adult testicles are located within a sac of cutaneous tissue called the scrotum. The scrotum is externally divided at the midline into two compartments by a structure known as the median raphe. Internally, it is divided by the tunica dartos. The scrotum provides a means for temperature control for the temperature-sensitive sperm. The cremaster muscle, a structure located within the spermatic cord, also alters the position of the testicle within the scrotum, which aids in their protection and temperature control.

The testes function as both endocrine glands and exocrine glands (Table 13-1). Spermatogenesis occurs within the seminiferous tubules that are found throughout each testicle. These tiny tubules converge into a structure called the rete testis, which is located within the mediastinum testis.

TABLE 13-1 Endocrine and exocrine functions of the testicles

Endocrine function (released directly into bloodstream)	Produce testosterone: determines male characteristics
Exocrine function (released through ducts)	Produce sperm: permits reproduction

Each testis is surrounded by a double layer of tissue called the tunica vaginalis, which consists of a parietal and closely applied visceral covering (Fig. 13-1). Hydroceles, or scrotal fluid collections, are most commonly found between the two layers of the tunica vaginalis. Beneath the layers of the tunica vaginalis, the testis is also intimately surrounded by a dense fibrous layer of tissue called the tunica albuginea. The tunica albuginea extends posteriorly and enters each testicle to help form the previously described mediastinum testis.

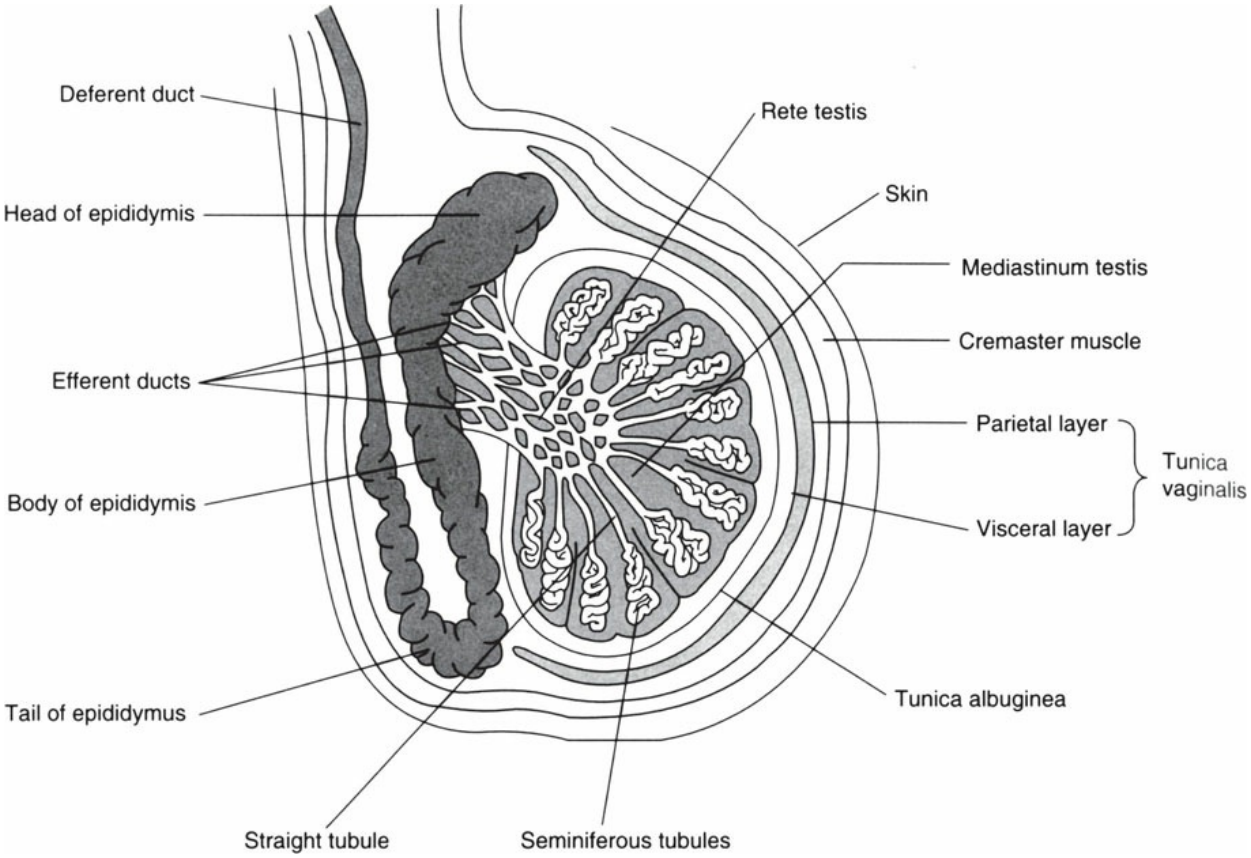


Figure 13-1 Sagittal anatomy of the normal testis.

TABLE 13-2 Parts and location of the epididymis

Part of the Epididymis	Location
Head	Superior to the upper pole of the testis
Body	Posterior to the testicle
Tail	Inferior to the lower pole of the testis

SOUND OFF
Hydroceles are most commonly located between the two layers of the tunica vaginalis.

The epididymis is a coiled structure. It is attached to the testicle and the posterior scrotal wall. It is divided into a head, body, and tail (Table 13-2). The epididymis is responsible for storing sperm in order for them to mature. It also transports sperm into the ductus (vas) deferens. The ductus (vas) deferens, also referred to as the deferent duct, is a tube that connects the epididymis to the seminal vesicles. Accordingly, the ductus (vas) deferens is the structure that is surgically interrupted in the surgical procedure referred

to as a vasectomy.

From the vas deferens, sperm is transported to the paired seminal vesicles, which are located posterior to the male urinary bladder and above the prostate gland. These small glands secrete fluid that helps produce semen. At their junction, the seminal vesicles and the vas deferens combine to create the ejaculatory duct. The fluid is then passed through the prostatic urethra, where additional fluid from the prostate is added. The bulbourethral gland, also referred to as the Cowper gland, secretes pre-ejaculate (preseminal) fluid that lubricates the penile urethra prior to ejaculation. The anatomy, physiology, and pathology of the penis, prostate, and seminal vesicles are discussed later in this chapter.

Vascular Anatomy of the Male Pelvis

The spermatic cord enters the scrotum through the inguinal canal and contains essential structures, including the vascular supply and venous drainage for the testicles (Table 13-3). The testicles receive most of their blood supply by means of the testicular arteries. These arteries emanate from the anterior abdominal aorta just below the level of the renal arteries (Fig. 13-2). Venous drainage is performed through the pampiniform plexus, which empties into the testicular veins. The right testicular vein drains into the inferior vena cava, and the left testicular vein drains into the left renal vein (Fig. 13-3).

SONOGRAPHY OF THE SCROTUM

Scrotal sonography is typically performed using a high-frequency, linear transducer. The scrotal wall thickness ranges between 2 and 8 mm. Normal testicles appear isoechoic, and a small amount of extratesticular fluid is typically noted around each testicle. The echotexture of the testis is similar to that of the thyroid gland. The normal mediastinum testis will be noted as an echogenic linear structure within the testicle in the sagittal plane or as a triangular structure in the transverse plane. Adult testicles measure 3 to 5 cm in length, 2 to 4 cm in width, and 3 cm in thickness. The blood flow within each testicle and epididymis, which should be analyzed with color and pulsed Doppler, should be symmetric. Each part of the epididymis should be thoroughly analyzed for masses, hyperemic flow, and/or enlargement. Often, the head of each epididymis is measured and its size compared to the size of the contralateral epididymal head. The normal head of the epididymis measures approximately 10 to 12 mm in size. The normal epididymis is either isoechoic or slightly more echogenic than the testis. Epididymal changes may be noted sonographically after a vasectomy, including

enlargement of the epididymis and possibly cystic areas within the epididymis. Any intratesticular or extratesticular masses should be analyzed with color Doppler as well.

TABLE 13-3 Components of the spermatic cord

Testicular artery
Pampiniform plexus
Lymph nodes
Nerves
Cremaster muscle

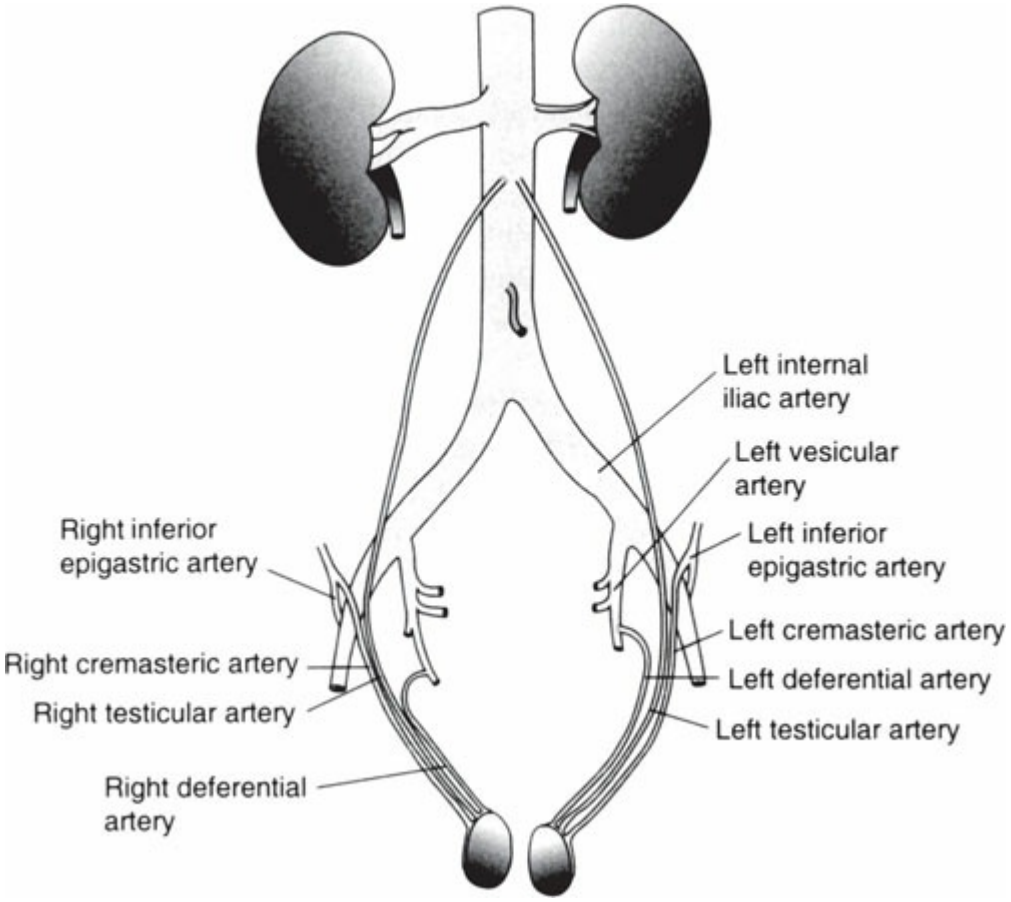


Figure 13-2 Arterial supply to the scrotum. (Image reprinted with permission from Kawamura D. Abdomen and Superficial Structures. 2nd Ed. Philadelphia, PA: Lippincott Williams & Wilkins, 1997:724.)

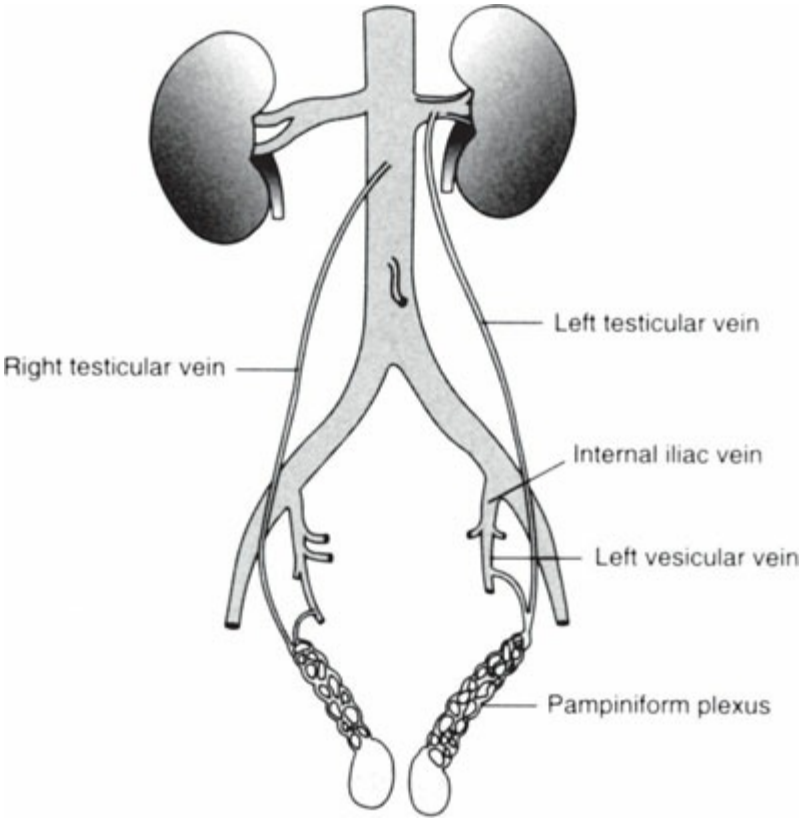


Figure 13-3 Venous drainage from the scrotum.

SOUND OFF

The normal mediastinum testis can be seen in the sagittal plane as an echogenic linear structure and in the transverse plane as an echogenic triangle.

PATHOLOGY OF THE SCROTUM

Cryptorchidism

Cryptorchidism describes the condition of having an undescended testis. Cryptorchidism, which is found in 3% to 4% of full-term births, is associated with infertility and an increase in the risk for malignancy in the involved testis. Seminoma is the most common cancer found in an undescended testis. Although they may be found within the abdomen, undescended testicles are most often found just above the scrotum or within the inguinal canal. Surgical correction of an undescended testis is referred to as orchiopexy. Clinically, the affected testis will not be palpable within the scrotum. Sonographically, the undescended testis will typically appear hypoechoic to the normal testis (Fig. 13-4).

SOUND OFF

An undescended testis is most often found within the inguinal canal.

CLINICAL FINDINGS OF CRYPTORCHIDISM

1. One or both testicles not palpable within the scrotum

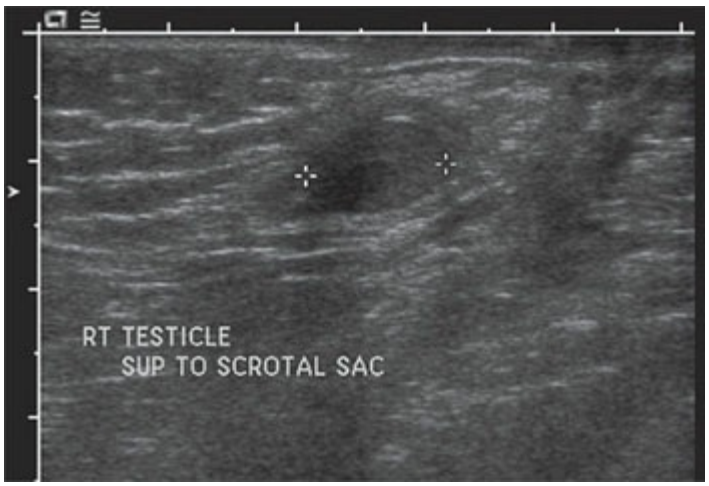


Figure 13-4 Cryptorchidism. This right testicle (*calipers*) was noted within the inguinal canal.

SONOGRAPHIC FINDINGS OF CRYPTORCHIDISM

1. Testis located outside of the scrotum (most likely in the inguinal canal)
2. The cryptorchid testis will appear hypoechoic to the normal testis

Testicular Torsion

Testicular torsion, which may also be referred to as spermatic cord torsion, occurs when the arterial blood supply to the testicle is cut off secondary to the twisting of the testicular axis. The degree of torsion can vary and can be intermittent. A 360-degree angle torsion will result in blocked venous drainage and arterial supply. This will lead to ischemia within the testis. Consequently, the amount of ischemic damage is directly related to the degree of the torsion. Testicular torsion occurs more often during adolescence, between 12 and 18 years of age. It is a true surgical emergency in which time is of the essence. In fact, salvage rates range from 80% to 100% if the patient is treated within 6 hours of symptom onset. After this time, the salvage rates drop considerably. The testicle is usually not salvageable after 24 hours.

Testicular torsion can be associated with trauma, strenuous exercise, and sexual activity. Often, patients who are predisposed to develop testicular torsion have a condition known as the “bell-clapper” deformity. This congenital abnormality describes the situation in which the patient lacks the

normal posterior fixation of the testis and epididymis to the scrotal wall. Bell-clapper deformity is classically bilateral. It is part of what is termed intravaginal torsion, which is the most common form of testicular torsion. With intravaginal torsion, the testis, which is not affixed to the scrotal wall, is permitted to migrate and twist freely within the scrotum. The other form of torsion is extravaginal torsion, which occurs in the neonatal period or in utero and is related to torsion of the spermatic cord within the inguinal canal.

Patients suffering from testicular torsion complain of a sudden onset of testicular pain, often during sleep. The torsed testis will be swollen, and it may be positioned higher in the scrotum and have a horizontal orientation. Pain may radiate into the lower abdomen and inguinal region as well. Nausea and vomiting can result from the intense pain that occurs with this abnormality.

SOUND OFF

Patients suffering from testicular torsion are often awakened in the middle of the night by severe scrotal pain.

The sonographic appearance of the torsed testis depends on the duration of time that has passed since the first sign of symptoms. In the acute stage, the testis will often appear enlarged and hypoechoic or heterogeneous (Fig. 13-5). There will be no detectable intratesticular vascularity with Doppler interrogation when the testis is completely torsed (Fig. 13-6). However, it is important to note that some intratesticular flow may be detectable with lesser degrees of torsion. For this reason, the sonographer should compare the flow within both testicles and should document both venous and arterial waveforms, if possible. In addition, the epididymis is often enlarged, and a reactive hydrocele may be present. The scrotal wall may also appear thickened.

Chronic testicular torsion is torsion that has lasted for more than 10 days. The epididymis, testis, and spermatic cord will become enlarged and heterogeneous. Areas of necrosis may be noted within the testis, and there may be hyperemic flow around the testis.

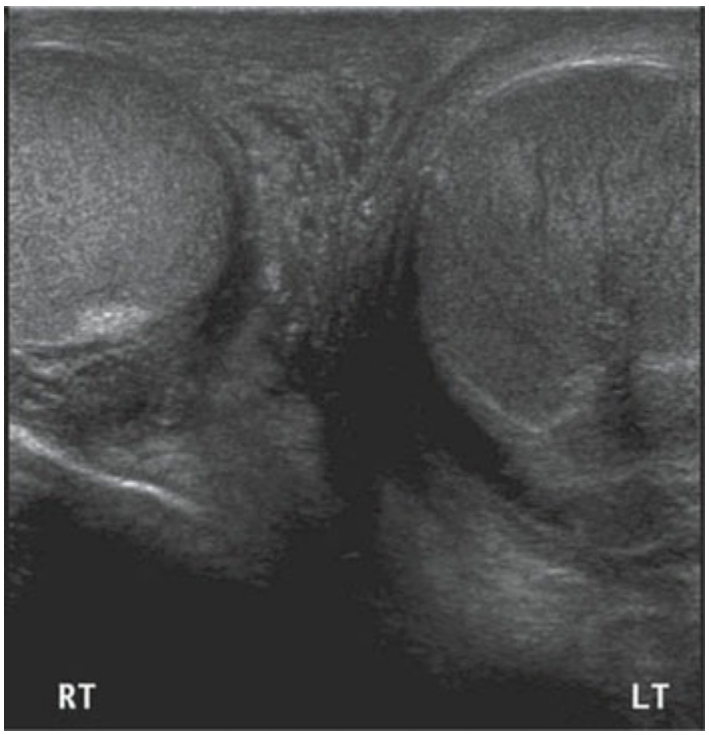


Figure 13-5 Left testicular torsion. Transverse image of both testicles. The left testicle (LT) had no detectable Doppler signals. Note that it has a heterogeneous echotexture compared to the normal right testicle (RT).

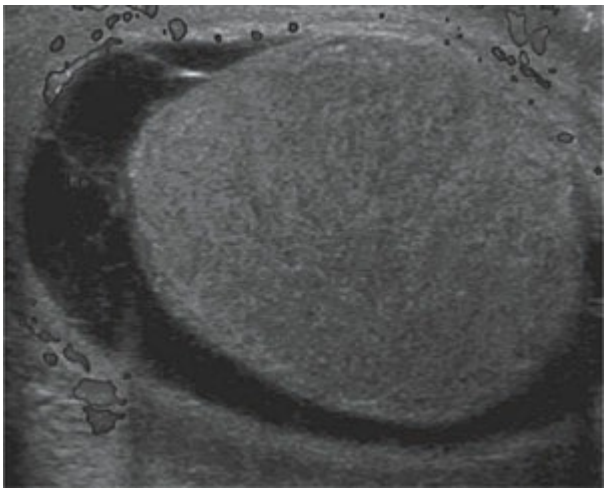


Figure 13-6 Testicle torsion. Left testicle torsion was diagnosed because no intratesticular flow was detected with color Doppler analysis. (Color image provided online.)

SOUND OFF

Intratesticular flow between the testes should be compared. A torsed testis can either lack flow completely or have decreased flow compared to the normal testis.

CLINICAL FINDINGS OF ACUTE TESTICULAR TORSION

1. Acute onset of testicular pain (often during sleep)
2. Possible pain within the lower abdomen and inguinal region
3. Swollen testis/scrotum
4. Nausea and vomiting
5. Higher positioned, painful testis with a horizontal position

SONOGRAPHIC FINDINGS OF ACUTE TESTICULAR TORSION

1. Enlargement of the spermatic cord, epididymis, and testis
2. Thickened scrotal wall
3. Hypoechoic or heterogeneous testis
4. Reactive hydrocele
5. No intratesticular flow
6. Decreased intratesticular flow (as compared to the asymptomatic testis)

SONOGRAPHIC FINDINGS OF CHRONIC TESTICULAR TORSION

1. Enlargement of the spermatic cord, epididymis, and testis
2. No intratesticular flow
3. Hyperemic flow around the testis
4. Heterogeneous testis with areas of necrosis

Torsion of the Testicular Appendages

Torsion of the appendix testis is the most common cause of acute scrotal pain in prepubertal boys. The appendix testis, appendix epididymis, and the appendix vas are appendages of the testis (Fig. 13-7). These structures are said to be the embryologic remnants of the müllerian duct, wolffian duct, and mesonephric duct, respectively. The appendix testis is located between the head of the epididymis and the superior pole of the testis, whereas the appendix epididymis is located at the head of the epididymis. The appendix vas is positioned between the body and tail of the epididymis. During a normal sonographic examination, the appendages are not routinely identified as distinct structures. However, they may be seen in the presence of a hydrocele or other scrotal fluid collections. If visualized, the normal appendage appears as a small, oval projection of tissue.

SOUND OFF

Torsion of the appendix testis is the most common cause of acute scrotal pain in prepubertal boys.

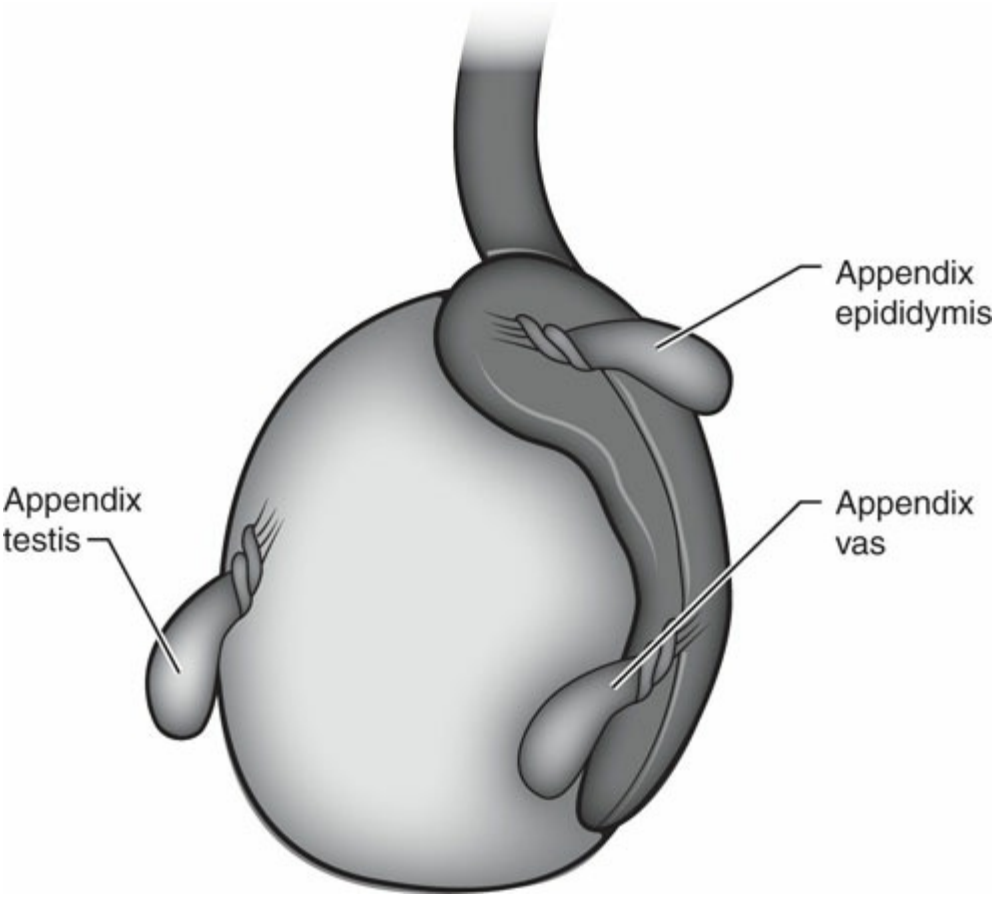


Figure 13-7 Locations of the testicular appendages.



Figure 13-8 Torsion of the appendix testis. This heterogeneous, avascular mass was seen adjacent to the superior pole of the testis. It was proven to be a torsed appendix testis.

Clinically, torsion of the appendix testis presents much like testicular torsion. However, instead of general testicular pain, patients will present with focal testicular pain, often localized to the superior pole of the testis. Physicians can manually inspect the testis for evidence of the "blue dot" sign. The blue dot sign describes the appearance of the torsed appendage as a blue dot just under the skin surface. Sonographically, the torsed appendage

will appear as a small, avascular, hypoechoic or hyperechoic mass adjacent to the superior pole of the testis (Fig. 13-8). There may also be evidence of scrotal wall thickening and a reactive hydrocele. Torsion of the appendix testis is treated with pain medication and bed rest.

SOUND OFF
The "blue dot" sign is the observable clinical finding associated with torsion of the appendix testis.

CLINICAL FINDINGS OF TORSION OF THE TESTICULAR APPENDAGE

1. Acute testicular pain
2. Pain localized to the superior pole of the testis
3. "Blue dot" sign

SONOGRAPHIC FINDINGS OF TORSION OF THE TESTICULAR APPENDAGE

1. Normal intratesticular flow
2. Small, avascular, hypoechoic or hyperechoic mass adjacent to the superior pole of the testis
3. Reactive hydrocele
4. Scrotal wall thickening

Hydrocele

A few milliliters of extratesticular fluid is a normal sonographic finding. Scrotal enlargement that is thought to be caused by excessive fluid can be considered clinically because fluid within the scrotum will transilluminate light. A simple fluid collection within the scrotum is referred to as a hydrocele (Fig. 13-9). Hydroceles are found between the two layers of the tunica vaginalis and often displace the testicles posteriorly. They can be idiopathic or described as reactive hydroceles when found in the presence of scrotal infections, testicular torsion, trauma, or tumors. Hydroceles are often accompanied by scrotal wall thickening.

CLINICAL FINDINGS OF A HYDROCELE

1. Transilluminates light
2. Painless scrotal swelling
3. May present with pain when found in the presence of scrotal infections, testicular torsion, trauma, or a tumor

SONOGRAPHIC FINDINGS OF A HYDROCELE

1. Simple fluid anterior to the testis
2. Scrotal wall thickening
3. Chronic hydroceles may have internal debris and septations

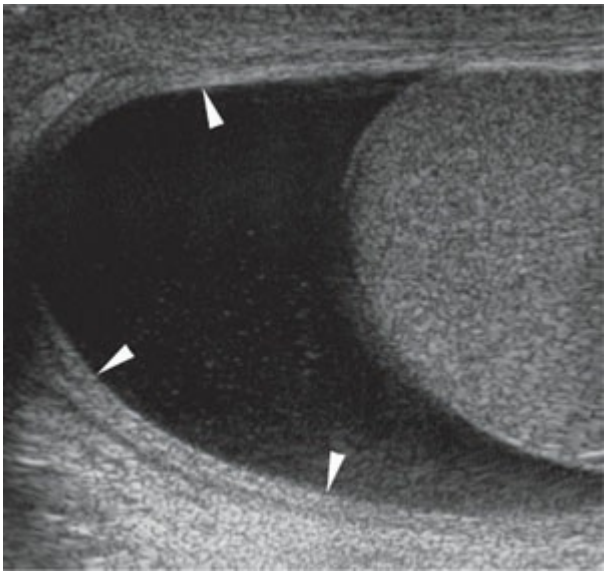


Figure 13-9 Hydrocele. Anechoic fluid can be noted surrounding the testicle. The scrotal wall (*arrowheads*) appears to be thickened as well.

Extratesticular Cysts

A spermatocele, which is said to be the most common scrotal mass, is a cyst found most often in the head of the epididymis. It is composed of nonviable sperm, fat, cellular debris, and lymphocytes. Although it may be palpable during a physical examination, usually it is not painful. The sonographic appearance of a spermatocele is that of a cyst in the head of the epididymis that may contain layering debris (Fig. 13-10). An epididymal cyst appears similar to a spermatocele and can be seen anywhere along the length of the epididymis. Lastly, tunica albuginea cysts are located anywhere along the periphery of the testicle, within the tunica albuginea.

SOUND OFF
The spermatocele is the most common scrotal mass.

CLINICAL FINDINGS OF A SPERMATOCELE, EPIDIDYMAL CYST, AND TUNICA ALBUGINEA CYST

1. If large enough, they may be palpable
2. Typically not painful

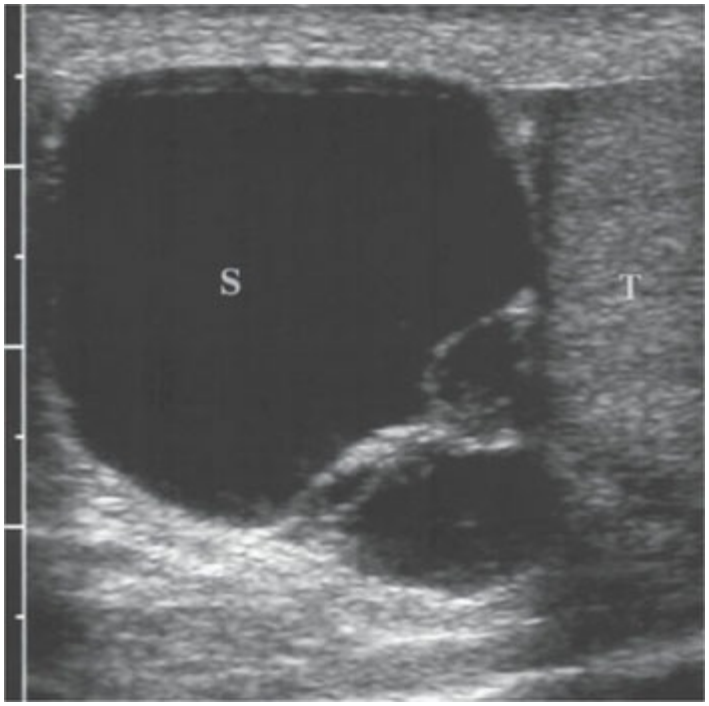


Figure 13-10 Spermatocele. Large cystic extratesticular mass (*S*) is noted superior to the testis (*T*) and is characteristic of a spermatocele.

SONOGRAPHIC FINDINGS OF A SPERMATOCELE, EPIDIDYMAL CYST, AND TUNICA ALBUGINEA CYST

1. Round, anechoic mass with acoustic enhancement
2. May contain some layering debris

Varicocele

A dilated group of veins found within the scrotum is termed a varicocele. Varicoceles are caused by incompetent or abnormal valves within the pampiniform plexus. Because of the increased heat released by excess blood within the scrotum, overheating of the fragile spermatozoa can occur. This overheating can influence the formation and mobility of sperm. In fact, varicoceles have been cited as the most common cause of correctable male infertility.

Varicoceles are usually painless, but if they become large, discomfort can result. There are two types of varicoceles: primary and secondary. Primary varicoceles are most often found on the left and are palpable during a physical examination. Their high incidence on the left is thought to be caused by the elevated vascular pressure on the left side or possibly as a result of the extended length of the left testicular vein (compared to the right testicular vein), and the sharp angle at which it enters the left renal vein. When found on the right side, this abnormality may be termed a secondary varicocele. Secondary varicoceles may be associated with a hepatic mass, marked

hydronephrosis, hepatomegaly, or a retroperitoneal neoplasm like a right-sided renal mass. Therefore, a prompt investigation of the right upper quadrant and retroperitoneum may be warranted when a varicocele is discovered on the right. One predisposing factor for some patients for a varicocele is an anomaly where left renal vein entrapment occurs between the superior mesenteric artery and abdominal aorta, which is termed the "nutcracker" syndrome.

SOUND OFF

Varicoceles are the most common causes of correctable male infertility and are most often located on the left side. Right-sided varicoceles may be associated with right-sided pathology of the retroperitoneum, including hepatomegaly, a hepatic mass, or right-sided renal mass.

Sonographically, a varicocele commonly appears as a group of anechoic, tubular structures located outside of the testis (Fig. 13-11). However, varicoceles can be intratesticular in location. To diagnose a varicocele using color Doppler, the Valsalva maneuver can be performed. When the intra-abdominal pressure is increased with this maneuver, the veins should fill with blood and become enlarged. These dilated veins will measure greater than 2 mm. The patient may also stand while he is being scanned to simulate the Valsalva maneuver.

CLINICAL FINDINGS OF A VARICOCELE

1. Typically painless (large varicoceles can cause discomfort)
2. Palpable extratesticular mass
3. Possible infertility

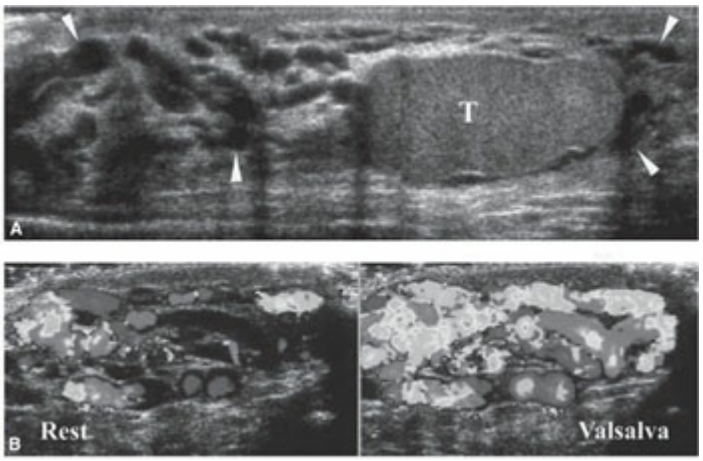


Figure 13-11 Varicocele. **A.** Multiple tubular structures (*arrowheads*) are seen

surrounding the testicle (*T*). **B.** Color Doppler confirms flow within these structures during rest. With the Valsalva maneuver, the veins enlarged and there is a dramatic increase in flow. (Color image provided online.)

SONOGRAPHIC FINDINGS OF A VARICOCELE

1. A group of anechoic, tubular structures located outside of the testis
2. Distended veins that fill with color flow when the Valsalva maneuver is performed
3. Dilated veins that measure greater than 2 mm
4. Possibly associated with hydronephrosis, hepatomegaly, or a retroperitoneal neoplasm if found on the right

Scrotal Pearl

A scrotal pearl is an extratesticular calculus. Scrotal pearls will be extremely echogenic, mobile, and will produce a posterior acoustic shadow. They are often incidentally noted and thought to be remnants of a formerly torsed and displaced testicular appendage.

SONOGRAPHIC FINDINGS OF A SCROTAL PEARL

1. Extremely echogenic, mobile extratesticular structure that produces acoustic shadowing

Epididymitis and Epididymo-orchitis

Inflammation of the epididymis is referred to as epididymitis. Epididymitis is the most common cause of acute testicular pain in adults. Patients with epididymitis can present with leukocytosis, fever, dysuria, urethral discharge, and scrotal wall edema. Infections that occur within the scrotum are ascending. Therefore, most infections start externally, or within the urinary tract or prostate, and then proceed into the vas deferens, epididymal tail, epididymal body, epididymal head, and perhaps into the testis. Inflammation of the testis is referred to as orchitis. Consequently, the combination of an infection within the epididymis and testis is termed epididymo-orchitis.

Although a frequent cause of epididymitis is the spread of bacteria from the prostate or urinary tract, it can be caused by trauma. Common causes of epididymitis in younger men are the sexually transmitted diseases chlamydia and gonorrhea. Epididymitis can be diffuse and involve the entire epididymis, or it may be focal and involve only one segment. Therefore, an analysis of the head, body, and tail of the epididymis is vital. Sonographically, the inflamed epididymis will appear enlarged, hypoechoic, or heterogeneous, and have increased vascularity when interrogated with

color or power Doppler. Orchitis will yield increased intratesticular vascularity with a low-resistance waveform pattern and is almost always accompanied by epididymitis (Fig. 13-12). Chronic epididymitis may appear as an enlarged, hyperechoic epididymis with calcifications.

SOUND OFF
Common causes of epididymitis in younger men are the sexually transmitted diseases chlamydia and gonorrhea.

CLINICAL FINDINGS OF EPIDIDYMITIS AND EPIDIDYMO-ORCHITIS

1. Acute testicular pain
2. Leukocytosis
3. Fever
4. Dysuria
5. Urethral discharge
6. Scrotal wall edema

SONOGRAPHIC FINDINGS OF EPIDIDYMITIS AND EPIDIDYMO-ORCHITIS

1. Enlargement of the entire epididymis (diffuse)
2. Enlargement of only part of the epididymis (focal)
3. Hypoechoic echotexture of the affected section(s) of the epididymis
4. Hypoechoic testis (with orchitis)
5. Hyperemia within the epididymis and/or testis
6. Thickened scrotal wall
7. Reactive hydrocele

Testicular Abscess and Pyocele

An abscess that occurs within the testicle is typically the result of untreated epididymo-orchitis. Patients will clinically present with a fever, leukocytosis, and a painful, swollen scrotum. With color Doppler imaging, a testicular abscess will appear as a complex intratesticular mass that has no flow centrally but increased flow around its margins. A pyocele is a complex hydrocele that contains pus. It is often seen in the presence of a persistent scrotal infection or ruptured testicular abscess. Sonographically, a pyocele will appear as a complex fluid collection within the scrotum that may contain septations and loculations. Clinical history is extremely important to make the differentiation between a hematocele, pyocele, or complex hydrocele.

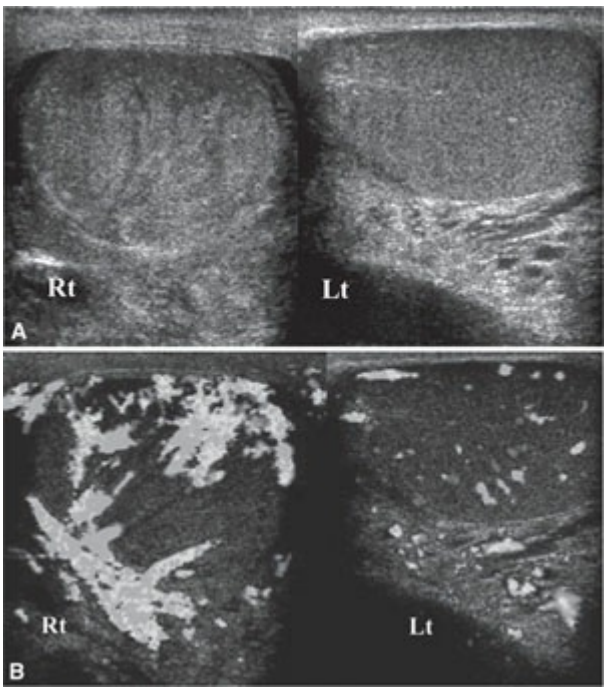


Figure 13-12 Acute epididymo-orchitis. **A.** The grayscale sonographic appearance of the testis reveals a right (*Rt*) testicle that appears heterogeneous compared to the left (*Lt*) testicle. **B.** Color Doppler reveals hyperemia in the right (*Rt*) testicle compared to the left (*Lt*) testicle, which is consistent with diffuse right-sided epididymo-orchitis. (Color image provided online.)

SOUND OFF

Although intratesticular abscesses lack detected flow within them, they are often surrounded by hyperemic flow.

CLINICAL FINDINGS OF A TESTICULAR ABSCESS

1. Painful, swollen scrotum
2. Fever
3. Leukocytosis

SONOGRAPHIC FINDINGS OF A TESTICULAR ABSCESS

1. Complex intratesticular mass
2. Mass that has no flow centrally but increased flow around its margins
3. May have a coexisting pyocele

SONOGRAPHIC FINDINGS OF A PYOCELE

1. Complex fluid collection within the scrotum
2. Scrotal wall thickening
3. May be seen in conjunction with rupture of a testicular abscess

Intratesticular Cyst and Testicular Microlithiasis

Intratesticular cysts are rarely large enough to be palpable. Multiple small intratesticular cysts are often seen along the mediastinum testis. These cysts are typically small and clinically insignificant and may be the result of tubular ectasia of the rete testes (Fig. 13-13). They are thought to represent cystic dilation of the rete testis. Epidermoid cysts may be noted within the testicle as well. Epidermoid cysts often appear to have a whorled or onion skin appearance.

SOUND OFF
Multiple small cysts located along the mediastinum testis represent cystic dilation of the rete testis, also referred to as tubular ectasia.

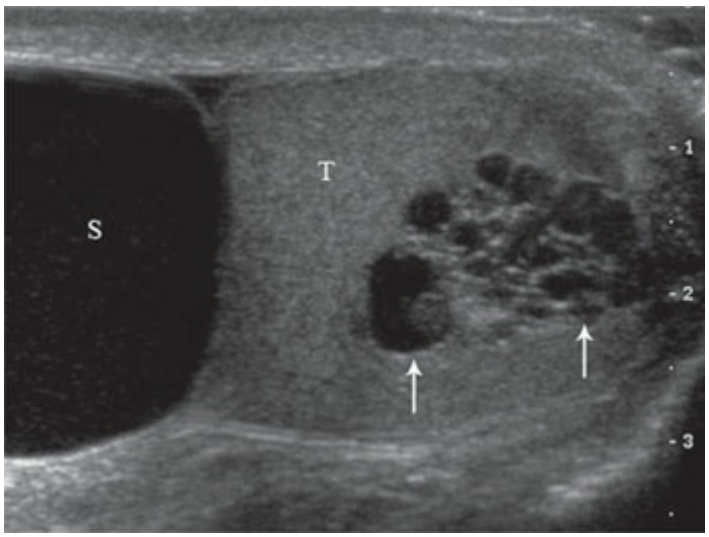


Figure 13-13 Tubular ectasia of the rete testis. Multiple cysts (*arrows*) are seen in the area of the mediastinum testes in this testicle (*T*). A large spermatocele (*S*) is also noted.



Figure 13-14 Intratesticular microlithiasis. Multiple echogenic foci with no acoustic shadowing are seen within this testis.

Testicular microlithiasis will appear as multiple echogenic foci with no acoustic shadowing within the testis (Fig. 13-14). These tiny calcifications have been associated with malignancies, infertility, Klinefelter syndrome, and cryptorchidism. Screening of patients with intratesticular microlithiasis has been studied, and the cost effectiveness has been questioned. However, there is a proven increased risk for cancer in patients who have microlithiasis in one testis and an identified intratesticular tumor in the contralateral testis. Therefore, a biopsy of the testis with microlithiasis may be warranted.

Adrenal Rests

Adrenal rests resemble a mass within the testicle and are associated with congenital adrenal hyperplasia or Cushing syndrome. Adrenal rests of the testis, which essentially consist of ectopic adrenal tissue, are caused by the migration of adrenal tissue with gonadal tissue during fetal development. Clinically, these patients will have evidence of increased levels of adrenocorticotropic hormone. Sonographically, adrenal rests appear as bilateral, round, hypoechoic, intratesticular masses, most commonly near the mediastinum testis.

CLINICAL FINDINGS OF ADRENAL RESTS

1. History of congenital adrenal hyperplasia

2. Elevated adrenocorticotropic hormone

SONOGRAPHIC FINDINGS OF ADRENAL RESTS

1. Bilateral, round, hypoechoic, intratesticular masses (most commonly near the mediastinum testis)

Malignant Testicular Tumors and Tumor Markers

As a rule, intratesticular masses are often considered malignant until proven otherwise, whereas the majority of extratesticular masses are typically benign. Most of the malignant intratesticular tumors are of germ cell origin (Table 13-4). Other, nongerm cell malignant tumors include sex cord–stromal tumors, lymphoma, leukemia, and metastases (Table 13-5). Lymphoma and leukemia can appear as either focal hypoechoic masses or produce diffuse involvement of the testicles. Metastatic disease to the testis is most commonly from melanoma, lung, kidney, and prostate cancer.

There are two laboratory values that are helpful to differentiate between benign and malignant intratesticular tumors, human chorionic gonadotropin (hCG) and alpha-fetoprotein (AFP). An elevation in hCG levels is found in conjunction with malignant intratesticular tumors 60% of the time. hCG is produced by these masses because they contain syncytiotrophoblastic cells. These cells, also found in the developing placenta, produce hCG in the abnormal cells that comprise the testicular malignancy. AFP levels may also be evaluated to determine whether an intratesticular mass is malignant. An elevated AFP level is most often associated with embryonal cell carcinoma, teratomas, and yolk sac tumors.

TABLE 13-4 Germ cell tumors of the testicles

Pure seminoma
Teratoma
Embryonal cell carcinoma
Yolk sac tumor
Choriocarcinoma
Burned-out germ cell tumor

TABLE 13-5 Sex cord–stromal tumors of the testicles

Leydig cell tumor
Sertoli cell tumor

SOUND OFF
Human chorionic gonadotropin and alpha-fetoprotein are laboratory values used in pregnancy. Malignant tumors within the testicles may abnormally produce hCG or AFP as well. Thus, these can be used as tumor markers for testicular malignancies.

SEMINOMA

The seminoma is the most common malignant neoplasm of the testicles. The seminoma is a germ cell tumor that is typically found in males between 30 and 50 years of age. This type of malignant tumor is often found in patients suffering from cryptorchidism as well. Most seminomas are unilateral and may actually replace the entire testicle. Clinically, patients will present with a painless scrotal mass, hardening of the testis, and possibly elevated hCG level. A seminoma has an intratesticular location and will appear as a solid, hypoechoic mass (Fig. 13-15). Large seminomas may become heterogeneous.

SOUND OFF
The seminoma is the most common malignant neoplasm of the testicle.

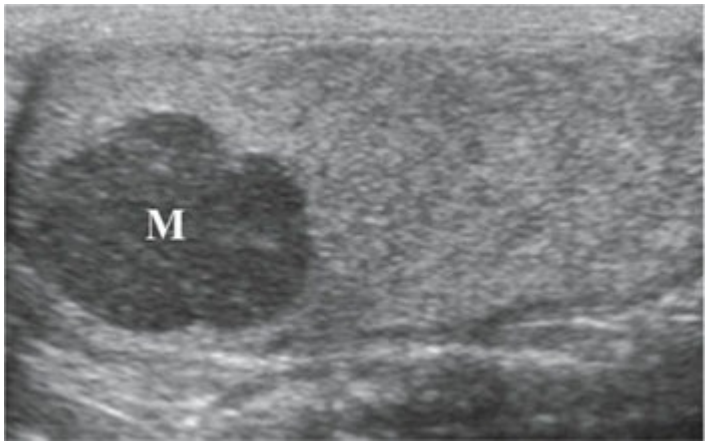


Figure 13-15 Seminoma. Longitudinal image of the testicle that contains a solid, hypoechoic mass (*M*), which was confirmed to be a seminoma.

CLINICAL FINDINGS OF A SEMINOMA

1. Painless scrotal mass
2. Hardening of the testis
3. Elevated hCG

SONOGRAPHIC FINDINGS OF A SEMINOMA

1. Solid, hypoechoic intratesticular mass
2. Large seminomas may become heterogeneous

Other Germ Cell Tumors of the Testicles

There are several different forms of nonseminomatous intratesticular tumors. These include choriocarcinoma, embryonal cell carcinoma, teratomas, and yolk sac tumors. These noteworthy tumors and their clinical and sonographic findings are summarized in Table 13-6. It is important to note that a tumor can be comprised of a mixture of these malignant tissues, and thus referred to as a mixed germ cell tumor.

Scrotal Trauma and Hematocele

The testicle can be fractured as a result of trauma to the scrotum. Rarely, a fracture line may be seen. The testicular margins may be unclear, and a hematoma may be noted in or around the testis. Blood that is present within the scrotum is referred to as a hematocele. Although hematoceles are often associated with trauma to the scrotum, they may also be found after recent pelvic surgery, scrotal surgery, or torsion. Sonographically, a hematocele will appear as a complex fluid collection within the scrotum that may contain septations and loculations. Clinical history is extremely important to make the differentiation between a hematocele, pyocele, or complex hydrocele.

CLINICAL FINDINGS OF SCROTAL TRAUMA

1. Trauma to the scrotum resulting in acute scrotal pain
2. Low hematocrit

SONOGRAPHIC FINDINGS OF SCROTAL TRAUMA

1. Possible fracture line
2. Indistinct testicular margins
3. Hematocele

CLINICAL FINDINGS OF A HEMATOCELE

1. Trauma to the pelvis or scrotum
2. Recent pelvic or scrotal surgery
3. Low hematocrit (possible)

SONOGRAPHIC FINDINGS OF A HEMATOCELE

1. Complex fluid collection within the scrotum
2. Scrotal wall thickening

Inguinal Hernia

An inguinal hernia may consist of intestine or omentum. Patients with an inguinal hernia often present with persistent or intermittent scrotal swelling. Patients may also have abdominal pain and blood within their stool. Sonographically, an inguinal hernia will often show a mass that has peristalsis and that may contain air and fluid. A hydrocele may also be an associated finding. The blood supply to the bowel can be lost when an inguinal hernia becomes incarcerated and strangulated. The Valsalva maneuver can be used to help demonstrate peristalsing bowel. Fluid or air within the loop of bowel may also be seen.

CLINICAL FINDINGS OF AN INGUINAL HERNIA

1. Persistent or intermittent scrotal swelling
2. May have abdominal pain and blood in stool

TABLE 13-6 Nonseminomatous germ cell tumors with associated clinical and sonographic findings

Nonseminomatous Germ Cell Tumor	Malignant or Benign	Clinical Findings	Sonographic Findings
Choriocarcinoma	Malignant	May be palpable Elevated human chorionic gonadotropin (hCG)	Heterogeneous mass with areas of hemorrhage, necrosis, and calcifications
Embryonal cell carcinoma	Malignant	May be palpable Elevated alpha-fetoprotein (AFP) and hCG	Heterogeneous mass with cystic components
Yolk sac tumors	Malignant	May be palpable Elevated AFP (exclusively)	Heterogeneous mass with areas of hemorrhage and calcifications
Teratoma	Benign (with malignant potential)	May be palpable Elevated AFP and hCG (if malignant)	Heterogeneous with calcifications representing cartilage, bone, and fibrosis; may contain hair and teeth

SONOGRAPHIC FINDINGS OF AN INGUINAL HERNIA

1. Heterogeneous mass within the scrotum that moves (peristalsis)
2. Mass may contain air and fluid
3. Hydrocele may be present

ANATOMY AND PHYSIOLOGY OF THE PENIS

The penis is a primary sex organ. It plays a vital role in both reproduction and urination. The penis is covered with skin, and subsequently a dense fibrous tissue termed Buck fascia. The inner penis is comprised of three cylindrical tissue components: a single corpus spongiosum and paired corpus cavernosa (singular form is cavernosum). These are comprised of smooth muscle, erectile tissue, and vascular structures. The urethra is housed within the corpus spongiosum, which is situated ventrally. The paired cavernosa are situated dorsally. Tunica albugenia surrounds the corpus cavernosa and partially covers the corpus spongiosum. All three corpura are covered by Buck fascia (Fig. 13-16).

SOUND OFF
The penis consists of two corpus cavernosa and one corpus spongiosum.

The vascular supply to the penis begins at the internal pudendal artery, which is a tributary of the internal iliac artery. The internal pudendal arteries branch into the deep artery of the penis or penile artery. The deep artery of the penis provides the blood supply to the corpus cavernosa. The cavernosal arteries are located within the corpus cavernosa bilaterally. When sexual arousal occurs, the arteries within the penis become engorged with blood, causing the compression of the adjacent veins, preventing venous drainage, and resulting in an erection.

SONOGRAPHY OF THE PENIS

The penis should be imaged using a high-frequency linear transducer. Most often, the patient is placed in the supine position, and the penis is allowed to rest upon the lower abdomen when flow assessment is warranted. This position will cause the dorsal surface of the penis to be placed alongside the abdomen, exposing the ventral surface (Fig. 13-17). Sonographically, the penis should be evaluated in both transverse and sagittal scan planes. In

transverse, the singular corpus spongiosum, which contains the urethra, will be seen ventrally located, whereas the paired corpus cavernosa will be noted dorsally. The spongiosum will be elliptical in shape and consist of medium- to low-level echoes, whereas the cavernosa will appear similar in echogenicity to the spongiosum, but have a more oval shape. The tunica albugenia, which is highly echogenic, can be seen separating and covering the corpora. Contained within each corpus cavernosum are the cavernosal arteries, which can be identified by their bright walls and apparent blood flow with color Doppler. In the sagittal plane, both the spongiosum and the cavernosa elongate, whereas the vascular channels can be seen stretching through the length of the cavernosa allowing for pulsed Doppler interrogation. The elongated penile urethra can be seen within the corpus spongiosum in the sagittal plane as well.

Sonography can aid in the detection of strictures of the penile urethra and vascular issues within the penis. For the identification of strictures of the urethra, the patient is often required to have a full bladder and to void during the examination. For vascular assessment, the penile flow is first analyzed in a flaccid state, and then an injection of an erection-inducing drug into the penis may be required to evaluate the vascularity of the penis using color Doppler while the penis is erect (Fig. 13-18). Sonography can also be used to evaluate any palpable lesions of the penis, such as a benign fibroma or a malignant penile tumor, the latter of which is most often caused by human papillomavirus and is typically in the form of squamous cell carcinoma.

PENILE PATHOLOGY

Vascular Impotence

Vascular impotence is caused by vascular compromise to or within the penis that results in the inability to obtain or maintain an erection. This disorder could be caused by diabetic neuropathy, in which case the tiny vessels within the penis are damaged. Upon pulsed Doppler interrogation in normal men, there is an increase in arterial flow to the cavernosal arteries that can be determined by evaluating the systolic velocities. In addition, normally, the venous outflow will become partially blocked and the diastolic flow will greatly decrease. The diagnosis of venous incompetence can be made if the diastolic flow does not decrease. It is important to note that in healthy individuals, the cavernosal artery velocities measure 10 to 15 cm per second in the flaccid state.

Peyronie Disease

Peyronie disease is the buildup of fibrous plaque (scar tissue) and

calcifications within the penis that results in a painful curvature. Patients typically have impotence and poor arterial flow and complain of painful erections. Clinically, the area of scar tissue buildup can typically be palpated. Sonographically, the area will appear as thickening of the tunica albugenia, which may also contain areas of calcification.

CLINICAL FINDINGS OF PEYRONIE DISEASE

1. Impotence
2. Painful erections
3. Area of scar tissue can typically be palpated
4. Marked curvature of the penis

Penile Trauma

Fracture of the penis can occur with blunt sexual trauma. The audible sound of a popping or cracking sound is often heard because typically one of the corpus cavernosa snaps under the pressure. Although this disorder can be diagnosed clinically on the basis of history and evidence of ecchymosis—which is a subcutaneous spot of bleeding—sonography may be used to further analyze the penis for soft tissue, urethral, and vascular damage. Sonographically, the area of hemorrhage within the penis can have the varying sonographic appearances associated with a new or aging hematoma, thus depending on the time of analysis. However, most likely, sonography will reveal an irregular hypoechoic or hyperechoic defect at the site of rupture. Careful assessment of the tunica albugenia for evidence of penile urethra is warranted because interruption to the urethra can lead to voiding complications. The damage, if not managed appropriately, can permanently disrupt penile function. Scar tissue development can result in the area of the fracture as well.

SONOGRAPHIC FINDINGS OF PEYRONIE DISEASE

1. Thickening of the tunica albugenia that may also contain areas of calcification

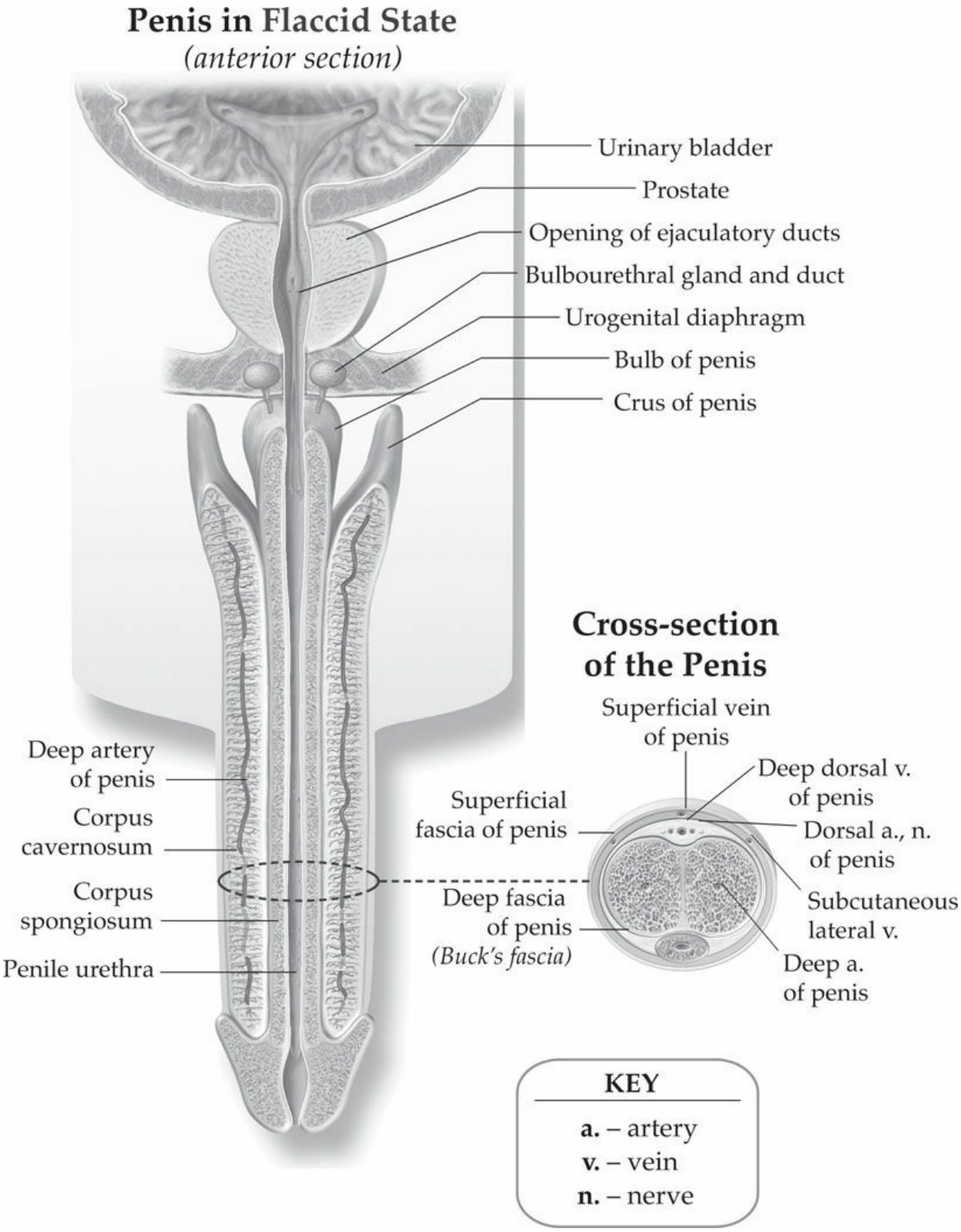


Figure 13-16 Anatomy of the penis.

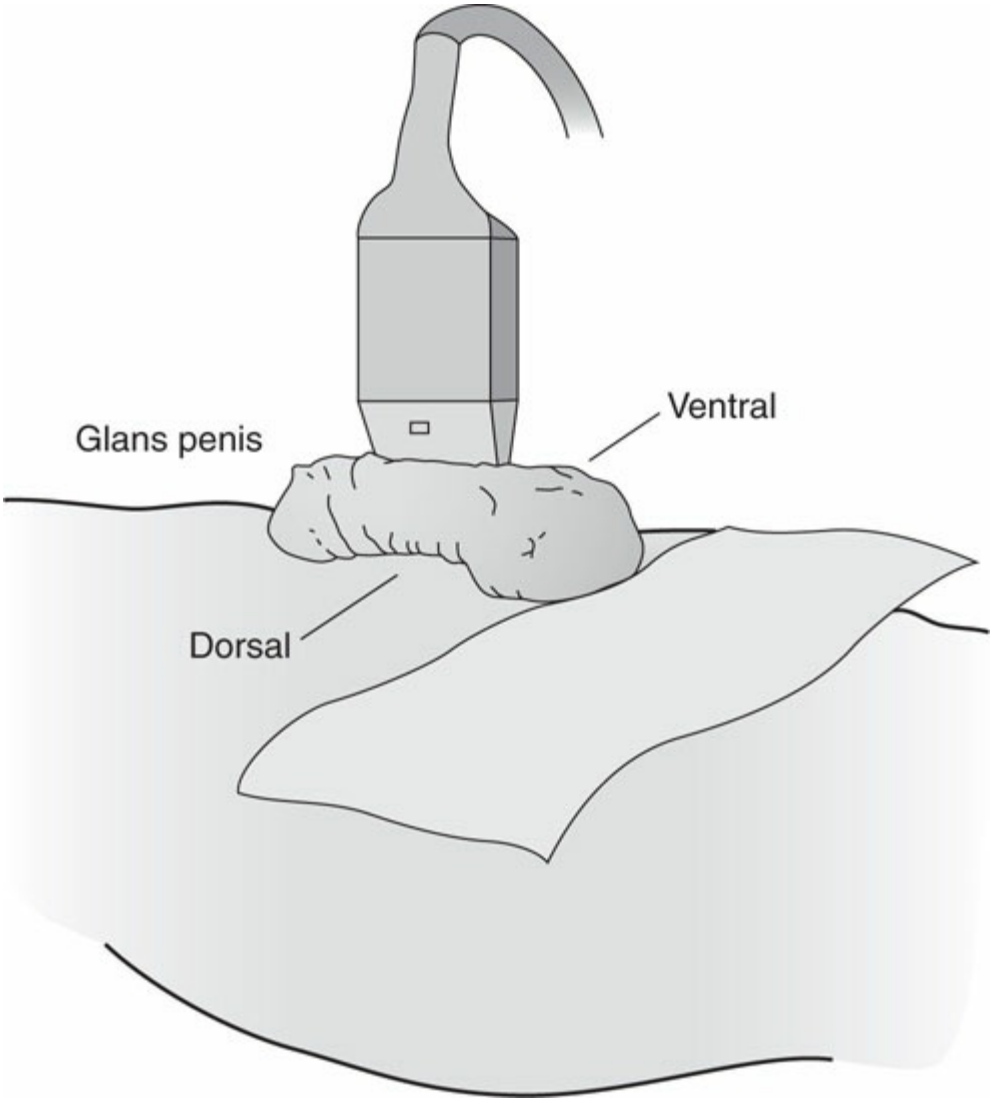


Figure 13-17 Positioning for penile sonogram.

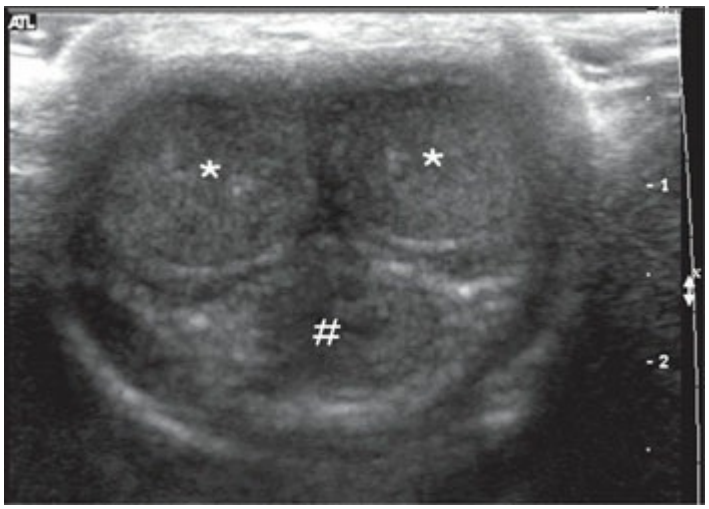


Figure 13-18 Transverse image of the penis. In this image, the transducer has been placed on the dorsal aspect of the penis in order to perform Doppler evaluation, which allows for the assessment of the two corpus cavernosa (*asterisk*), with the corpus spongiosum noted ventrally (*hash*).

SOUND OFF

Careful assessment of the tunica albugenia for evidence of penile urethra damage is warranted because interruption to the urethra can lead to voiding complications.

CLINICAL FINDINGS OF PENILE TRAUMA

1. History of hearing an audible popping sound during intercourse
2. Subcutaneous bleeding area

SONOGRAPHIC FINDINGS OF PENILE TRAUMA

1. An irregular hypoechoic or hyperechoic defect at the site of rupture

ANATOMY, PHYSIOLOGY, AND PATHOLOGY OF THE PROSTATE GLAND AND SEMINAL VESICLES

The prostate is a retroperitoneal gland that produces and secretes an alkaline fluid that constitutes between 13% and 30% of the volume of semen. The gland is located inferior to the urinary bladder, between the symphysis pubis and the rectum. It is shaped like an inverted pyramid, with its base located superior and its apex positioned inferior. The prostate is divided into four zones. The prostatic urethra, which is used as the point of reference for the zones, travels through the center of the prostate. Zonal anatomy is described in Table 13-7 (Fig. 13-19). An additional area, the anterior fibromuscular stroma, is located anterior to the prostatic urethra and is of little clinical significance.

The paired seminal vesicles are located superior to the prostate gland and posterior to the base of the bladder. They secrete an alkaline-based fluid and empty into the paired ejaculatory ducts. The ejaculatory ducts are formed by the union of the seminal vesicles and ductus deferens. These tiny ducts travel through the prostate and empty into the urethra at an area called the verumontanum.

SONOGRAPHY OF THE PROSTATE GLAND AND SEMINAL VESICLES

Oftentimes, a patient will undergo a digital rectal examination prior to having a targeted sonogram of the prostate. The prostate can be imaged transabdominally or transrectally (Fig. 13-20). Transabdominal imaging is

useful for measuring the overall size of the prostate, whereas transrectal imaging is used for biopsies and provides superior resolution. The patient is typically placed in the left lateral decubitus position with the knees flexed toward the chest or in the lithotomy position for transrectal imaging of the prostate. The prostate and seminal vesicles are examined in both coronal and sagittal planes. The prostatic zones are typically homogeneous and may be differentiated by visualizing landmarks such as the prostatic urethra and ejaculatory ducts. Patients may have benign calcification and simple-appearing cysts within the prostate as well.

TABLE 13-7 Four prostatic zones: their locations and significant characteristics

Prostatic Zone	Location	Significance
Peripheral zone	Posterior lateral, apical gland	Largest prostatic zone Most common site for malignancy
Central zone	Base of prostate	Second largest prostatic zone
Transitional zone	On both sides of the proximal urethra	Site for benign prostatic hyperplasia Second most common site of malignancies
Periurethral glandular zone	Embedded in the muscle of the proximal urethra	Smallest prostatic zone

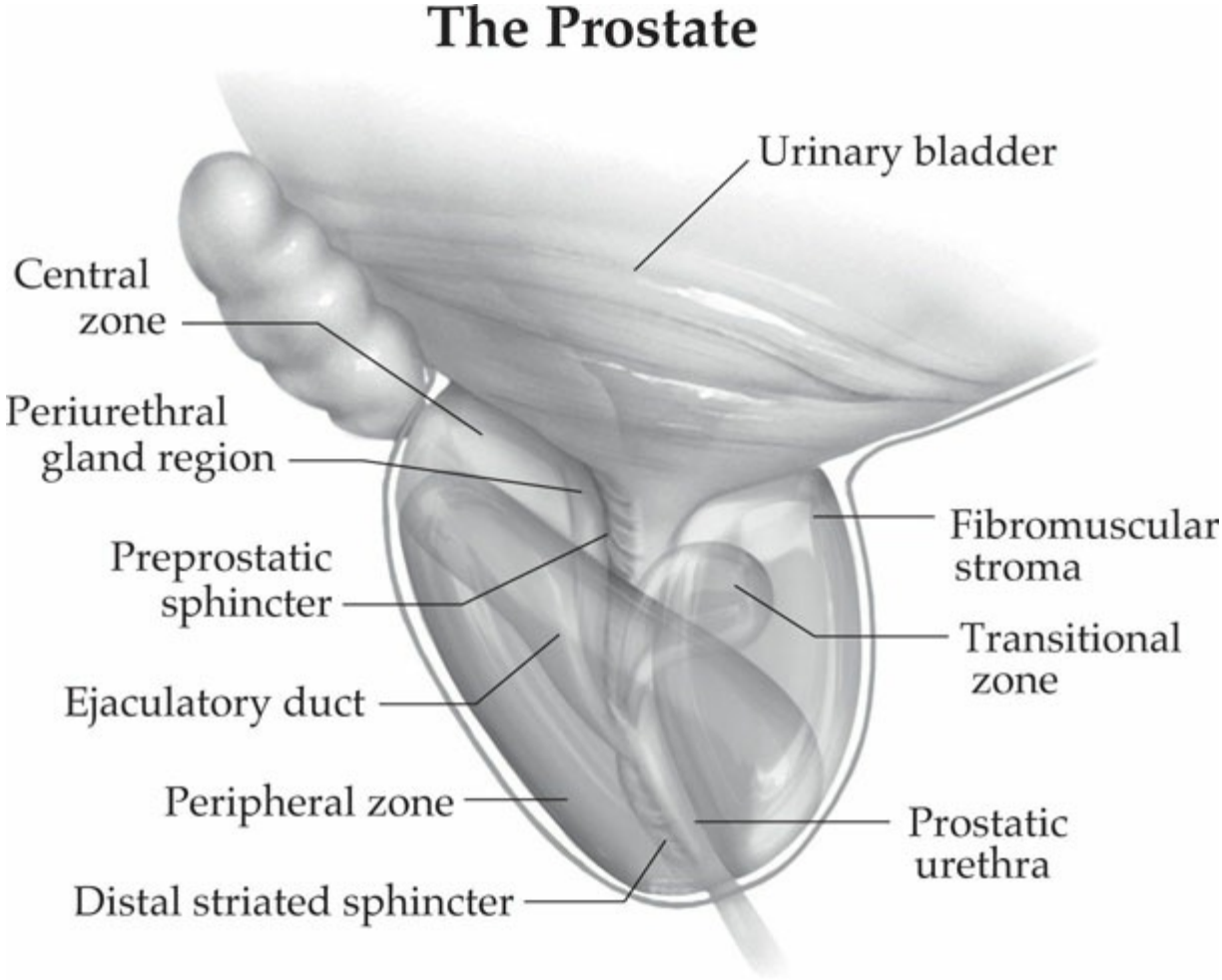


Figure 13-19 Zonal anatomy of the prostate in the sagittal plane.

The seminal vesicles appear as hypoechoic structures between the bladder and prostate (Fig. 13-21). When the seminal vesicles are filled with fluid, they become enlarged and contain low-level echoes and anechoic fluid. The seminal vesicles can be imaged transabdominally or endorectally.

PROSTATE PATHOLOGY

Prostate-Specific Antigen

Prostate-specific antigen (PSA) is a protein produced by the prostate gland. There are several methods currently used to evaluate PSA levels, including PSA velocity, volume-corrected PSA, age-adjusted PSA, and free and attached PSA. An elevation in this protein can be indicative of some disease processes such as benign prostatic hypertrophy, prostatic cancer, prostatitis, and prostatic infarcts. It has been claimed that the higher the PSA level, the more likely the patient will have prostate cancer. However, a normal PSA level can also be found in the presence of cancer.

SOUND OFF
An elevated PSA is not specific for prostate cancer.

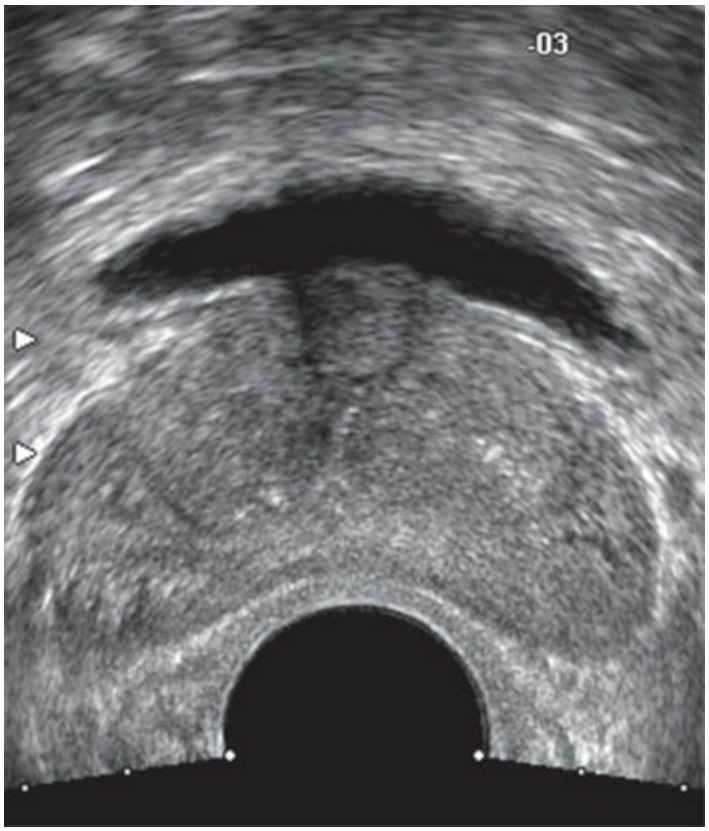


Figure 13-20 Transverse transrectal image of the normal prostate.

Prostate Cancer

Prostate cancer, in the form of adenocarcinoma, is the most common cancer in men. Patients with prostate cancer often present with blood in the urine or semen, back pain, pelvic pain, hip or thigh pain, impotence, and a decrease in the amount of ejaculated fluid. Prostate cancer may cause an enlarged prostate that can be determined with a digital rectal examination. Patients may also have elevated PSA values.

As mentioned earlier, the most common location for prostate cancer is within the peripheral zone. It may produce areas of hypervascularity, and it can have variable sonographic appearances. However, most prostate cancers will appear hypoechoic to normal adjacent prostatic tissue (Fig. 13-22). It is important to note that the sonographic appearance of prostatic cancer can mimic normal anatomy, prostatitis, and benign prostatic hypertrophy (BPH). Therefore, experience is needed to perform these procedures correctly. Biopsy is warranted for a definitive diagnosis.

SOUND OFF

Prostate cancer is most commonly located within the peripheral zone.

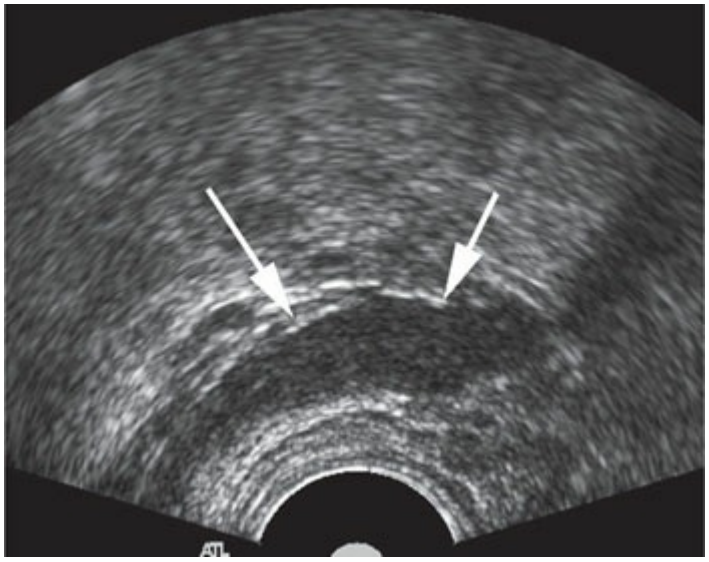


Figure 13-21 Transrectal image of a seminal vesicle (*arrows*).

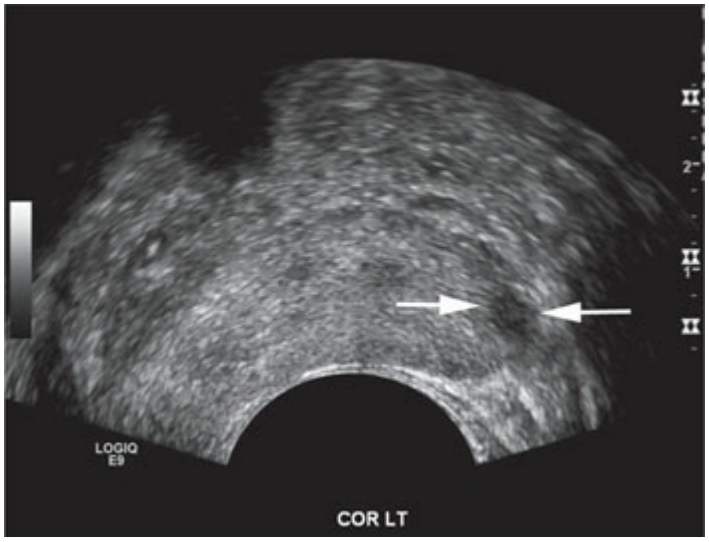


Figure 13-22 Prostate cancer. This image of the prostate reveals a small hypoechoic mass (*between arrows*) in the peripheral zone, which was eventually diagnosed as prostate carcinoma.

CLINICAL FINDINGS OF PROSTATE CANCER

1. Elevated PSA
2. Enlarged prostate
3. Blood in the urine (hematuria) or semen (hematospermia)
4. Back pain, pelvic pain, hip or thigh pain
5. Impotence
6. Decrease in the amount of ejaculated fluid

SONOGRAPHIC FINDINGS OF PROSTATE CANCER

1. Varying sonographic appearances
2. Hypoechoic mass
3. May be hypervascular

Benign Prostatic Hypertrophy

The benign enlargement of the prostate gland is termed benign prostatic hypertrophy (BPH). BPH is most often located within the transitional zone. An enlarged prostate can obstruct the flow of urine through the urethra. Symptoms of BPH include nocturia, increased urinary frequency, a sense of urinary urgency, and a constant feeling of having a full bladder. Patients will also have elevated PSA. Sonographically, BPH will show an enlargement of the inner gland, and it can lead to hypoechoic areas within the prostate, calcifications, diffusely heterogeneous gland, and cystic changes. Patients with BPH may undergo transurethral resection of the prostate to remove some of the hypertrophic prostatic tissue causing urinary complications.



SOUND OFF
BPH is most commonly located within the transitional zone.

CLINICAL FINDINGS OF BENIGN PROSTATIC HYPERTROPHY

1. Nocturia
2. Increased urinary frequency
3. Sense of urinary urgency
4. Constant feeling of having a full bladder
5. Elevated PSA

SONOGRAPHIC FINDINGS OF BENIGN PROSTATIC HYPERTROPHY

1. BPH will show an enlargement of the inner gland
2. Can lead to hypoechoic areas within the gland
3. Calcifications within the gland
4. Diffusely heterogeneous gland
5. Cystic changes within the gland

Prostatitis

Prostatitis is inflammation of the prostate. Patients may complain of hematospermia, painful ejaculation, perineal pain, and dysuria. Sonographically, prostatitis appears as an enlarged, more hypoechoic prostate with evidence of hyperemia upon color Doppler interrogation.

CLINICAL FINDINGS OF PROSTATITIS

1. Hematospermia
2. Painful ejaculation
3. Perineal pain
4. Dysuria

SONOGRAPHIC FINDINGS OF PROSTATITIS

1. Enlarged, hypoechoic prostate
2. Hypermia evident with color Doppler

Seminal Vesicle Cysts

Occasionally, seminal vesicle cysts may be identified as anechoic or complex cystic structures in the area of the seminal vesicles. Although seminal vesicle cysts are rare, they are said to be either congenital or acquired. Seminal vesicle cysts may be asymptomatic, but they can also be associated with Zinner syndrome. Zinner syndrome consists of unilateral renal agenesis, ipsilateral seminal vesicle cyst, and ejaculatory duct obstruction. Patients with Zinner syndrome present with perineal pain, recurrent prostatitis, painful ejaculation, and infertility.

CLINICAL FINDINGS OF SEMINAL VESICLE CYSTS

1. Asymptomatic
2. May be associated with Zinner syndrome (perineal pain, recurrent prostatitis, painful ejaculation, and infertility)

SONOGRAPHIC FINDINGS OF SEMINAL VESICLE CYSTS

1. Anechoic or complex cystic structures in the area of the seminal vesicles

REVIEW QUESTIONS

1. Which of the following is not a component of the spermatic cord?
   a. Epididymis
   b. Testicular artery
   c. Cremaster muscle
   d. Lymph nodes

2. What is the most common malignancy of the testicles?
   a. Embryonal cell carcinoma

b. Seminoma
c. Choriocarcinoma
d. Spermatocele

3. Secondary varicoceles are most likely associated with all of the following except:
a. Left-sided location
b. Right-sided location
c. Hepatomegaly
d. Renal mass

4. The most common location of BPH is the:
a. Peripheral zone
b. Transitional zone
c. Central zone
d. Verumontanum

5. During a sonographic examination of the right testis, you visualize multiple small cysts located along the mediastinum testis. What is the most likely diagnosis?
a. Epididymitis
b. Tubular ectasia of the rete testis
c. Multiple spermatoceles
d. Epidermoid cysts

6. Enlargement of the prostate in older men is most often caused by:
a. Prostatitis
b. Prostate cancer
c. Benign prostatic hypertrophy
d. Klinefelter syndrome

7. Which of the following is a benign intratesticular mass that typically has a whorled or onion skin sonographic appearance?
a. Seminoma
b. Teratoma
c. Epidermoid cyst
d. Adrenal rest

8. Which of the following best describes a spermatocele?
a. The most common malignant neoplasm of the scrotum
b. A benign intratesticular cyst
c. A cyst, found within the head of epididymis, that may contain debris
d. A dilated group of veins found within the scrotum

9. A dilated group of veins found within the scrotum is called a:
   a. Varicocele
   b. Spermatocele
   c. Seminoma
   d. Hydrocele

10. Which of the following would most likely resemble a solid intratesticular mass and be associated with Cushing syndrome?
   a. Choriocarcinoma
   b. Epidermoid cyst
   c. Intratesticular varicocele
   d. Adrenal rest

11. Primary varicoceles are associated with all of the following except:
   a. Left-sided location
   b. Retroperitoneal mass
   c. Infertility
   d. Palpable extratesticular mass

12. A common cyst most often seen in the head of the epididymis that contains nonviable sperm is the:
   a. Epididymal cyst
   b. Tunica albuginea cyst
   c. Spermatocele
   d. Seminoma

13. What scrotal abnormality is caused by incompetent valves within the pampiniform plexus?
   a. Testicular carcinoma
   b. Testicular microlithiasis
   c. Testicular torsion
   d. Varicocele

14. What laboratory value can be assessed as a tumor marker to evaluate a patient for testicular malignancy?
   a. Serum bilirubin
   b. Amylase
   c. Alpha-Fetoprotein
   d. Adrenocorticotropic hormone

15. The blue dot sign is indicative of:
   a. Testicular torsion

b. Epididymitis
c. Orchitis
d. Torsion of the testicular appendage

16. A 23-year-old man presents to the sonography department with a history of infertility. Which of the following is associated with male infertility?
a. Spermatocele
b. Choriocarcinoma
c. Varicocele
d. Hydrocele

17. Which of the following houses the male urethra?
a. Corpus spongiosum
b. Buck fascia
c. Bulbourethral gland
d. Corpus cavernosum

18. All of the following are sonographic findings consistent with torsion of the testicular appendage except:
a. No intratesticular flow
b. Small hyperechoic mass adjacent to the testis
c. Reactive hydrocele
d. Scrotal wall thickening

19. What is the most common correctable cause of male infertility?
a. Varicocele
b. Chlamydia
c. Hydrocele
d. Testicular torsion

20. A simple fluid collection surrounding the testis is referred to as a:
a. Hematocele
b. Hydrocele
c. Varicocele
d. Spermatocele

21. What is the most common malignancy of the penis?
a. Cystadenocarcinoma
b. Adenocarcinoma
c. Follicular carcinoma
d. Squamous cell carcinoma

22. A patient presents to the sonography department for a penile sonogram.

He complains of a painful curvature of the penis and impotence. What is the most likely diagnosis?
a. Squamous cell carcinoma
b. Peyronie disease
c. Tinner syndrome
d. Testicular fracture

23. The exocrine function of the testicles is to produce:
a. Testosterone
b. Human chorionic gonadotropin
c. Alpha-Fetoprotein
d. Sperm

24. The most common location of a hydrocele is:
a. Superior to the testis
b. Within the scrotal wall
c. Between the two layers of the tunica vaginalis
d. Between the tunica vaginalis and tunica albuginea

25. Acute onset of testicular pain at rest is a common clinical finding with:
a. Testicular carcinoma
b. Hydrocele
c. Testicular trauma
d. Testicular torsion

26. A 7-year-old boy presents to the emergency department with acute testicular pain localized to the superior pole of his right testis. What is the most likely diagnosis?
a. Testicular torsion
b. Hydrocele
c. Torsion of the testicular appendage
d. Yolk sac tumor

27. Zinner syndrome consists of unilateral renal agenesis, ejaculatory duct obstruction, and
a. Prostate cancer
b. Seminoma
c. Bulbourethral stones
d. Seminal vesicle cysts

28. Dilated veins of a varicocele will measure:
a. >8 mm
b. >4 mm

c. <2 mm
d. >2 mm

29. The lack of the normal fixation of the testis to the posterior scrotal wall is referred to as:
    a. Klinefelter syndrome
    b. Blue dot sign
    c. Bell-clapper deformity
    d. Cryptorchidism

30. Which of the following techniques is useful for providing sonographic evidence of a varicocele?
    a. Valsalva maneuver
    b. Sitting position
    c. Pulsed Doppler
    d. Right lateral decubitus position

31. The endocrine function of the testicles is to produce:
    a. Testosterone
    b. Human chorionic gonadotropin
    c. Alpha-Fetoprotein
    d. Sperm

32. All of the following are sonographic findings consistent with the diagnosis of testicular torsion except:
    a. Hyperemic flow within the testis
    b. Hypoechoic testis
    c. Reactive hydrocele
    d. Decreased intratesticular flow (as compared with the asymptomatic testis)

33. Spermatogenesis occurs within the:
    a. Tunica albuginea
    b. Rete testis
    c. Mediastinum testis
    d. Seminiferous tubules

34. You have been asked to perform a study to rule out cryptorchidism. The term cryptorchidism denotes:
    a. One or both of the testicles have a malignancy
    b. That the testicle has torsed
    c. One or both of the testicles have not descended into the scrotum
    d. The patient has been kicked in the scrotum

35. The most common germ cell tumor of the testis is the:
    a. Yolk sac tumor
    b. Embryonal cell carcinoma
    c. Seminoma
    d. Teratoma

36. The most common location of a varicocele is:
    a. The right side of the scrotum
    b. The left side of the scrotum
    c. The inguinal canal
    d. Within the testis

37. The most common location of prostatic cancer is the:
    a. Peripheral zone
    b. Transitional zone
    c. Central zone
    d. Verumontanum

38. Which of the following is consistent with the sonographic features of testicular abscess?
    a. Hyperemic flow around the abscess but not within it
    b. Onion skin sonographic appearance and hyperemic epididymis
    c. Hyperemic flow within an anechoic mass
    d. Hyperemic flow within the abscess but not around it

39. What is the most common cancer found in men?
    a. Testicular cancer
    b. Lung cancer
    c. Liver cancer
    d. Prostate cancer

40. What would be the most likely sonographic appearance of a seminoma?
    a. Hyperechoic
    b. Anechoic
    c. Heterogeneous with calcifications
    d. Hypoechoic

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14

Musculoskeletal Imaging, Breast, and Superficial Structures

Introduction

Because the certification examinations may contain some questions on musculoskeletal specialty topics, this chapter is provided to offer a brief overview of musculoskeletal imaging, including infant hip and the Achilles tendon. Breast imaging may also be performed by the abdominal sonographer, especially in emergency situations. However, the aim of this chapter is not to prepare the sonographer for the breast sonographic certification examination, but rather focus the information on basic anatomy of the breast and pathology that may arise in emergency situations. Imaging of superficial structures is also reviewed in this chapter.

Key Terms

acetabulum—the bowl-shaped surface of the pelvis where the head of femur normally rests

Achilles tendon—tendon located along the posterior ankle that connects the calf muscle to the posterior surface of the heel

arthrogryposis—a congenital disorder associated with severe joint contractures

Baker cyst—a synovial cyst located within the popliteal fossa; may also be referred to as a popliteal cyst

Barlow test—clinical test for developmental hip dysplasia that is used to

evaluate the hip for dislocation

cellulitis—inflammation and infection of the skin and subcutaneous tissues

developmental dysplasia of the hip—a congenital anomaly in which the ball of the hip is prohibited from resting appropriately in the natural socket provided for it on the pelvis

galactocele—a milk-filled breast cyst

ganglion cyst—a common cyst found adjacent to a joint or tendon; most often found along the dorsal aspect of the hand, wrist, ankle, or foot

Graf technique—a technique used to measure the relationship of the femoral head and acetabulum by evaluating the alpha and beta angles created by the relationships of these structures

gynecomastia—the benign enlargement of the male breast; typically located posterior to the areola

hemangioma—a benign tumor composed of blood vessels

hip joint effusion—buildup of fluid within the hip secondary to inflammation

ilium (pelvis)—the largest and most superiorly located pelvic bone

lactiferous ducts—the ducts of the breast used to transport milk to the nipple

lipoma—a benign, fatty tumor

mastitis—inflammation of the breast

natal cleft—area located between the groove of the buttocks

Ortolani test—clinical test for developmental hip dysplasia that is used to evaluate the hip for the reduction or relocation of a dislocated hip

pannus—a hanging flap of tissue

pilonidal cyst—cyst located along the natal cleft that is comprised of loose hairs and skin debris

puerperal mastitis—inflammation of the breast that is related to pregnancy

refractive shadowing—acoustic shadowing caused by bending of a sound beam at the edge of a curved reflector; may be referred to as edge artifact or edge shadowing

subluxation—partial dislocation of the hip

superficial epidermal cyst—cysts commonly found in the scalp, face, neck, trunk, or back; they can be congenital, the result of trauma, or the result of an obstructed hair follicle

tendosynovitis—inflammation of the tendon and synovial tendon sheath

Thompson test—clinical test used to evaluate for a complete tear of the Achilles tendon

MUSCULOSKELETAL IMAGING

Sonographic Appearance of Muscles, Tendons, and Ligaments

As a sonographer, it is important to have a basic appreciation for the location of bones and superficial muscles of the body (Figs. 14-1 and 14-2). Musculoskeletal structures are typically imaged with a linear array transducer for improved resolution. Muscles appear sonographically as hypoechoic tissue that contains linear, echogenic strands. Tendons may be noted as echogenic, fibrous structures connecting muscle to bone. Although in most situations, the transducer must be placed perpendicular to the tendon for it to be appropriately imaged with sonography, occasionally altering the angle of insonation can help differentiate the tendon from adjacent fat (Fig. 14-3). Ligaments, which connect bones to other bones, appear echogenic as well.

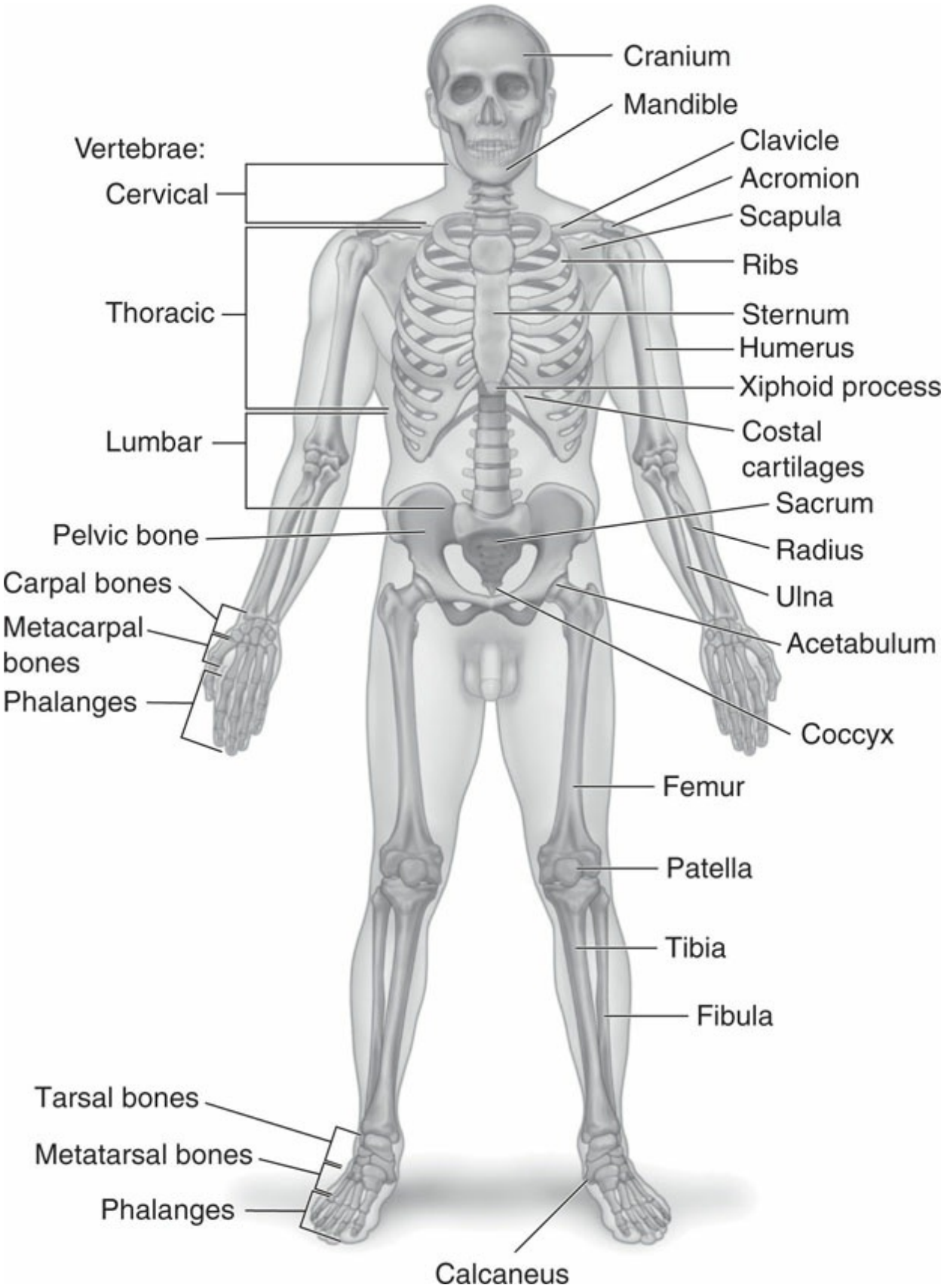


Figure 14-1 Anterior view of the skeleton.

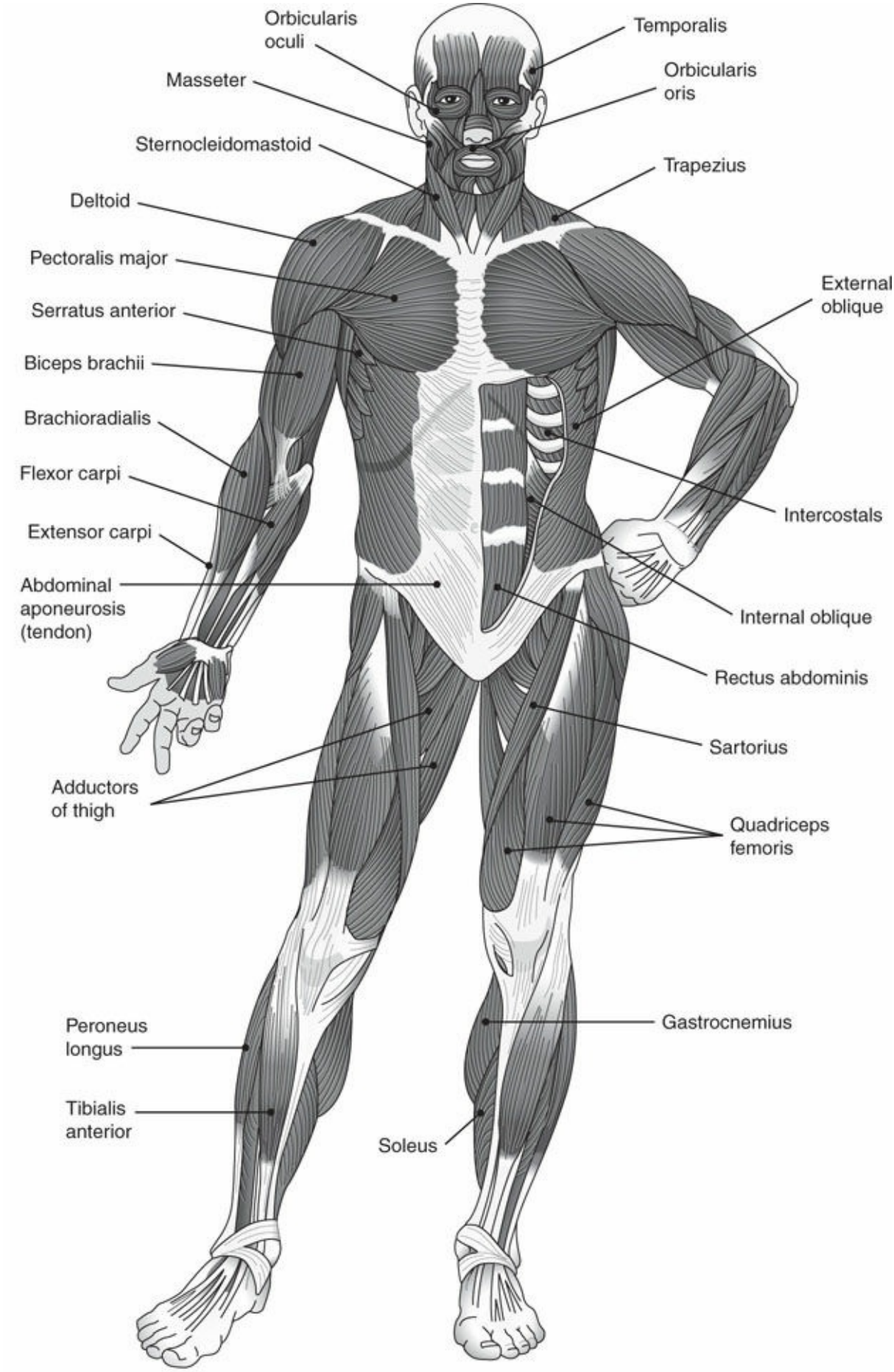
Tendon Pathology

Tendonitis

Inflammation of a tendon, termed tendonitis, can be diffuse or focal. It may be caused by overuse or strain. Diffuse tendonitis appears as a thickened and hypoechoic tendon, whereas focal tendonitis will appear as a localized, enlarged hypoechoic area within the tendon. Hyperemic flow may be noted within the tendon as well (Fig. 14-4). Fluid within the synovial sheath is often indicative of tendosynovitis. Patients will present with pain, swelling, and possibly fever in the troubled area.

CLINICAL FINDINGS OF TENDONITIS

1. Pain
2. Painful region may be swollen
3. Painful region may be warm to touch


Orbicularis oculi
Temporalis
Masseter
Orbicularis oris
Sternocleidomastoid
Trapezius
Deltoid
Pectoralis major
External oblique
Serratus anterior
Biceps brachii
Brachioradialis
Flexor carpi
Intercostals
Extensor carpi
Abdominal aponeurosis (tendon)
Internal oblique
Rectus abdominis
Sartorius
Adductors of thigh
Quadriceps femoris
Peroneus longus
Gastrocnemius
Tibialis anterior
Soleus
Anterior view
A

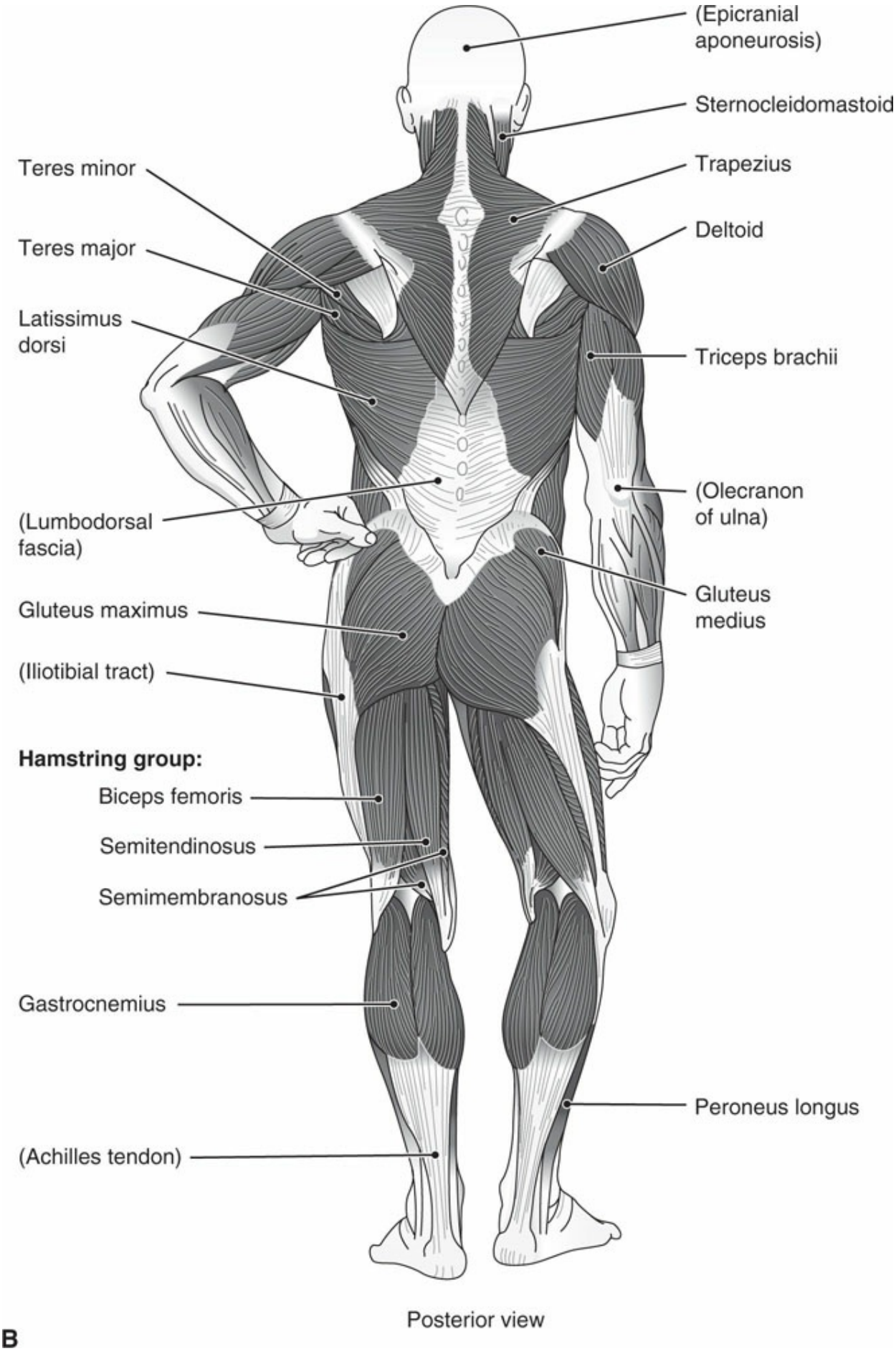


Figure 14-2 Anterior (**A**) and posterior (**B**) view of the muscles.

SONOGRAPHIC FINDINGS OF TENDONITIS

1. Diffuse: enlarged, hypoechoic tendon
2. Focal: localized, enlarged hypoechoic area within the tendon
3. Fluid may be noted
4. Hyperemic flow may be noted

SOUND OFF
Tendonitis may yield hyperemic flow with color Doppler.

Tendon Rupture

A tendon rupture may also be referred to as a tear, and it most likely results from some manner of recreational sport. Tendon tears can be partial or complete. Partial tears can appear as focal hypoechoic areas within the tendon, whereas complete tears are seen as an anechoic or heterogeneous area within the tendon, often indicative of a hematoma (Fig. 14-5). Complete ruptures may also be sonographically identified as refractive shadowing in the area of the separated tendon, with fat, a hematoma, or granulomatous material filling in the gap created by the tear. Surrounding the area of rupture will most likely be extensive edema, with corresponding fluid accumulation. A patient with a torn tendon will be suffering from edema and significant pain in the wounded region.

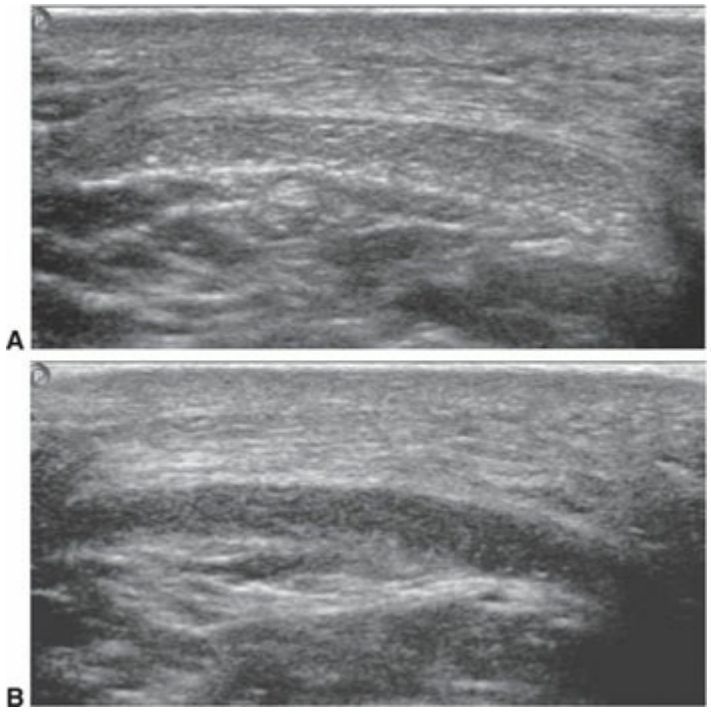


Figure 14-3 Angle of insonation for tendons. **A.** Image of the patellar tendon taken perpendicular to the tendon, resulting in the typical hyperechoic echogenicity of the normal tendon. **B.** Image slightly angled to cause the tendon to appear more

hypoechoic, thus making it more distinguishable from the adjacent fat.

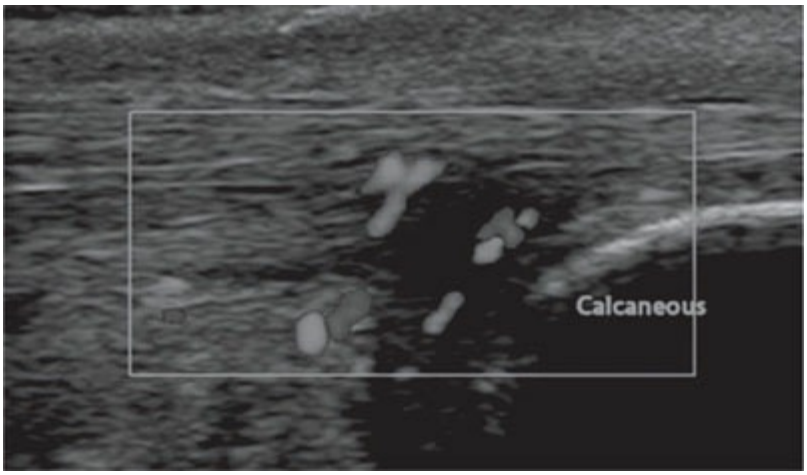


Figure 14-4 Tendonitis. Longitudinal color Doppler image of the Achilles tendon. Note the neovascularity, which suggests tendinitis. Color figure provided online.

CLINICAL FINDINGS OF A TENDON RUPTURE

1. Pain
2. Edema
3. Audible snap may be heard

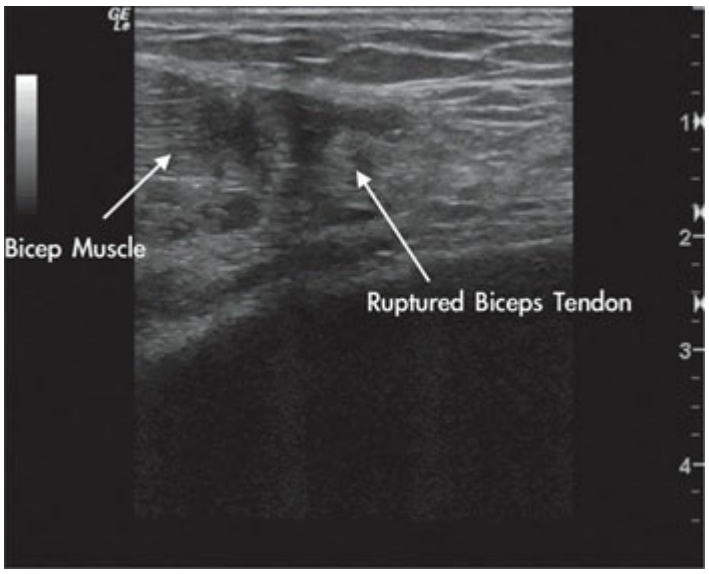


Figure 14-5 Tendon rupture. This biceps tendon has ruptured, with a resulting anechoic fluid collection that is most likely hemorrhage.

SONOGRAPHIC FINDINGS OF A TENDON RUPTURE

1. Partial tears: appear as focal hypoechoic areas within the tendon
2. Complete tears: seen as an anechoic or heterogeneous area within the tendon, often indicative of a hematoma; may also be sonographically identified as refractive shadowing in the area of the separated tendon, with fat, a hematoma, or

granulomatous material filling in the gap created by the tear

Achilles Tendon Rupture

The Achilles tendon is the most commonly injured ankle tendon. It is located along the posterior ankle and connects the calf muscle to the posterior surface of the heel, or calcaneus. To evaluate the Achilles tendon with sonography, the patient lies prone, with his or her feet hanging off the end of the bed. Both the symptomatic and asymptomatic Achilles tendons should be scanned for comparison. The entire tendon should be evaluated in sagittal and transverse scan planes. A landscape image of the entire length of the painful tendon may be useful.

The Achilles tendon should be assessed for the sonographic signs of tendonitis and rupture, as described in this chapter (Figs. 14-6 and 14-7). Patients will present with posterior ankle and leg pain, and they may state that they heard an audible snap as the tendon ruptured. Clinically, the Thompson test can be performed to see if there is a complete tear of the tendon. The Thompson test is conducted with the patient prone as well and can be performed prior to the sonographic examination. The calf is squeezed, and the foot should plantarflex in a patient who does not have a complete tear of the Achilles tendon (Fig. 14-8).

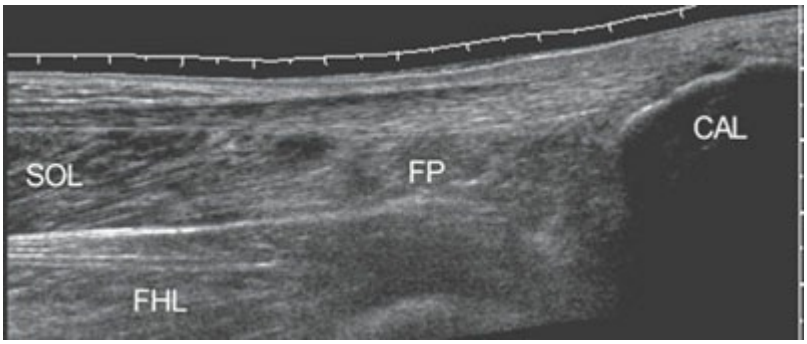


Figure 14-6 Normal Achilles tendon. Longitudinal image of the normal Achilles tendon demonstrating the fat pad (*FP*), soleus muscle (*SOL*), flexor hallucis longus tendon (*FHL*), and the calcaneus (*CAL*).

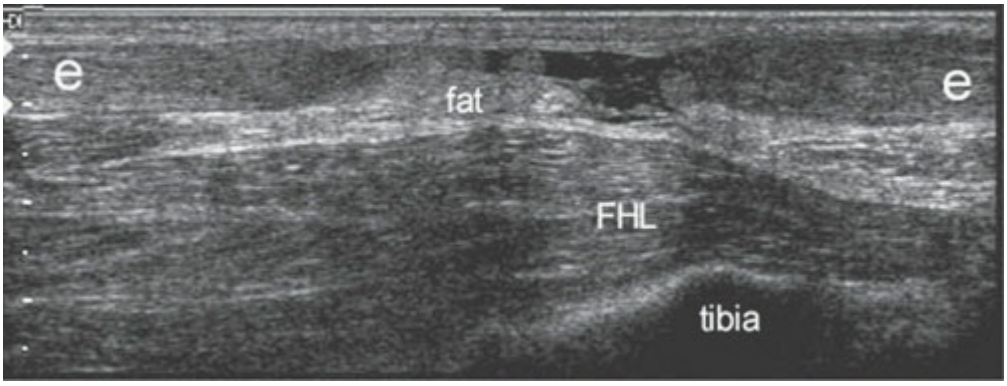


Figure 14-7 Ruptured Achilles tendon. Longitudinal image of a complete rupture of the Achilles tendon. The two ends (*e*) of the tendon, the flexor hallucis longus tendon (*FHL*), fat (*fat*), and the tibia (*tibia*) are all seen. A hypoechoic fluid gap in the area of the rupture is seen separating the two ends of the tendon.

CLINICAL FINDINGS OF ACHILLES TENDON RUPTURE

1. Audible snap may be heard
2. Posterior ankle and leg pain
3. Positive Thompson test

SONOGRAPHIC FINDINGS OF ACHILLES TENDON RUPTURE

1. Partial tears: appear as focal hypoechoic areas within the tendon
2. Complete tears: seen as an anechoic or heterogeneous area within the tendon, often indicative of a hematoma; may also be sonographically identified as refractive shadowing in the area of the separated tendon, with fat, a hematoma, or granulomatous material filling in the gap created by the tear

SOUND OFF

Patients with a torn Achilles tendon may have heard an audible snap when the tendon ruptures.

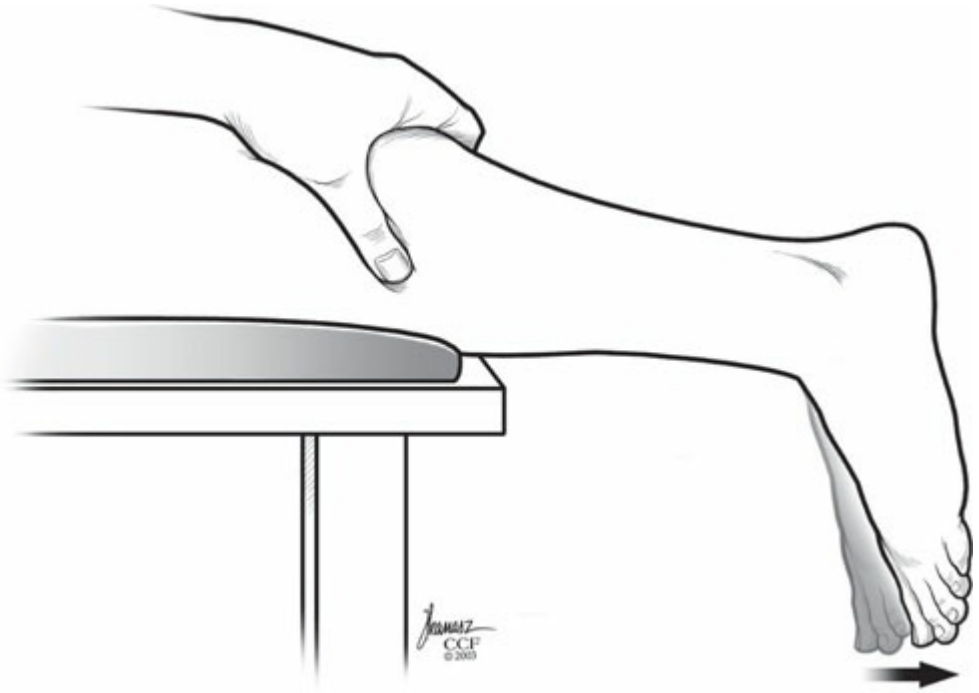


Figure 14-8 Thompson test. The Thompson test is conducted with the patient prone and can be performed prior to the sonographic examination. The calf is squeezed, and the foot should plantarflex in a patient who does not have a complete tear of the Achilles tendon.

Developmental Dysplasia of the Infant Hip

Sonographers should have a basic understanding of the anatomy of the infant hip (Fig. 14-9). Developmental dysplasia of the hip (DDH) is a congenital anomaly that may be described as a shallow hip socket. With DDH, the ball of the hip—the femoral head—is prohibited from resting appropriately in the natural socket—the acetabulum—which is provided for it on the pelvis. DDH is thought to be caused by abnormal fetal ligament development within the hip that is intensified by the excessive levels of circulating maternal estrogen. Fetal malposition, such as breech, and oligohydramios, greatly increases the risk for developing DDH as well. DDH is more common in female patients and on the left side. It has been linked with spina bifida and arthrogryposis, and there is a familial link as well. These young patients are recommended to be screened between 4 and 6 weeks after birth. Clinically, patients will have asymmetric skinfolds on the legs, have leg length discrepancy, and have limited limb abduction. There are two clinical tests that can be performed to evaluate an infant for DDH—the Barlow test and the Ortolani test (Fig. 14-10).

The Barlow test is used to evaluate the hip for dislocation. For the Barlow test, the hip is flexed and adducted, and the knee is pushed posteriorly and superiorly. The Ortolani test, which evaluates for the reduction or relocation of a dislocated hip, is performed by abducting and lifting the thigh, essentially relocating the hip back into the acetabulum. During the Ortolani test, an audible “click” may be heard and a palpable “clunk” felt as the head of the femur passes over the acetabulum.

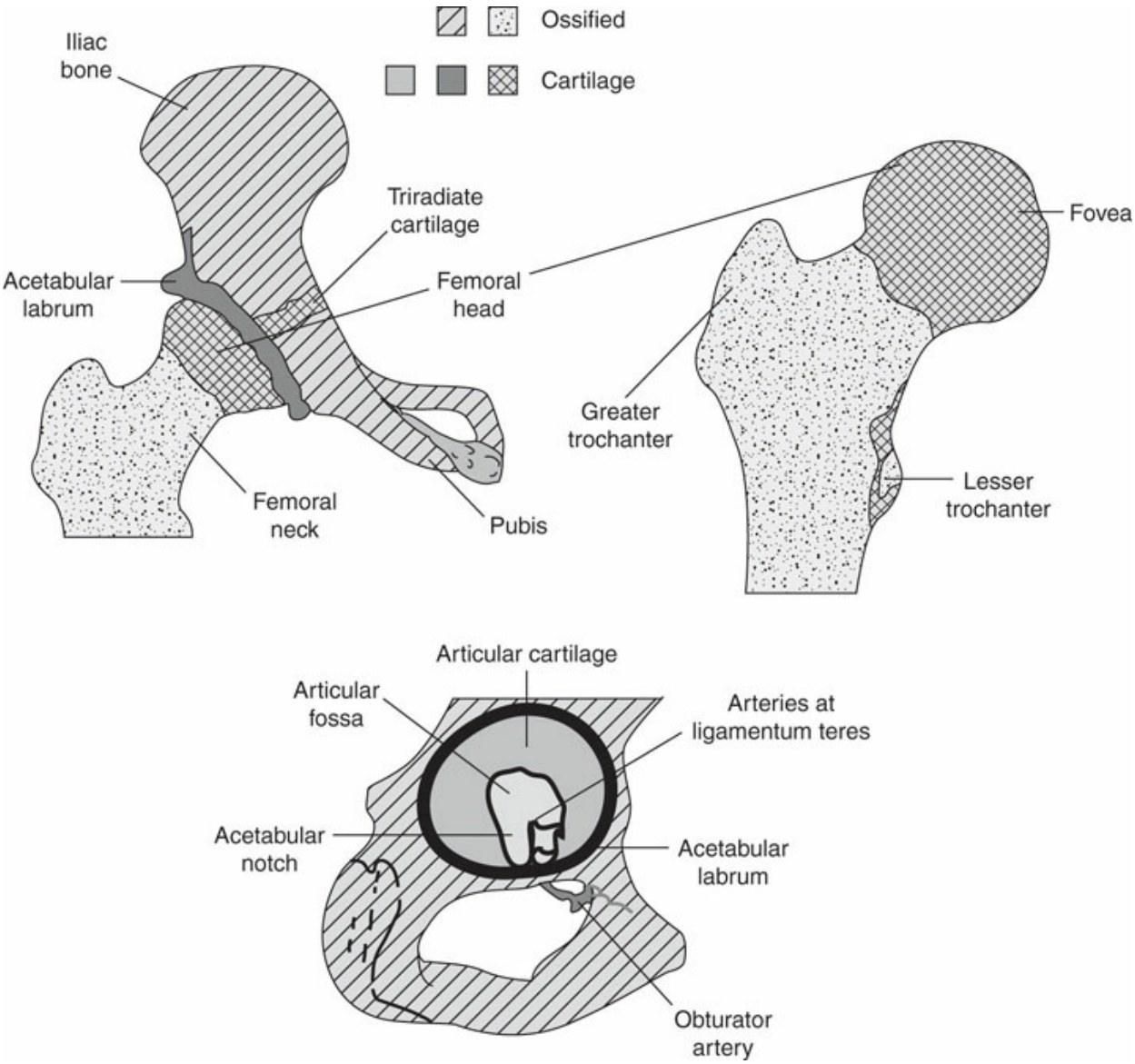


Figure 14-9 Parts of the infant hip.

During sonographic imaging of the infant hip, several important landmarks should be evaluated while the hip is examined in both flexion and at rest. Specifically, the femoral head and its relationship to the acetabelum should be examined in both stress and relaxed states. The position of the head of the femur, as it relates to the acetabelum, can be described as normal, subluxed, or dislocated (Fig. 14-11). Subluxation is a term used to denote partial dislocation of the hip. Sonographically, the infant hip is examined in both coronal and transverse in either the supine or lateral decubitus position. Although protocols may vary, it is recommended that both hips be examined, and a neutral or resting coronal view and a transverse view of the flexed hip with and without stress be obtained. In the coronal plane, the femoral head appears as a hypoechoic rounded structure that contains echogenic stripes throughout. The ilium can be noted appearing to extend from the femoral head as an echogenic linearly structure producing an acoustic shadow. The

acetabelum is the recessed region of the pelvis where the femoral head should rest.

SOUND OFF
The Barlow test requires for the leg to be adducted, whereas the Ortolani test requires the leg to be abducted.

Sonographic imaging of the infant hip, which offers a dynamic analysis, should include both coronal and transverse images using a high-frequency linear transducer. The sonographic diagnosis of DDH can be definitive when the femoral head rests clearly outside the acetabulum, denoting dislocation. While a normal hip rests centrally within the acetabulum, a subluxed hip will rest more laterally, although it is partially covered by the acetabulum. Because several techniques have been suggested, the interpretation results may depend upon the criteria utilized by the physician for the diagnoses of DDH. For example, in the coronal view, the Graf technique can be obtained. This technique is used to measure the relationship of the femoral head and acetabulum by evaluating alpha and beta angles created by the relationships of these structures (Fig. 14-12). To assess the depth of the acetabulum, from the coronal view a line can be drawn along the ilium and through the femoral head, with two other lines drawn along the acetabulum and adjacent to the femoral head, to obtain the two pertinent angles. Essentially, the smaller the alpha angle and the larger the beta angle, the more likely the infant is suffering from DDH.

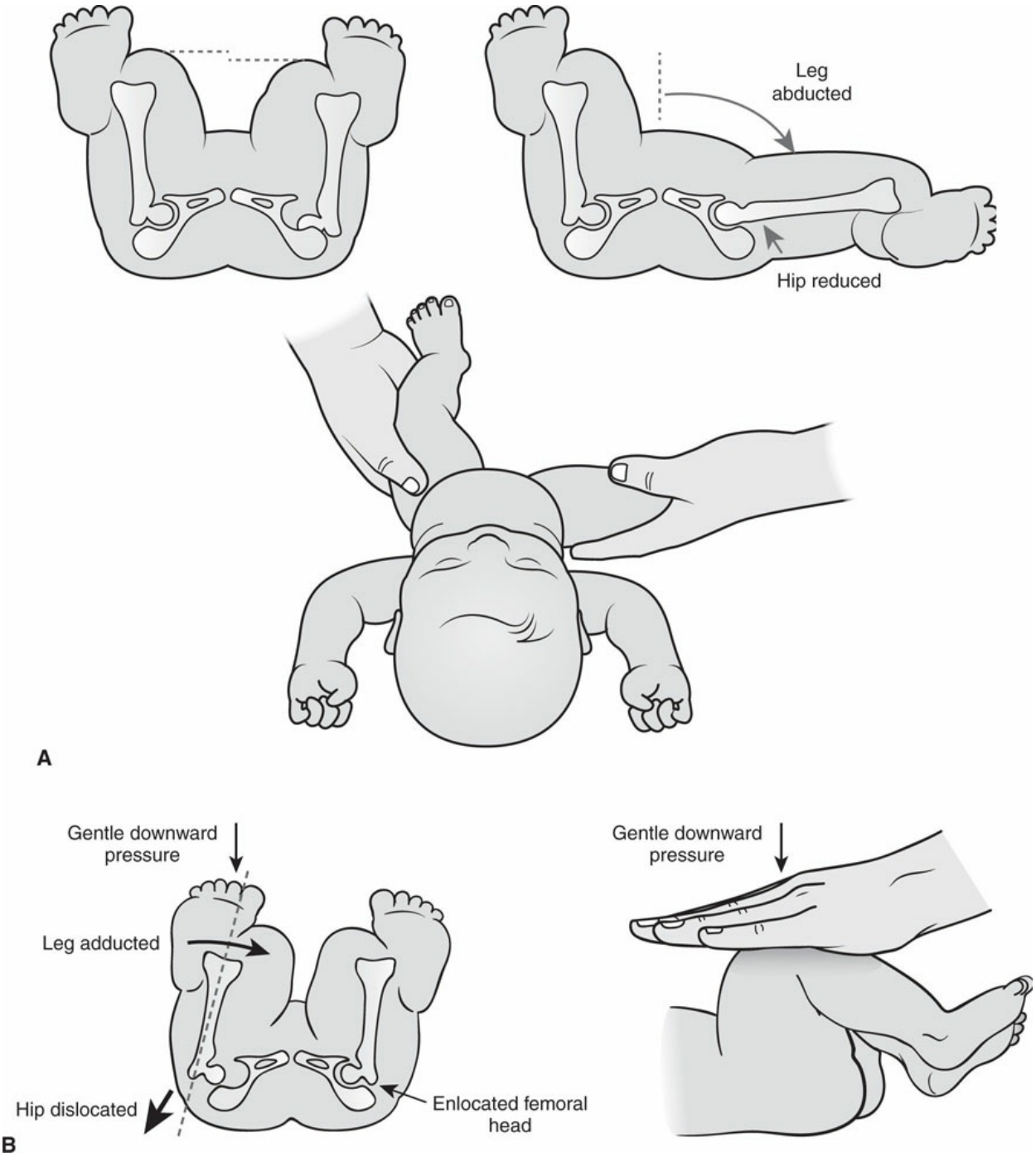


Figure 14-10 A. Ortolani test. **B.** Barlow test.

Another test can be used to evaluate the amount of coverage of the femoral head by the acetabulum by obtaining a coronal image and drawing parallel lines along the ilium, and the maximum depth and height of the femoral head. Coverage of the femoral head by the acetabulum of greater than 55% is said to be normal, whereas 50% or less is said to be shallow, and less than 45% is considered very shallow. Nonsurgical treatment for DDH can be performed with casting or by means of a Pavlik harness. Sonography may be used as a follow-up imaging tool subsequent to treatment.

CLINICAL FINDINGS OF DEVELOPMENTAL DYSPLASIA OF THE INFANT HIP

1. History of breech birth
2. Family history of DDH
3. Asymmetric skinfolds on the legs
4. Leg length discrepancy
5. Limited limb abduction
6. Positive Barlow or Ortolani test

SONOGRAPHIC FINDINGS OF DEVELOPMENTAL DYSPLASIA OF THE INFANT HIP

1. Femoral head located completely outside the acetabulum (complete dislocation)
2. Partially coverage of the femoral head by the acetabulum (subluxation)
3. Evidence of a shallow acetabulum (<50% coverage of femoral head)
4. Small alpha angle (Graf technique)
5. Large beta angle (Graf technique)

SOUND OFF

The smaller the alpha angle and the larger the beta angle, the more likely the infant is suffering from DDH.

Infant Hip Joint Effusion—Transient Synovitis

A hip joint effusion, which is the buildup of fluid within the hip secondary to inflammation, typically occurs in children between 5 and 10 years of age, and is most likely the result of transient synovitis—also referred to as toxic synovitis or irritable hip. Transient synovitis is the most common cause of a painful hip and joint effusion in children. The cause is unknown, although viral causes, trauma, and an allergic reaction have been suspected. Patients typically present with leg and knee pain, a reluctance to walk, irritability, low-grade fever, and mild leukocytosis. The sonographic appearance of a joint effusion is that of anechoic or hypoechoic fluid that elevates the anterior capsule of the joint. Often, the abnormal joint capsule width exceeds 5 mm (Fig. 14-13). A sonographic analysis of the asymptomatic hip first can provide the sonographer with a valid baseline before the symptomatic hip is analyzed. An ultrasound-guided hip aspiration may be performed to relieve pain and to differentiate the disorder from the more worrisome diagnosis of septic arthritis.

CLINICAL FINDINGS OF HIP JOINT EFFUSION

1. Leg and knee pain
2. Reluctance to walk
3. Irritability
4. Low-grade fever
5. Mild leukocytosis

Sonographic Findings of Hip Joint Effusion

1. Anechoic or hypoechoic fluid that elevates the anterior capsule of the joint
2. Width of the abnormal hip joint capsule typically exceeds 5 mm

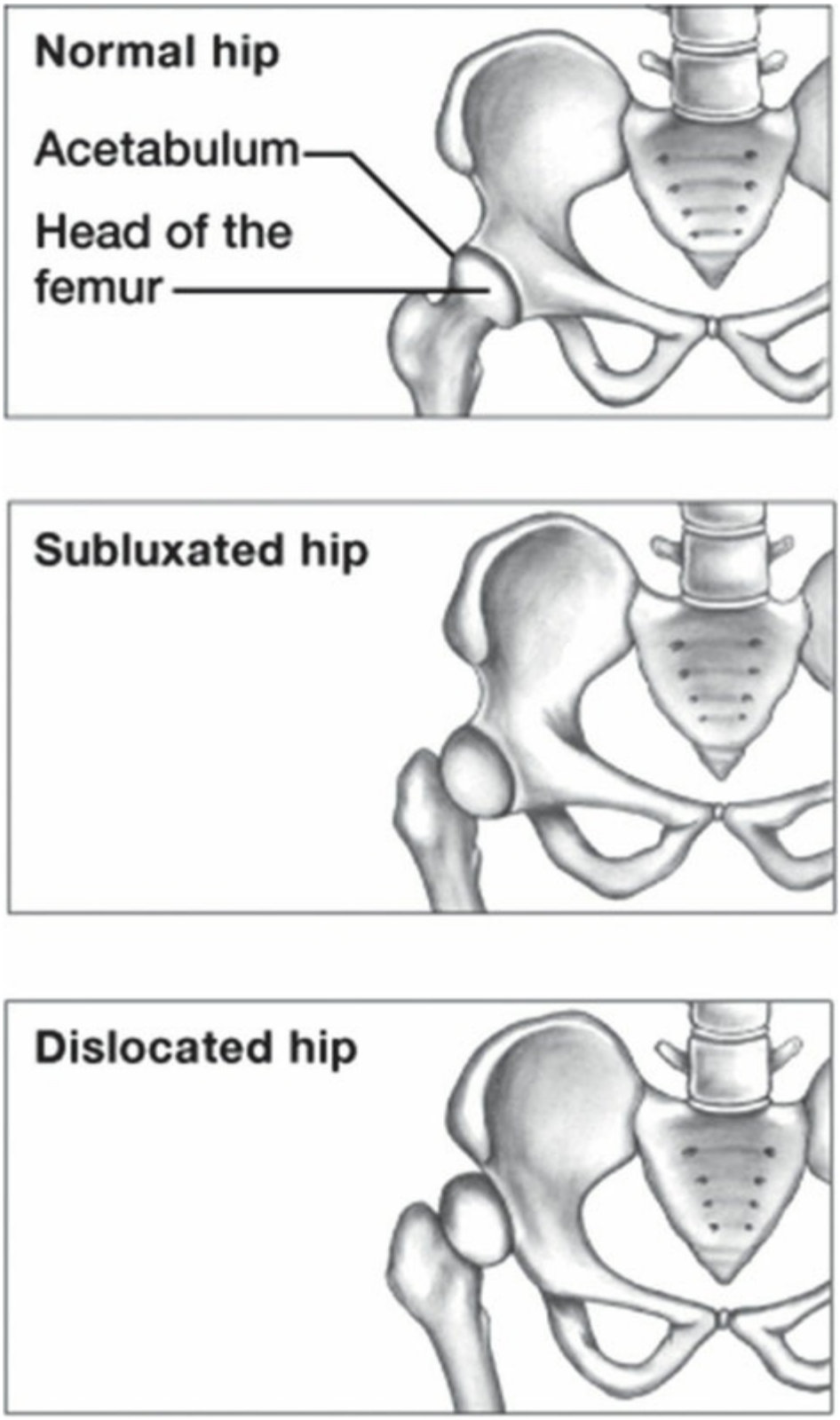


Figure 14-11 Developmental dysplasia of the hip (DDH). Normally, the head of the femur should sit snuggly within the acetabulum (**top image**). With DDH, flattening of the acetabulum prevents the head of the femur from rotating properly. The acetabelum may be shallow. Subluxation (**middle image**) is partial dislocation of the hip. With complete dislocation, the femoral head is located outside the acetabulum (**bottom image**).

BREAST

Sonographers should have a fundamental appreciation of breast anatomy (Fig. 14-14). Sonographic annotation of the breast is typically based on the quadrant or clockface (Fig. 14-15). However, some institutions may also employ the 123 and ABC annotation, which are used to further describe the breast tissue based on distance from the nipple and depth, respectively (Fig. 14-16). In addition, some institutions may use fingers from the nipple or use a measuring device to be precise in the localization of breast pathology.

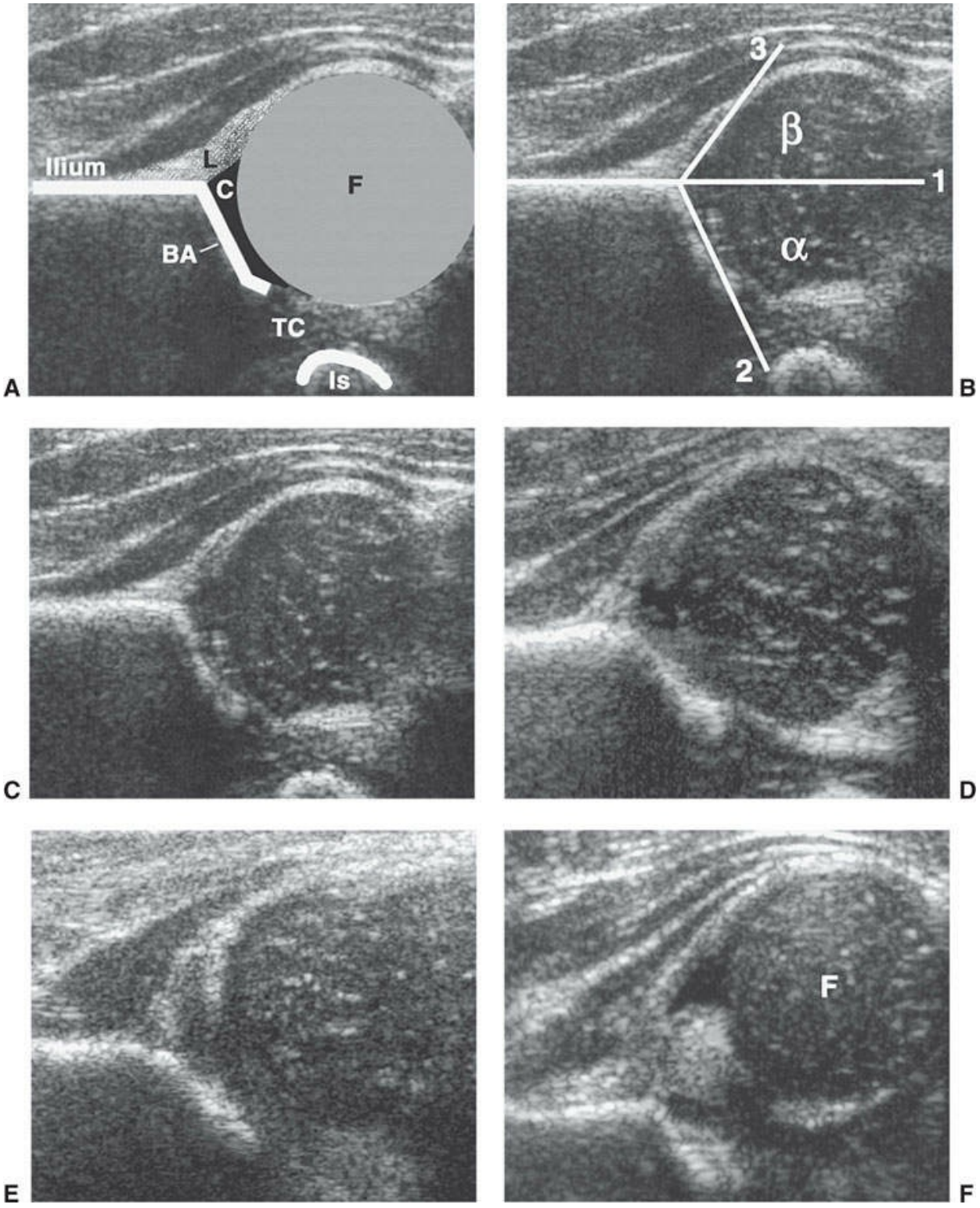


Figure 14-12 Sonographic anatomy of the hip evaluated by the Graf technique. **A.** Schematic representation of the coronal view of the hip: femoral head (*F*), bony acetabulum (*BA*), labrum (*L*). *C*, acetabular roof cartilage; *TC*, triradiate cartilage; *Is*, ischium. **B.** In the Graf technique, horizontal line is drawn along the ilium (*1*), and lines are drawn along the BA (*2*) and labrum (*3*) to obtain alpha (α) and beta (β) angles. The α angle is equal to or greater than 60 degrees in infants with seated hips and less than 50 degrees in patients with dysplasia. The β angle increases proportionally with the degree of hip dysplasia and displacement. **C.** Normal hip. **D.** Slightly shallow acetabulum. **E.** Shallow acetabulum and the femoral head is

minimally covered and displaced laterally. **F.** Dislocation.

Using a linear transducer, the breast may be imaged with the patient in a slight posterior oblique position to evenly distribute the breast tissue over the chest. Superficial pathology can be better visualized with a standoff device or a large amount of mounded gel. Images may be obtained in both the transverse and longitudinal planes. However, because of the radial arrangement of the lactiferous ducts, radial and antiradial imaging planes may be used by some institutions as well.

The normal sonographic appearance of the breast tissue layers should be appreciated by sonographers. The three layers of breast tissue from superficial to deep are the subcutaneous layer, the mammary layer, and the retromammary layer. The subcutaneous layer is typically hypoechoic and is composed mostly of fat. The mammary layer, which is typically hyperechoic and contains the ducts and glandular tissue, is the functional layer of the breast. The sonographic appearance of the mammary layer can vary based on many factors, including the age of the patient and the distribution of the various functional elements. The retromammary layer is typically hypoechoic and contains fat as well.

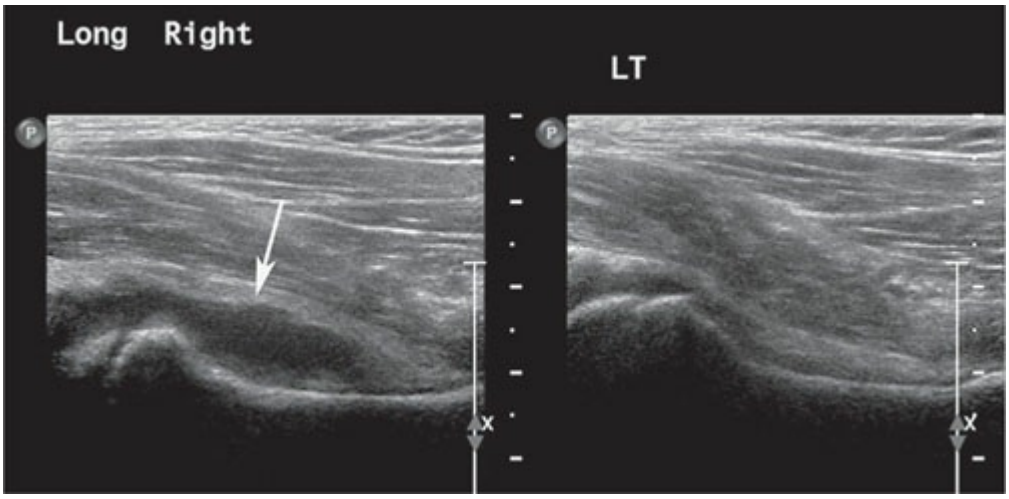


Figure 14-13 Hip effusion in a 7-year-old female. Sonogram of the hip reveal hypoechoic fluid within the right hip joint (*arrow*). The left hip joint is normal.

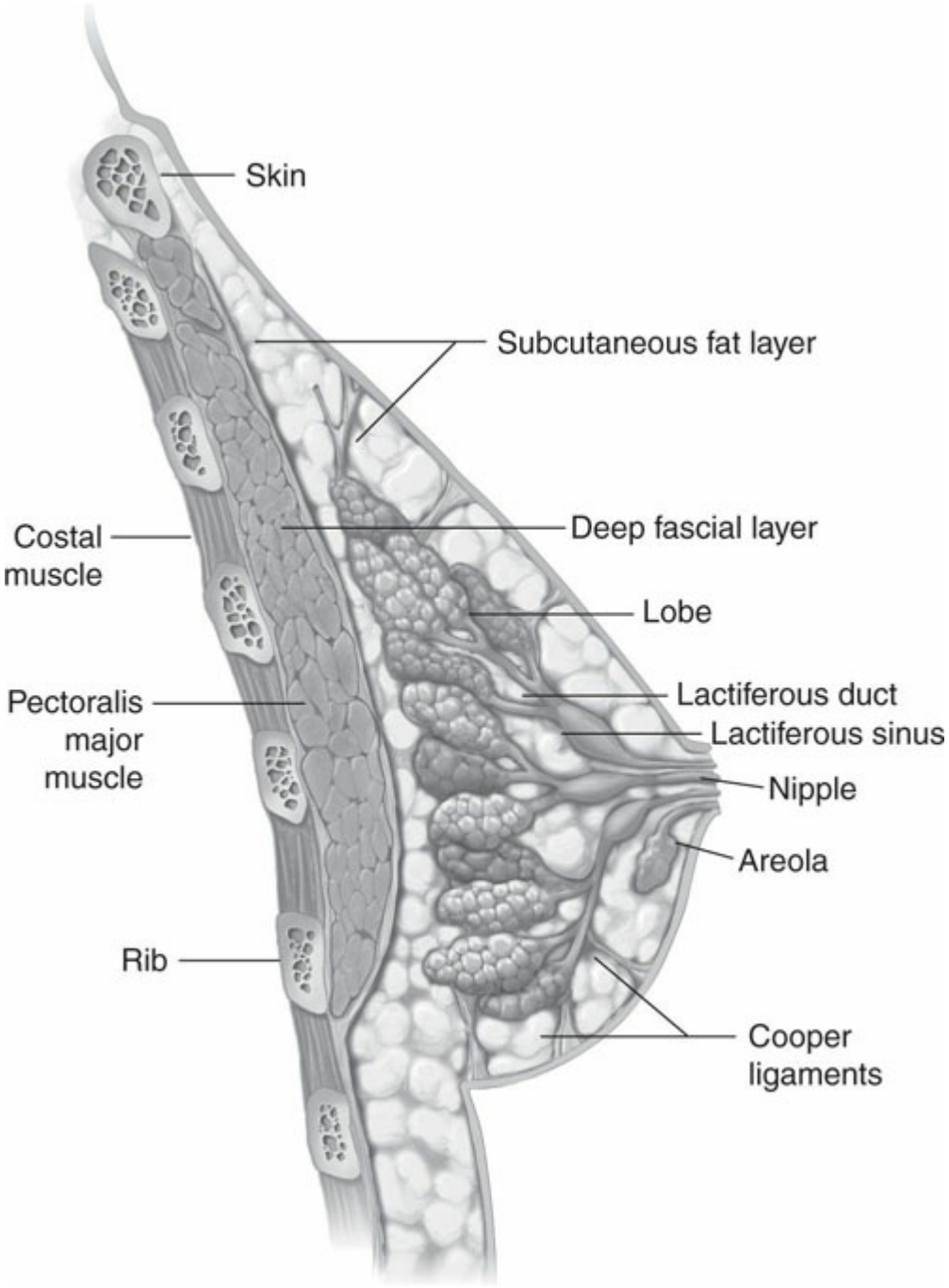


Figure 14-14 Basic breast anatomy.

BREAST PATHOLOGY

Mastitis and Breast Abscess

Breast infection—termed mastitis—is most often associated with lactation. Specifically, the type of mastitis associated with breast feeding is referred to as puerperal mastitis. The infection is characteristically caused by the staphylococcus or streptococcus organisms. Patients with mastitis will suffer from pain, swelling, and warmth and redness in the area. The patient may also suffer from fever and leukocytosis. The primary role of sonography is to

determine the presence of a focal abscess within a breast that is affected with mastitis. Sonographically, mastitis will appear as ill-defined areas of echogenicity with diffuse edema and hypoechoic fluid within the subcutaneous tissue that may outline the fat lobules (Fig. 14-17). The affective skin may measure greater than 2 mm in thickness. Reactive, enlarged lymph nodes may be seen as well.

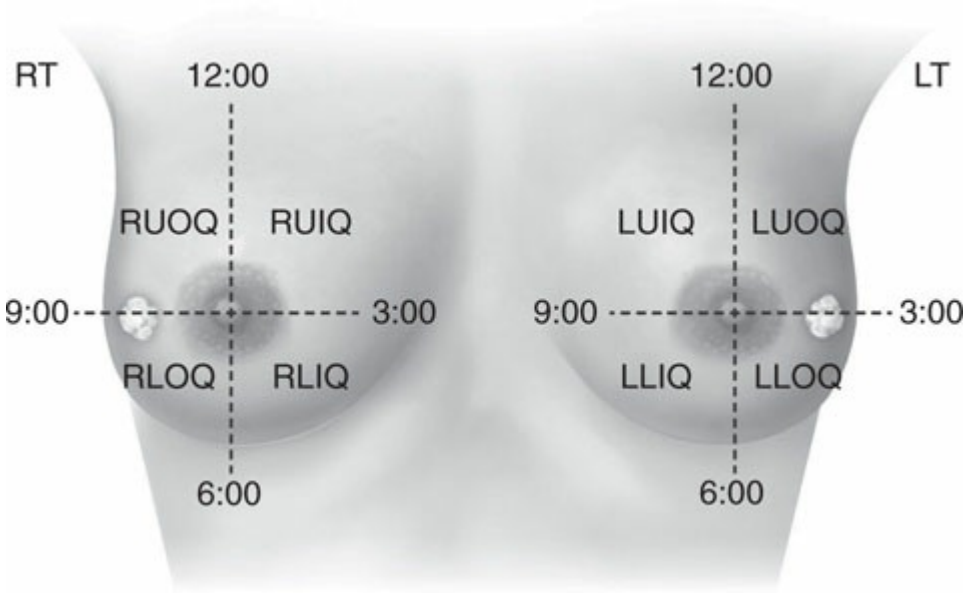


Figure 14-15 Quadrants and clockface annotation.

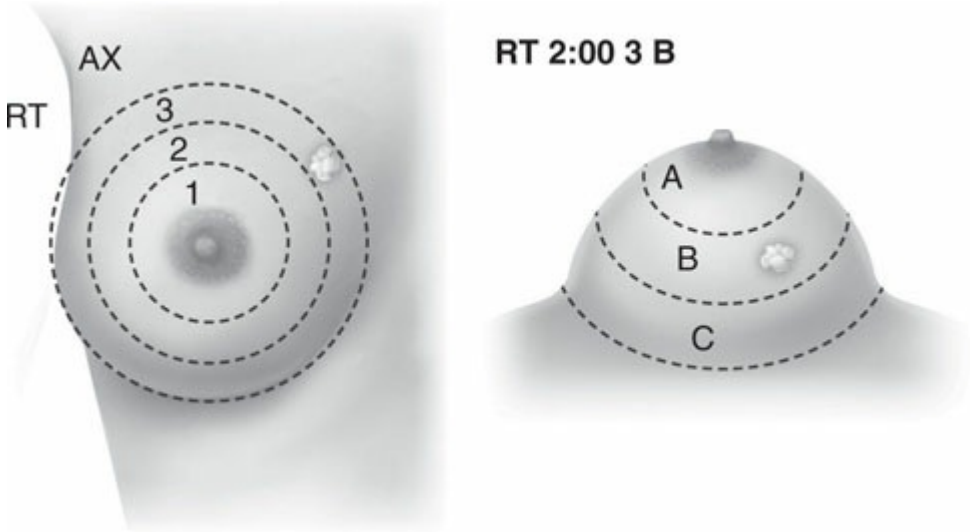


Figure 14-16 123 and ABC annotation.

A breast abscess is a focal area of pus. The patient will present clinically much like someone suffering from mastitis. Where diffuse pain may be seen more with mastitis, with an abscess, the patient may have a palpable, painful lump. Sonographically, an abscess is typically a focal, complex fluid collection that can contain debris (Fig. 14-18). As with mastitis, enlargement

of the lymph nodes may be evident as well in the presence of a breast abscess.

SOUND OFF
Mastitis is most often associated with breastfeeding.

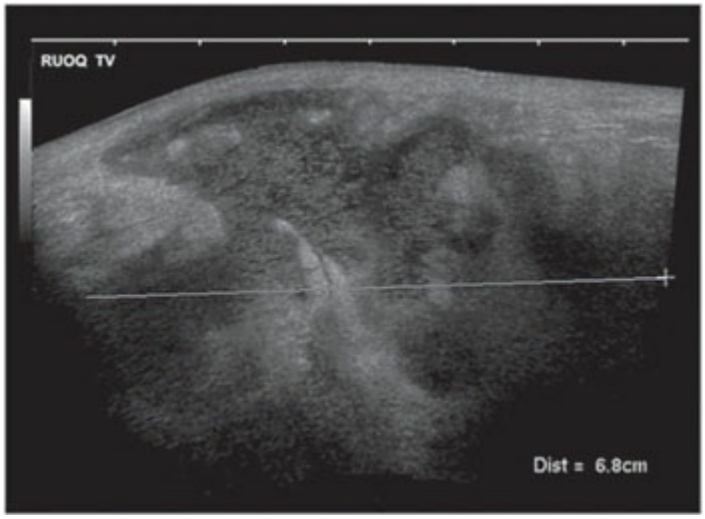


Figure 14-17 Mastitis. As seen in this image, mastitis may appear as ill-defined areas of echogenicity with diffuse edema and hypoechoic fluid within the subcutaneous tissue that outlines the fat lobules.

Clinical Findings of Mastitis

1. Pain
2. Swelling
3. Warmth and redness in the area
4. Fever
5. Leukocytosis

Sonographic Findings of Mastitis

1. Ill-defined areas of echogenicity
2. Diffuse edema
3. Hypoechoic fluid within the subcutaneous tissue that outlines the fat lobules
4. Breast skin thickening greater than 2 mm
5. Enlarged lymph nodes may be present

Sonographic Findings of a Breast Abscess

1. Palpable, tender lump
2. Complex, focal mass that contains debris

Galactocele

Lactating patients may present to the emergency department with a palpable mass that may be painful. A galactocele is a milk-filled cyst that can develop after an abrupt termination to breast feeding or result from an obstruction to the lactiferous duct or ducts. The mass is typically palpable and located near the areola. These cysts can be painful and can become infected as well. Sonographically, a galactocele will appear as a round mass with good borders. They may appear complex or contain a fluid–fluid level.

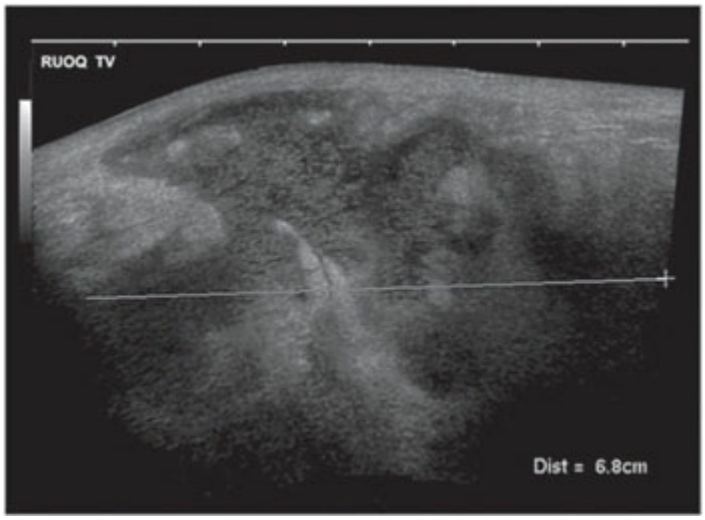


Figure 14-18 Breast abscess. This 6.8 cm complex mass was diagnosed as a breast abscess and was noted in a patient with coexisting mastitis.

CLINICAL FINDINGS OF A GALACTOCELE

1. Palpable, periareolar mass
2. Possible pain

SONOGRAPHIC FINDINGS OF GALACTOCELE

1. Round, complex mass
2. May contain a fluid–fluid level

Gynecomastia

Gynecomastia is the benign enlargement of the male breast. Gynecomastia can occur at any time, but is most commonly encountered just after birth, during puberty, and during mid-to-late adulthood between 50 and 80 years of age. Gynecomastia can be bilateral and can be associated with high levels of human chorionic gonadotropin, which may be produced by some testicular tumors, high levels of estrogen, adrenal tumors, hepatoblastoma, Klinefelter syndrome, and with some drugs, including steroids and marijuana. Patients

most often present with a tender, palpable retroareolar breast mass that is firm to touch. Sonographically, gynecomastia most likely appears as a triangular hypoechoic mass posterior to the areola.

CLINICAL FINDINGS OF GYNECOMASTIA

1. Tender, palpable retroareolar breast mass that is firm to touch

SONOGRAPHIC FINDINGS OF GYNECOMASTIA

1. Hypoechoic mass posterior to the areola
2. May have a triangular shape

SONOGRAPHY OF SUPERFICIAL STRUCTURES

Soft-tissue sonography typically requires the use of a high-frequency linear transducer, although if the area of interest lies deeper than expected, a lower frequency transducer may be utilized. Sonographers should have an appreciation of the anatomy and the sonographic appearance of the skin, subcutaneous tissue, fascia, and muscle (Fig. 14-19). The skin consists of two layers—the epidermis and the dermis. These two layers are indistinguishable and appear collectively as a hyperechoic linear structure. The subcutaneous layer appears hypoechoic with interspersed hyperechoic linear echoes representing connective tissue septa. Fascia appears as a hyperechoic layer of varying thickness.

PATHOLOGY OF SUPERFICIAL STRUCTURES

Superficial Epidermal Cyst

A superficial epidermal cyst may also be referred to as an epidermal inclusion cyst, an epidermoid cyst, or possibly a sebaceous cyst, although a sebaceous cyst implies that the cyst is sebaceous in origin, which is not always true. True sebaceous cysts are uncommon. Superficial epidermal cysts are most likely found in the scalp, face, neck, trunk, or back. These cysts, which can be congenital or the result of trauma, are potentially the result of an obstructed hair follicle. Clinically, the patient will have a palpable mass that raises the skin and is most likely asymptomatic. However, infection can result in pain and oozing of fluid or solid material from the cyst. An epidermal cyst can have varying sonographic appearances, including anechoic, hypoechoic, complex, or hyperechoic. They have been described as having a pseudotestis appearance. To better visualize the cyst, a

standoff device can be utilized.

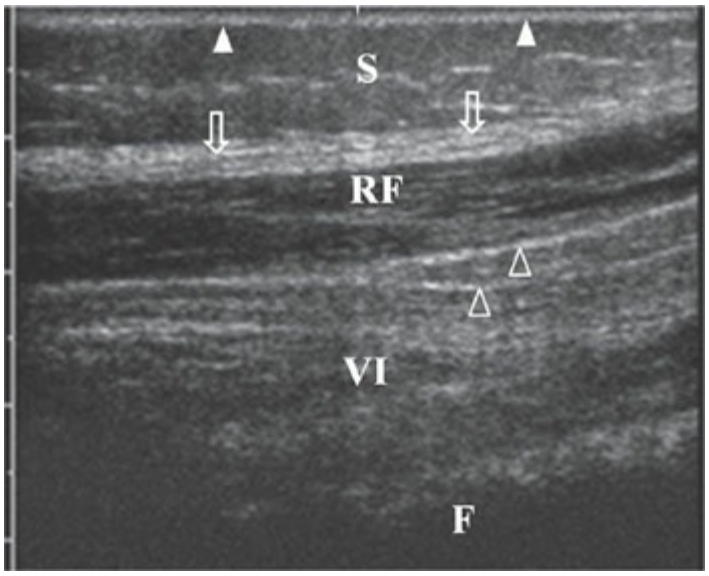


Figure 14-19 Sonographic appearance of skin layers and muscle in the thigh. Longitudinal image of the epidermis and dermis (*white arrowheads*), the subcutaneous fat (*S*), the rectus femoral muscle (*RF*), connective tissue (*open arrowheads*), the vactus intermedius muscle (*VI*), and the femur (*F*).

CLINICAL FINDINGS OF A SUPERFICIAL EPIDERMAL CYST

1. Visible, palpable mass just under the skin
2. Pain and redness in the area

SONOGRAPHIC FINDINGS OF A SUPERFICIAL EPIDERMAL CYST

1. Anechoic, hypoechoic, complex, or hyperechoic cyst or mass
2. Pseudotestis appearance

SOUND OFF
Superficial epidermal cysts are most likely found in the scalp, face, neck, trunk, or back.

Ganglion Cyst

A ganglion cyst is a common mass found along the dorsal aspect of the hand and wrist, although they can arise from any joint, and are thus discovered in the foot and ankle as well. Large ganglion cysts in the wrist have been referred to as Bible bumps, because individuals in the past have used large books—like the Bible—to reduce the cyst by slamming the large book against it. This practice is not a recommended course of treatment however. Clinically, it may be hard to touch and painful. It is often treated with an

injection of corticosteroids or it may have to be surgically removed. Sonographically, it typically appears as a noncompressible, anechoic mass with acoustic enhancement (Fig. 14-20). However, they may contain debris and septations.

CLINICAL FINDINGS OF A GANGLION CYST

1. Palpable mass most often located along the dorsal aspect of the hand or wrist
2. Can be painful

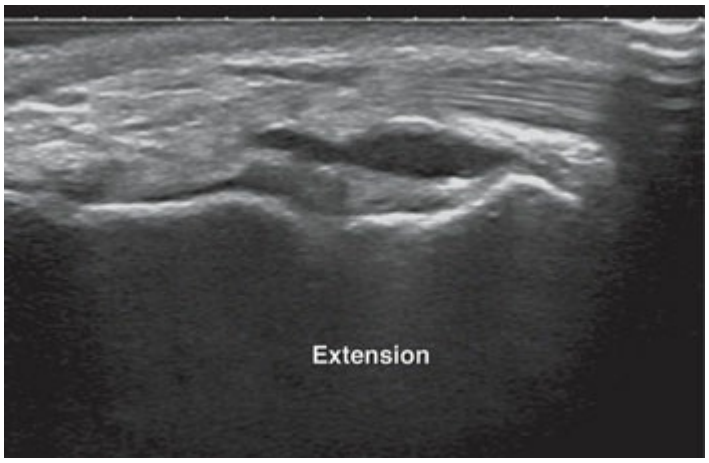


Figure 14-20 Ganglion cyst. This small cyst was located in a patient's wrist and was determined to be a ganglion cyst.

SONOGRAPHIC FINDINGS OF A GANGLION CYST

1. Noncompressible, anechoic mass with acoustic enhancement
2. May contain debris or septations

SOUND OFF

Large ganglion cysts in the wrist have been referred to as Bible bumps, because individuals in the past have used large books—like the Bible—to reduce the cyst by slamming the large book against it.

Superficial Lipoma and Hemangioma

A lipoma is a benign, fatty tumor. Superficial lipomas are typically oval in shape and isoechoic to the surrounding fat, but they can appear hypoechoic or hyperechoic (Fig. 14-21). Lipomas are usually compressible and may be observed during a physical examination. Patients are typically asymptomatic, but may complain of an unsightly bulging of the skin in the area of the lipoma.

A superficial hemangioma is a benign mass that is comprised of vascular

channels. They are typically asymptomatic and appear as a raised, red or reddish-purple mass on the skin. Blood flow may be detectable with color Doppler, and superficial hemangiomas are typically sonographically hypoechoic in appearance.

CLINICAL FINDINGS OF A SUPERFICIAL LIPOMA

1. Asymptomatic
2. Obvious mass under the skin
3. Compressible

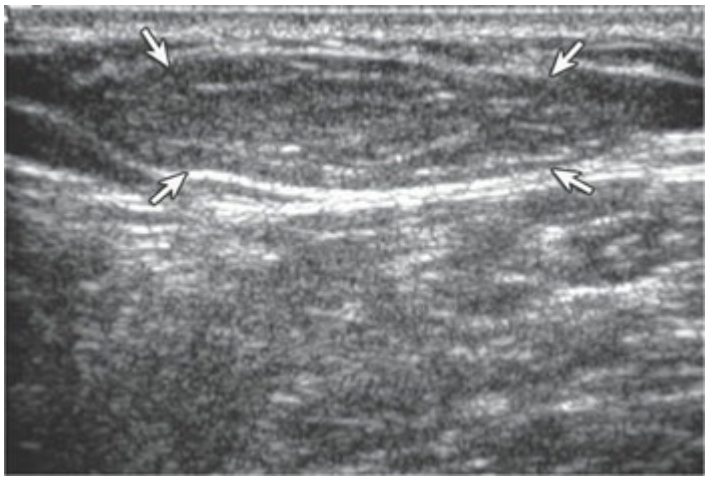


Figure 14-21 Lipoma. This lipoma (*between arrows*) appearing as an oval hyperechoic mass is noted just under the skin.

SONOGRAPHIC FINDINGS OF A SUPERFICIAL LIPOMA

1. Most likely an isoechoic mass as compared to the surrounding tissues
2. Typically have an oval shape

CLINICAL FINDINGS OF A SUPERFICIAL HEMANGIOMA

1. Asymptomatic
2. Red or reddish-purple, raised mass on the skin

SONOGRAPHIC FINDINGS OF A SUPERFICIAL HEMANGIOMA

1. Hypoechoic
2. Blood flow may be detectable with color Doppler

Baker Cyst

A Baker cyst, or popliteal cyst, is located in the popliteal fossa, behind the knee. These cysts are common and a result from the accumulation of

synovial fluid from a weakening in the joint capsule of the knee, as seen in conditions such as rheumatoid arthritis or osteoarthritis. A channel may be seen connecting the cyst to the joint space.

Baker cysts may be asymptomatic. However, they may also present with focal tenderness secondary to hemorrhage, rupture, or impingement on adjacent structures. Clinical findings of a Baker cyst may mimic those of a deep venous thrombosis. Sonographically, a Baker cyst appears as an anechoic mass with posterior enhancement in the popliteal fossa (Fig. 14-22). Complicated Baker cysts may contain echogenic fluid, debris, pannus, or septations.

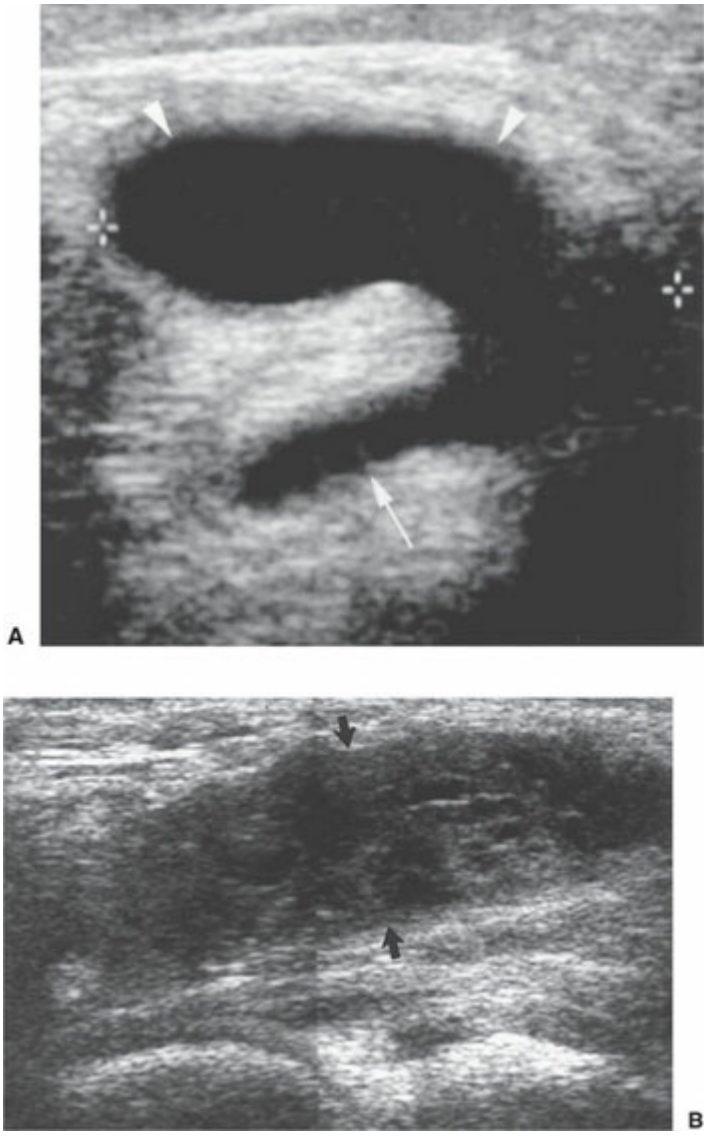


Figure 14-22 Baker cysts. **A**. An uncomplicated Baker cyst (*between calipers and arrows*) appears as an anechoic mass in the popliteal fossa. **B**. A large Baker cyst (*arrows*) in a patient with rheumatoid arthritis contains some echogenic debris and pannus.

SOUND OFF

A Baker cyst may be seen in the presence of rheumatoid arthritis or other knee joint issues.

CLINICAL FINDINGS OF A BAKER CYST

1. Asymptomatic
2. Focal tenderness in the popliteal fossa

SONOGRAPHIC FINDINGS OF A BAKER CYST

1. Anechoic mass with posterior enhancement
2. Complicated Baker cysts may contain echogenic fluid, debris, or septations

Pilonidal Cyst

A pilonidal cyst is most often found within the natal cleft, which is also referred to as the intergluteal cleft or gluteal cleft, and is located between the buttocks (Fig. 14-23). However, pilonidal cysts may also be referred to as pilonidal sinus and may also be seen within the fingers or toes. Pilonidal means "nest of hair." Consequently, these cysts are comprised of loose hairs and skin debris. Some pilonidal cysts are asymptomatic, but they can become infected and develop into an abscess that requires intervention. Patients will present with skin edema, warmth, and pain in the area of the cyst that may produce bloody drainage. Patients who are more prone to pilonidal cyst include those who sit for an extended amount of time and hairdressers. During World War II, the cysts were linked with soldiers who had to endure long, bumpy jeep rides, and thus they were termed "jeep disease." Sonographically, pilonidal cysts are identified as a complex mass, and a hypoechoic tract may be noted extending from the cyst to the external surface of the skin (Fig. 14-24). Color Doppler can be used to confirmed hyperemia secondary to infection. A standoff device of some sort can be utilized for better visualization.

CLINICAL FINDINGS OF A PILONIDAL CYST

1. Edema, warmth, and pain in the area of the cyst
2. Bloody drainage from the cyst may be present

SONOGRAPHIC FINDINGS OF A PILONIDAL CYST

1. Complex, subcutaneous mass
2. Hyperemia around the mass
3. Hypoechoic tract may be seen extending from the cyst to the skin surface

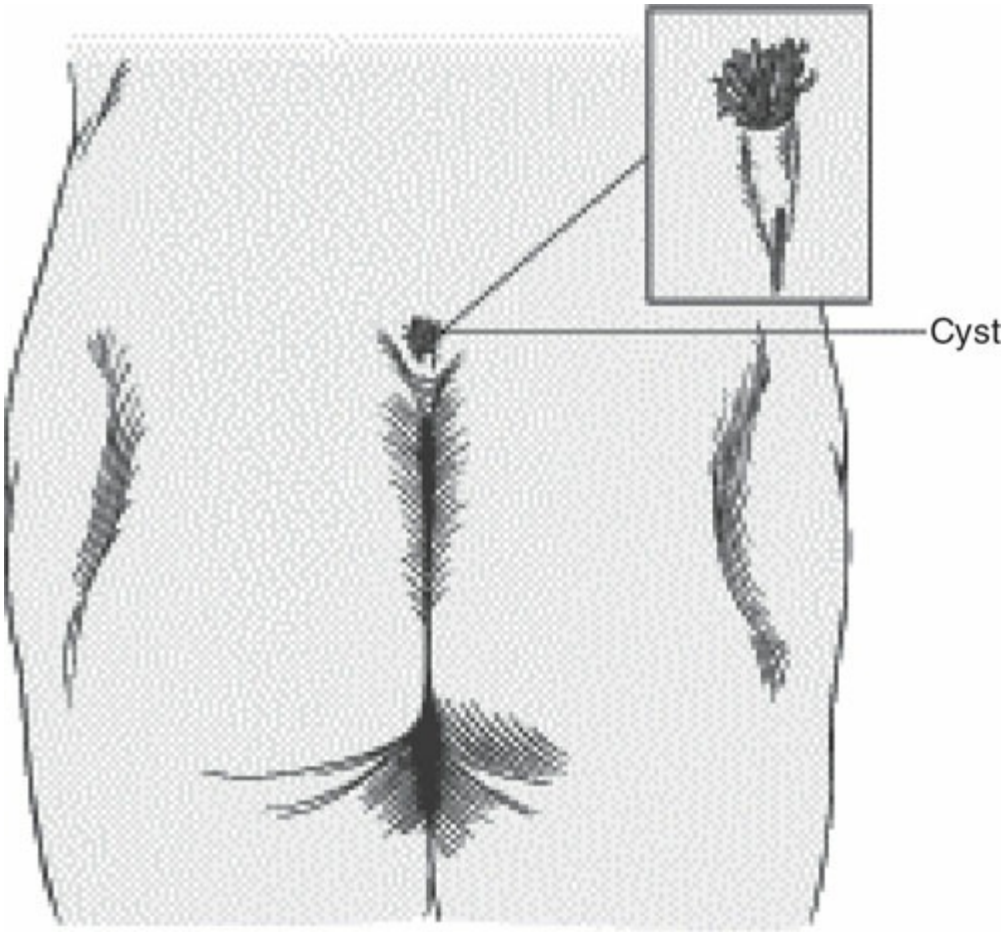


Figure 14-23 Typical location of a pilonidal cyst.

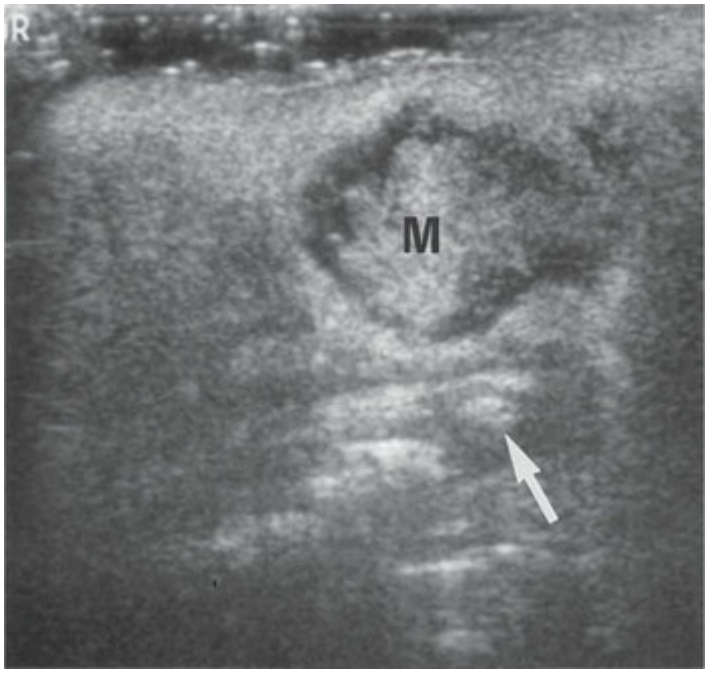


Figure 14-24 Pilonidal cyst. This pilonidal cyst appeared as a complex mass (*M*) at the tip of the distal spine (*arrow*) in this infant.

Cellulitis and Superficial Abscess

Cellulitis is infection and subsequent inflammation of the skin and subcutaneous tissue. It is most often caused by Staphylococcus aureus and Streptococcus pyogenes. Often, the skin is red, tender, and warm. There may be evidence of leukocytosis as well, especially if an abscess is present. Sonographically, cellulitis appears as hypoechoic, edematous strands within the soft tissue, and has been described as a cobblestone appearance (Fig. 14-25). When cellulitis is identified, a thorough investigation for a focal abscess should ensue. A hidden abscess is termed an occult abscess. Abscesses can have a wide range of sonographic features. They are focal fluid collections that are often complex and have a peripheral rim of hyperemia that can be detected with color Doppler.

SOUND OFF
When cellulitis is identified, the sonographer should look carefully for a complex focal fluid collection that may represent abscess development.

CLINICAL FINDINGS OF CELLULITIS

1. Red, tender, warm area of the skin
2. Possible elevated white blood cell count (especially with abscess development)

SONOGRAPHIC FINDINGS OF CELLULITIS

1. Hypoechoic, edematous strands within the soft tissue (cobblestone appearance)

SONOGRAPHIC FINDINGS OF A SUPERFICIAL ABSCESS

1. Hypoechoic, edematous strands within the soft tissue (cobblestone appearance)
2. Focal fluid collection that is often complex, denoting the abscess
3. A peripheral rim of hyperemia may be detectable with color Doppler

Primary and Metastatic Melanomas

Malignant melanoma accounts for up to 11% of skin cancers. Primary melanoma classically appears hypoechoic, with increased vascular flow noted with color Doppler. Melanoma is also the most likely primary tumor to metastasize to the subcutaneous fat. It will most often appear sonographically as a solid, vascular hypoechoic mass as well.

SONOGRAPHIC FINDINGS OF METASTATIC MELANOMA

1. Solid, vascular hypoechoic mass

FOREIGN BODIES

Sonographic Assessment of Foreign Bodies

A high-frequency linear array transducer is utilized to image for foreign bodies. Foreign bodies just below the skin surface may require the aid of a standoff pad for improved visualization. Sonography can aid in the localization and removal of some objects, particularly wooden fragments, which may not be recognized with radiography. Most foreign bodies appear as hyperechoic structures with some degree of posterior shadowing. Bullets, shrapnel, and other metallic objects may cause ring-down or comet-tail artifact as well. Inflammation around a foreign body will appear as a hypoechoic area adjacent to the structure. It is important to note that air at the site of a foreign body may produce bright echoes and therefore cause some ambiguity about the correct orientation of the object. To aid in the removal of the object, a distance can be obtained from the surface of the skin to the foreign object by using electronic calipers (Fig. 14-26).

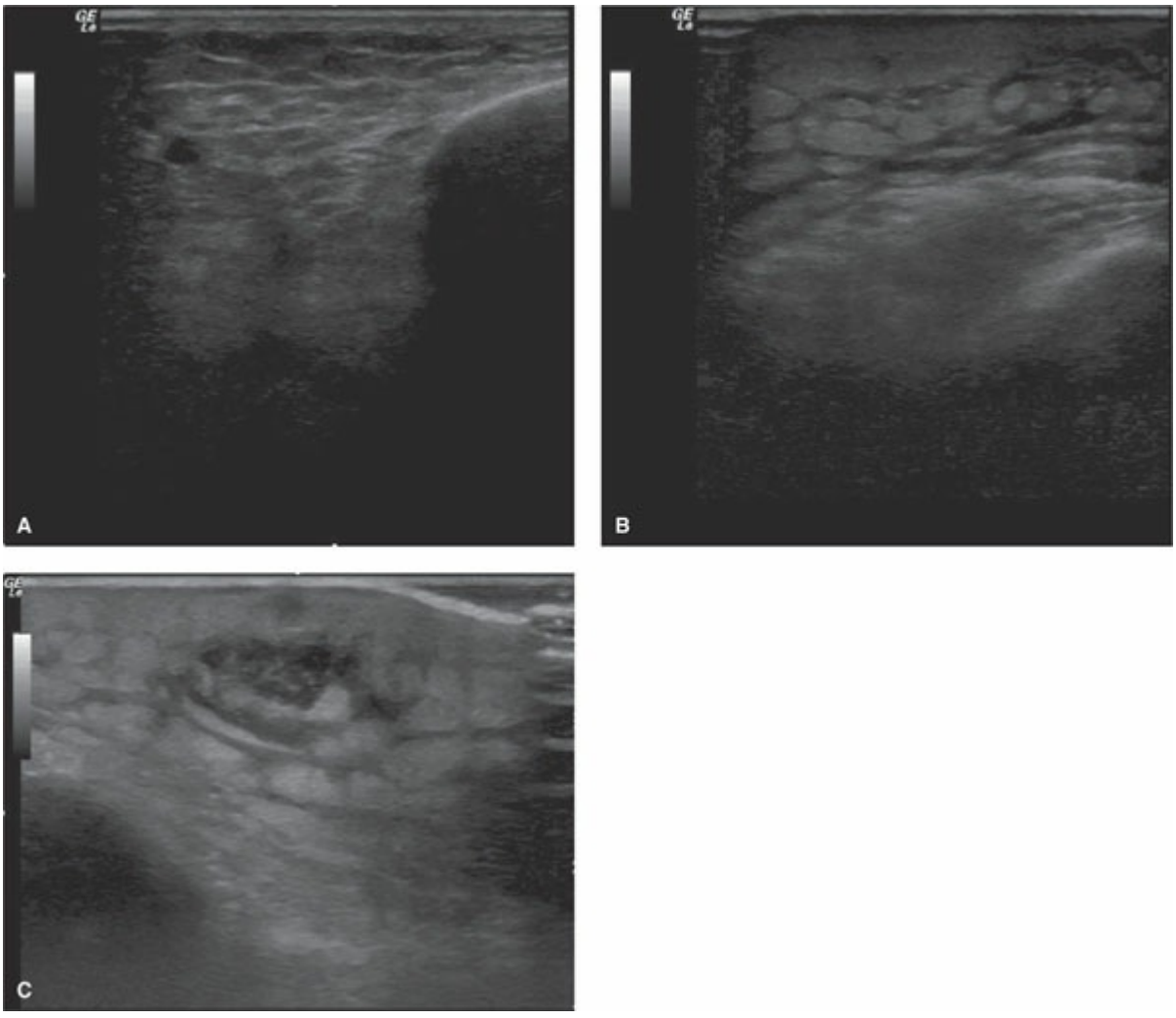


Figure 14-25 Cellulitis and superficial abscess. **A.** Sonogram of normal superficial soft tissue. **B.** Sonogram of cellulitis demonstrating the cobblestone appearance of the

soft tissue when induration if present. **C.** Sonogram demonstrating a well-circumscribed fluid collection with surrounding cobblestoning seen in a patient with cellulitis with underlying abscess.

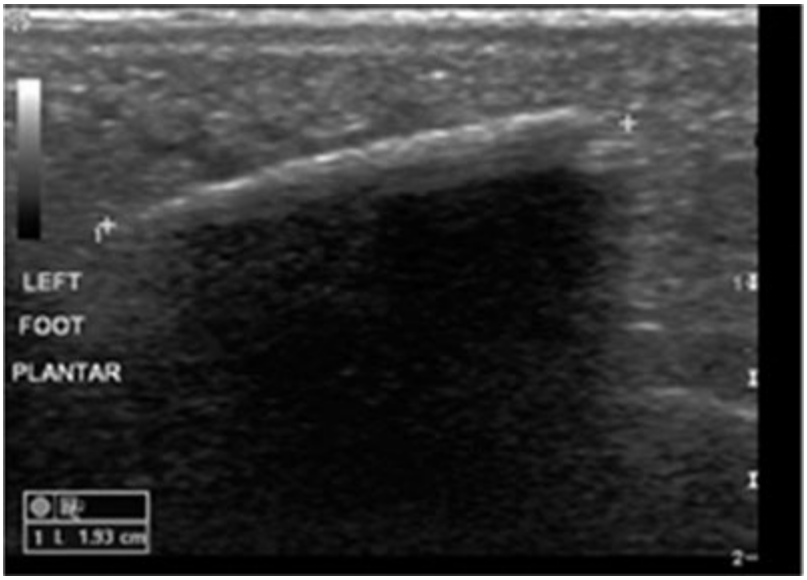


Figure 14-26 Foreign body. This foreign body in the foot is hyperechoic and produces posterior shadowing.

REVIEW QUESTIONS

1. Which of the following techniques is used to measure the relationship of the femoral head and acetabulum by evaluating the alpha and beta angles?
   a. Graf
   b. Ortolani
   c. Barlow
   d. Thompson

2. Inflammation and infection of the skin and subcutaneous tissue is termed:
   a. Ascites
   b. Retroperitoneal fibrosis
   c. Cellulitis
   d. Subcutaneous edema

3. Clinical findings of tendonitis include all of the following except:
   a. Itching in the area of the tendon
   b. Pain
   c. Edema
   d. The area is warm to touch

4. Which of the following is a clinical test for developmental hip dysplasia that is used to evaluate the hip for the reduction or relocation of a dislocated hip?
   a. Graf
   b. Ortolani
   c. Barlow
   d. Thompson

5. What test can be performed to determine a torn Achilles tendon?
   a. McBurney test
   b. McDonald test
   c. Thompson test
   d. Baker test

6. A cystic mass located within the popliteal fossa is most likely a:
   a. Baker cyst
   b. Thompson cyst
   c. Ganglion cyst
   d. Lipoma

7. A patient presents with a palpable, oozing mass at the level of the natal cleft. What is the most likely etiology of this mass?
   a. Pannus cyst
   b. Epidermoid
   c. Hemangioma
   d. Pilonidal cyst

8. A common mass found along the dorsal aspect of the hand and wrist is the:
   a. Baker cyst
   b. Thompson cyst
   c. Ganglion cyst
   d. Lipoma

9. The Achilles tendon connects the:
   a. Ankle to the knee
   b. Heel to the ankle
   c. Heel to the calf muscle
   d. Knee to the calf muscle

10. In what position should the patient placed to better evaluate the Achilles tendon?
   a. Prone

b. Supine
c. Right lateral decubitus
d. Left lateral decubitus

11. Inflammation of the breast that is related to pregnancy is referred to as:
a. Puerperal mastitis
b. Retromammary mastitis
c. Chronic mastitis
d. Emphysematous mastitis

12. Which of the following best describes the Thompson test?
a. The patient lies prone and performs plantarflexion
b. The patient lies prone while the symptomatic calf is squeezed
c. The patient lies supine and performs plantarflexion
d. The patient lies prone and performs dorsiflexion

13. Which of the following is true about patients with a lipoma?
a. They often complain of pain in the area of the mass.
b. They are often obese.
c. They are only slightly tender in the area of the mass.
d. They feel no pain in the area of the mass.

14. Subluxation denotes:
a. Synovial joint obstruction
b. Partial hip dislocation
c. Rupture of the bursa
d. Inflammation of the acetabulum

15. All of the following are keys to identifying foreign bodies with sonography except:
a. Most foreign bodies appear hypoechoic.
b. A linear array transducer should be used.
c. Most foreign bodies are better visualized using a standoff pad.
d. Comet-tail artifact may be seen posterior to metallic objects.

16. A 6-year-old female patient presents to the sonography department for a hip sonogram with irritability, unwillingness to walk, and low-grade fever. Sonographically, you visualize a hypoechoic fluid collection that elevates the joint capsule. What is the most likely diagnosis?
a. Developmental hip dysplasia
b. Subluxation
c. Joint effusion
d. Hip dislocation

17. Which of the following would be best described as a benign tumor comprised of fat?
    a. Hemangioma
    b. Lipoma
    c. Hamartoma
    d. Oncocytoma

18. What is the most likely cause of a hip joint effusion in infants?
    a. Tendonitis
    b. Bursitis
    c. Developmental hip dysplasia
    d. Transient synovitis

19. Which of the following would be best described as a benign tumor comprised of blood vessels?
    a. Hemangioma
    b. Lipoma
    c. Hamartoma
    d. Oncocytoma

20. Which of the following transducers would be best suited to sonographically assess for a splinter in a patient's hand?
    a. High-frequency linear array transducer
    b. Low-frequency curved array transducer
    c. High-frequency sector transducer
    d. Low-frequency linear array transducer

21. The accumulation of synovial fluid from a weakening in the joint capsule of the knee, as seen in conditions such as rheumatoid arthritis can result in a:
    a. Hemangioma
    b. Lipoma
    c. Baker cyst
    d. Ganglion cyst

22. Fluid within the synovial sheath is indicative of:
    a. Hyperemic flow
    b. Tendosynovitis
    c. Cartilaginous inflammation
    d. Cartilaginous extension

23. Which of the following best describes the most common sonographic

appearance of gynecomastia?
a. Hypoechioc, retroareolar mass
b. Hyperechoic, exophytic mass
c. Anechoic, retroareolar mass
d. Hyperechoic, areolar mass

24. Acoustic shadowing caused by bending of a sound beam at the edge of a curved reflector is referred to as:
a. Mirror image artifact
b. Indirect artifact
c. Reflective shadowing
d. Refractive shadowing

25. Inflammation of the tendon and synovial tendon sheath is referred to as:
a. Tendosynovitis
b. Tendonitis
c. Cellulitis
d. Pannus

26. A patient presents to the sonography department with a history of cellulitis on his abdomen. The patient has fever, edema, and complains of focal tenderness in a specific region affected by the cellulitis. Sonographically, you identify a localized complex collection of fluid. What is the most likely diagnosis?
a. Superficial hemangioma
b. Subcutaneous carcinoma
c. Mastitis
d. Superficial abscess

27. A complicated Baker cyst may contain a thin flap of tissue referred to as:
a. Pannus
b. Plicae
c. Septation
d. Lipoma

28. Which of the following is also referred to as a Bible bump?
a. Ganglion cyst
b. Superficial endodermal cyst
c. Superficial epidermal cyst
d. Epidermoid

29. Clinical findings of a Baker cyst may mimic those of a(n):
a. Arteriovenous malformation

b. Deep venous thrombosis
c. Knee fracture
d. Ganglion cyst

30. Sonographically, normal muscle appears as:
    a. Hyperechoic tissue that contains linear, echogenic strands
    b. Complex tissue that contains linear, hypoechoic strands
    c. Hypoechoic tissue that contains linear, echogenic strands
    d. Echogenic tissue that contains linear, hypoechoic strands

31. All of the following are true of ganglion cysts except:
    a. A ganglion cyst is a common mass found along the superior aspect of the hand and wrist, between the tarsals.
    b. Ganglion cysts typically appear sonographically as an incompressible, anechoic mass with acoustic enhancement.
    c. Clinically, ganglion cysts may be hard to touch and painful.
    d. Ganglion cysts are often treated with an injection of corticosteroids.

32. A partial tear of a tendon typically appears as:
    a. Focal hypoechoic areas within the tendon
    b. A focal echogenic area within the tendon
    c. A diffusely heterogeneous area within the tendon
    d. Edema and refractive shadowing in the area of the divided tendon

33. Tendons sonographically appear as:
    a. Echogenic, fibrous structures connecting muscles to bone
    b. Echogenic, fibrous structures connecting bone to bone
    c. Hypoechoic, linear arrangements within hyperechoic tissue
    d. Hyperechoic tissue that contains linear, echogenic strands

34. A standoff pad is most useful in imaging:
    a. Deep structures that produce acoustic enhancement
    b. Deep structures that produce acoustic shadowing
    c. Structures that produce refractive shadowing
    d. Superficial structures

35. Hyperemic flow within or around a structure is often indicative of:
    a. Malignancy
    b. Benignancy
    c. Inflammation
    d. Rupture

36. All of the following will aid in the sonographic assessment of an Achilles

tendon except:

a. The patient lies prone, with his or her feet hanging off the end of the bed.
b. Both the symptomatic and asymptomatic Achilles tendons should be scanned for comparison.
c. The entire tendon should be evaluated in sagittal and transverse scan planes.
d. The patient is scanned standing, with a small amount of pressure placed on the symptomatic side.

37. Which of the following best describes the Thompson test?

a. The calf is squeezed and the foot should plantarflex in a patient who does not have a complete tear of the Achilles tendon.
b. The calf is squeezed and the foot should not plantarflex in a patient who does not have a complete tear of the Achilles tendon.
c. The Achilles tendon is squeezed and the foot should plantarflex in a patient who does not have a complete tear of the Achilles tendon.
d. The Achilles tendon is squeezed and the foot should not plantarflex in a patient who does not have a complete tear of the Achilles tendon.

38. Superficial lipomas may appear as all of the following except:

a. Hypoechoic to the surrounding tissue
b. Isoechoic to the surrounding tissues
c. Hyperechoic to the surrounding tissue
d. Anechoic to the surrounding tissue

39. Bullets, shrapnel, and other metallic objects may cause:

a. Acoustic enhancement
b. Comet-tail artifact
c. Edge enhancement
d. Mirror image artifact

40. Which of the following at the site of a foreign body may produce bright echoes and therefore cause some ambiguity about the correct orientation of the object?

a. Fluid
b. Enhancement
c. Dust
d. Air

SUGGESTED READINGS

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Section II: Gynecologic Sonography Review

15

Gynecologic Sonography Overview

Introduction

A synopsis of gynecologic sonography practice is provided in this chapter. Accordingly, the subsequent chapters will build upon the foundation established in it. It is important for the sonographer to obtain and recognize vital clinical information from patients, including laboratory results and other data that are obtained through patient inquiry. This chapter offers relevant laboratory findings, imaging artifacts, a brief overview of physics and instrumentation, infection control, and serves as a gynecologic sonography imaging guide. Lastly, cross-referencing of potential information that may be encountered on the obstetrics and gynecology certification examination offered by the American Registry for Diagnostic Medical Sonography (www.ardms.org) and the gynecology portion of the examination offered by the American Registry of Radiologic Technologists (www.arrt.org) has been performed to establish this chapter.

Key Terms

adnexa—the area located posterior to the broad ligaments, adjacent to the uterus, which contains the ovaries and fallopian tubes

alpha-fetoprotein—a protein produced by the fetal yolk sac, fetal gastrointestinal tract, and the fetal liver; may also be produced by some malignant tumors

ambiguous genitalia—birth defect in which the external genitalia appear

neither recognizably male nor female

amenorrhea—the absence of menstruation

ascites—a collection of abdominal fluid within the peritoneal cavity

CA-125—a tumor marker in the blood that can indicate certain types of cancers such as cancer of the ovary, endometrium, breast, gastrointestinal tract, and lungs; stands for cancer antigen 125

computed tomography—a diagnostic modality that utilizes ionizing radiation to produce images of the human body in cross-sectional and reconstructed 3D formats

dysmenorrhea—difficult or painful menstruation

dyspareunia—painful sexual intercourse

dysuria—painful or difficult urination

echotexture—the sonographic appearance of a structure

ectopic pregnancy—a pregnancy located outside the endometrial cavity of the uterus

endoscopy—a means of looking inside the human body by utilizing an endoscope

fluid–fluid level—the distinct layering of fluids within a cyst or cystic structure that is caused by the presence of at least two different fluid compositions

Foley catheter—a catheter placed into the urinary bladder via the urethra that is used to drain urine; it can also be clamped and used to temporarily distend the bladder for pelvic sonography

hematocrit—a laboratory value that indicates the amount of red blood cells in blood

hirsutism—excessive hair growth in women in areas where hair growth is normally negligible

human chorionic gonadotropin—a hormone produced by the trophoblastic cells of the early placenta; may also be used as a tumor marker in nongravid patients and males

hydronephrosis—the dilation of the renal collecting system resulting from the obstruction of the flow of urine from the kidney(s) to the bladder; also referred to as pelvocaliectasis, pelviectasis, or pyelectasis

hypomenorrhea—decreased or scant menstrual flow; regular timed menses but light flow

infertility—the inability to conceive a child after 1 year of unprotected intercourse

intrauterine device—a common form of birth control in which a small

device is placed within the endometrium to prevent pregnancy; also referred to as an intrauterine contraceptive device

lactate dehydrogenase—an enzyme found within the blood that may be used to monitor renal function; may also be used as a tumor marker for some ovarian tumors

leukocytosis—an elevated white blood cell count

magnetic resonance imaging—a diagnostic modality that utilizes electromagnetic radiation to produce images of the human body in cross-sectional and reconstructed 3D formats

Meigs syndrome—ascites and pleural effusion in the presence of some benign ovarian tumors

menometrorrhagia—excessive or prolonged bleeding between periods

menorrhagia—abnormally heavy and prolonged menstruation

metrorrhagia—irregular menstrual bleeding between periods; intermenstrual bleeding

multiloculated—having multiple chambers or compartments

mural nodules—growth or masses attached to the wall of a structure, most likely a cyst

neoplasm—a mass of tissue that contains abnormal cells; also called a tumor

nuclear medicine—a diagnostic imaging modality that utilizes the administration of radionuclides into the human body for an analysis of the function of organs, or for the treatment of various abnormalities

ovarian torsion—an abnormality that results from the ovary twisting on its mesenteric connection, consequently cutting off the blood supply to the ovary

pelvic inflammatory disease—an infection of the female genital tract that may involve the ovaries, uterus, and/or the fallopian tubes

pelvic kidney—kidney located within the pelvis

pleural effusion—the abnormal accumulation of fluid in the pleural space

polycystic ovary syndrome—a syndrome characterized by anovulatory cycles, infertility, hirsutism, amenorrhea, and obesity; may also be referred to as Stein–Leventhal syndrome

pseudomyxoma peritonei—an intraperitoneal extension of mucin-secreting cells that result from the rupture of a malignant mucinous ovarian tumor or, possibly, a malignant tumor of the appendix

radiography—a diagnostic imaging modality that uses ionizing radiation for imaging bones, organs, and some soft tissue structures

septations—separations; structures that divide something into separate

sections

simple cyst—an anechoic, round mass that has smooth walls and demonstrates through transmission

sonohysterogram—a sonographic procedure that uses saline instillation into the endometrial cavity and fallopian tubes to evaluate for internal abnormalities

tamoxifen—a breast cancer drug that inhibits the effects of estrogen in the breast

translabial sonogram—sonogram that requires the transducer be placed against the labia; often used for imaging of the cervix

unilocular—having one chamber or compartment

virilization—changes within the female that are caused by increased androgens; may lead to deepening of the voice and hirsutism

SONOGRAPHIC TERMINOLOGY AND PRACTICE GUIDELINES

Before beginning your studies, you must have a fundamental appreciation of sonographic terminology and commonly used sonographic descriptive terms (Table 15-1). Female pelvic sonograms may be requested for various reasons. The American Institute of Ultrasound in Medicine publishes the practice guidelines for a pelvic sonogram on their website at www.aium.org (Table 15-2).

SONOGRAPHIC DESCRIPTION OF ABNORMAL FINDINGS

The appreciation and recognition of sonographic pathology is vital for the sonographer. Not only should the sonographer be able to recognize the normal echogenicity of organs and structures, he or she must be capable of identifying abnormalities. Pathology is often described sonographically, relative to surrounding or adjacent tissue. For example, a uterine mass may be described as hypoechoic compared to the surrounding echotexture of the uterus. Solid tumors may be hyperechoic (occasionally described as echogenic), hypoechoic, homogeneous, heterogeneous, complex, isoechoic, cystic, or a combination of terms. For example, an ovarian mass may be described as a complex mass that contains both cystic and solid components.

TABLE 15-1 Sonographic descriptive terms

Sonographic Descriptive Term	Definition	Example
Anechoic	Without echoes	Simple ovarian cyst
Complex	Having both cystic and solid components	Pelvic abscess
Echogenic	Structure that produces echoes	Pelvic ligaments
Heterogeneous	Of differing composition	Irregular endometrium
Homogeneous	Of uniform composition	Normal uterus
Hyperechoic	Having many echoes	Endometrium in the secretory phase
Hypoechoic	Having few echoes	Leiomyoma
Isoechoic	Having the same echogenicity	Normal ovaries

TABLE 15-2 AIUM indications for female pelvic sonogram[a]

- Evaluation of pelvic pain
- Evaluation of pelvic masses
- Evaluation of endocrine abnormalities, including polycystic ovaries
- Evaluation of **dysmenorrhea** (painful menses)
- Evaluation of **amenorrhea**
- Evaluation of abnormal bleeding (e.g., **menorrhagia**, **metrorrhagia**, **menometrorrhagia**)
- Evaluation of delayed menses
- Follow-up of a previously detected abnormality
- Evaluation, monitoring, and/or treatment of infertility patients
- Evaluation in the presence of a limited clinical examination of the pelvis
- Evaluation for signs or symptoms of pelvic infection
- Further characterization of a pelvic abnormality noted on another imaging study
- Evaluation of congenital uterine and lower genital tract anomalies
- Evaluation of excessive bleeding, pain, or signs of infection after pelvic surgery, delivery, or abortion
- Localization of an intrauterine contraceptive device
- Screening for malignancy in high-risk patients
- Evaluation of incontinence or pelvic organ prolapse
- Guidance for interventional or surgical procedures
- Preoperative and postoperative evaluation of pelvic structures

[a]This is an edited and limited list of indications. Other indications exist.
AIUM, American Institute of Ultrasound in Medicine.

Lastly, a cyst must meet certain criteria to be referred to as a simple cyst. Simple cysts have smooth walls or borders, demonstrate through transmission, are anechoic, and are round in shape (STAR criteria). Occasionally, with higher frequency transducers with superior resolution, a diminutive amount of internal debris may be noted within a simple cyst. However, cysts that have a large amount of internal debris, septations, mural nodules, have a fluid–fluid level, or other components may be described as complex cysts. Cysts may also be referred to as multiloculated or unilocular. Whereas simple cysts may not be worrisome, complex cysts may be followed with frequent sonograms, further analyzed with another imaging modality, or biopsied.



SOUND OFF

A simple cyst should have *s*mooth walls, demonstrate *t*hrough transmission, be completely *a*nechoic, and be *r*ound in shape (STAR criteria).

PATIENT PREPARATION FOR PELVIC SONOGRAPHY

Transabdominal imaging of the female pelvis requires the patient to have a full bladder. Patients are typically required to drink 32 ounces of water before the examination. Whether the bladder is retrofilled via a Foley catheter or filled by drinking fluids, it must be distended adequately to visualize the entire uterus and adnexa. This practice will provide an acoustic window via the bladder and also displace bowel from the field of view. Sonography can be performed using both transabdominal and endovaginal, also referred to as transvaginal, techniques. If possible, a pelvic sonogram should be performed prior to studies that require the administration of barium.

One of the chief advantages of transabdominal imaging of the pelvis is that this technique provides a global view of the entire pelvis. A disadvantage of transabdominal imaging is that it lacks the detail of endovaginal imaging because the transducer is much farther away from the organs that are being investigated. Obese patients and patients with a retroverted or retroflexed uterus present a unique challenge to the transabdominal technique as well.

Some facilities perform endovaginal imaging of the pelvis exclusively for certain indications, without the need for transabdominal imaging. Sonograms following a computed tomography or magnetic resonance imaging study may only need endovaginal imaging for sonographic correlation. Endovaginal imaging does not require a full bladder. Consequently, endovaginal imaging leads to reduced waiting time for the patient and quicker medical management. Another advantage of endovaginal imaging is that it offers improved resolution of the endometrium, uterus, and ovaries, especially in the obese patient. The disadvantages of endovaginal imaging include the possibility of unintentionally omitting pathology that is not within the field of view. A thorough explanation of the endovaginal sonogram procedure should be provided to the patient before proceeding, and the patient must grant consent. Some institutions may require written consent for endovaginal sonograms. It is also recommended that male sonographers utilize a female staff chaperone while performing an endovaginal or a translabial sonogram. In addition, some institutions require a chaperone for all endovaginal studies, regardless of the gender of the sonographer.



SOUND OFF

An advantage of endovaginal imaging is that it offers improved resolution of the endometrium, uterus, and ovaries, especially in the obese patient.

GATHERING A CLINICAL HISTORY AND LABORATORY FINDINGS

A review of prior examinations should be performed by the sonographer before any interaction with the patient. This review includes an analysis of previous sonograms, computed tomography scans, magnetic resonance imaging studies, nuclear medicine studies, radiography procedures, endoscopy examinations, and any additional related diagnostic reports available. Moreover, sonographers must be capable of analyzing the clinical history and complaints of their patients, and also explore family history. Another important component of pelvic imaging is the act of inquiring about the patient's reproductive history. The sonographer should investigate the number of pregnancies—Gravida—and inquire about how many of those pregnancies were carried to term—Para. Further information about this procedure is provided in the "Obstetric Sonography Overview" Section (Chapter 22). It is important to keep in mind that the optimal way to communicate with a patient who does not speak your language is to get the

assistance of a trained medical interpreter.

SOUND OFF
The number of pregnancies is Gravida, whereas Para is the number of those pregnancies that the patient carried to term.

Analyzing clinical history is vital. This practice will not only aid in clinical practice but also assist in answering complex certification examination questions. By correlating clinical findings with sonographic findings, the sonographer can directly impact the patient's outcome by providing the most targeted examination possible. Furthermore, when faced with a complicated, in-depth registry question, the registrant will be able to eliminate information that is not relevant to answer the question appropriately. Table 15-3 provides a review of common clinical indications for a pelvic sonogram and a list of differential gynecologic disorders.

LABORATORY FINDINGS RELEVANT TO GYNECOLOGIC SONOGRAPHY

Among the list of laboratory values that may warrant a pelvic sonogram are human chorionic gonadotropin, hematocrit, and white blood cell count. Although some rare ovarian tumors may cause an elevation in human chorionic gonadotropin, it is typically produced by a developing gestation, and therefore most often indicates the existence of a pregnancy. It is important to note that simply having a positive human chorionic gonadotropin does not necessarily mean that the pregnancy is normal.

Hematocrit is a laboratory value that should be evaluated in cases of suspected ectopic pregnancy. Patients suffering from hemorrhage as a result of an ectopic pregnancy or pelvic trauma will have an abnormally low hematocrit level. Thus, a decrease in hematocrit indicates bleeding. Patients with pelvic inflammatory disease will often have an elevated white blood cell count, also referred to as leukocytosis. Patients who have some form of "itis" (such as salpingitis), or possibly even an abscess, will most likely have an abnormal white blood cell count with existing infection as well. Other labs and specific associated pathologies will be included in organ-specific chapters.

TABLE 15-3 Clinical indications and potential differential gynecologic disorders[a]

Clinical Findings	Potential Differential Gynecologic Diagnosis (Nongravid Patient)[b]
Abdominal distension	Ascites Leiomyoma (fibroid uterus) Ovarian hyperstimulation syndrome Ovarian malignancy
Acute pelvic pain	Ovarian mucinous cystadenocarcinoma Ovarian mucinous cystadenoma Ovarian serous cystadenocarcinoma Ovarian serous cystadenoma Ovarian torsion Pelvic inflammatory disease Ruptured ovarian hemorrhagic cyst Perforated intrauterine contraceptive device
Amenorrhea	Asherman syndrome **Polycystic ovary syndrome**
Chronic pelvic pain	Adenomyosis Endometriosis (endometrioma) Leiomyoma (fibroid uterus) Pelvic inflammatory disease
Constipation or painful bowel movements	Endometriosis (endometrioma) Leiomyoma (fibroid uterus) Leiomyosarcoma Ovarian mucinous cystadenocarcinoma Ovarian mucinous cystadenoma Ovarian serous cystadenocarcinoma Ovarian serous cystadenoma
Dysmenorrhea	Adenomyosis Endometriosis
Dyspareunia	Adenomyosis Endometriosis Pelvic inflammatory disease
Dysuria	Leiomyoma (fibroid uterus) Leiomyosarcoma
Elevated **CA-125**	Endometriosis Leiomyoma (possibly) Ovarian carcinoma Pelvic inflammatory disease
Elevated serum **alpha-fetoprotein**	Ovarian yolk sac tumor
Elevated serum **human**	Ovarian dysgerminoma (possibly)

chorionic gonadotropin (nongravid)	
Elevated serum **lactate dehydrogenase**	Ovarian dysgerminoma
Elevated white blood cell count **(leukocytosis)**	Endometritis Pelvic inflammatory disease
Enlarged uterus	Adenomyosis Endometrial carcinoma Leiomyoma (fibroid uterus) Leiomyosarcoma
Fever	Endometritis Pelvic inflammatory disease
Hirsutism	Polycystic ovary syndrome Sertoli–Leydig cell tumor (androblastoma)
Hypomenorrhea	Asherman syndrome
Infertility	Asherman syndrome (repeated pregnancy loss) Endometrial carcinoma Endometrial polyp Endometriosis (endometrioma) Leiomyoma (repeated pregnancy loss) Pelvic inflammatory disease (chronic) Polycystic ovary syndrome
Intermenstrual bleeding	Endometrial polyp
Lost intrauterine contraceptive device	Expelled intrauterine device Perforated myometrium/uterus
Meigs syndrome	Brenner tumor Fibroma (most often) and Thecoma
Menometrorrhagia	Adenomyosis Endometrial polyp Pelvic inflammatory disease Perforated intrauterine device
Menorrhagia	Endometrial hyperplasia Endometriosis (endometrioma) Leiomyoma (fibroid uterus) Leiomyosarcoma
Nausea and vomiting	Ovarian hyperstimulation syndrome Ovarian torsion
Oliguria	Ovarian hyperstimulation syndrome
Ovarian enlargement	Ovarian hyperstimulation syndrome (cystic enlargement)
Palpable abdominal mass	Leiomyoma (fibroid uterus)

	Leiomyosarcoma
Palpable adnexal mass	Leiomyoma (pedunculated) Ovarian mass Pelvic inflammatory disease
Pelvic pressure and/or tenderness	Adenomyosis Endometritis Leiomyoma (fibroid uterus) Leiomyosarcoma Ovarian mucinous cystadenocarcinoma Ovarian mucinous cystadenoma Ovarian serous cystadenocarcinoma Ovarian serous cystadenoma Pediatric—hydrocolpos or hematocolpos Pelvic inflammatory disease
Postdilatation and postcurettage	Asherman syndrome Endometritis Retained products of conception
Postmenopausal vaginal bleeding	Endometrial atrophy Endometrial hyperplasia Ovarian granulosa cell tumor Ovarian mucinous cystadenocarcinoma Ovarian mucinous cystadenoma Ovarian serous cystadenocarcinoma Ovarian serous cystadenoma Ovarian thecoma
Precocious puberty	Ovarian dysgerminoma Ovarian granulosa cell tumor
Right upper quadrant pain	Fitz-Hugh–Curtis syndrome
Tamoxifen therapy	Endometrial hyperplasia
Urinary frequency	Leiomyoma (fibroid uterus) Leiomyosarcoma
Vaginal discharge	Pelvic inflammatory disease
Virilization	Sertoli–Leydig cell tumor (androblastoma) Ovarian carcinoma

[a]These abnormalities will be discussed in the following chapters.
[b]Please note that these listed differentials are for nongravid individuals and gynecologic-related pathology. Other possible abnormalities may be present, but for review purposes, these disorders should be initially considered.
CA-125, cancer antigen 125.

SOUND OFF
A decrease in hematocrit indicates bleeding.

BASIC PATIENT CARE DURING PELVIC IMAGING

Sonographers must be capable of providing basic patient care for every patient equitably and in a timely manner. Although we may spend a limited amount of time with each patient, we must also be prepared for emergency situations and how to respond. Basic patient care includes the assessment of body temperature, pulse, respiration, and blood pressure if needed (Table 15-4). Sonographers should be competent at transferring patients safely from wheelchairs and stretchers to the examination stretcher, being mindful of intravenous therapy, postsurgical, and urinary catheter needs. For patients with intravenous therapy, the intravenous fluid bag should be continually elevated to prevent retrograde flow. For urinary catheter care, the urinary bag should be placed below the level of the urinary bladder to prevent retrograde urine flow that could result in a urinary tract infection. One of the most common causes of nosocomial infections, or hospital-acquired infections, is a urinary tract infection.

TABLE 15-4 Normal numbers or ranges for basic patient care assessment

Basic Patient Assessment	
Body temperature	98.6°F (oral)
Adult pulse	60–100 beats per minute
Adult blood pressure	<120/80
Adult respiration	12–20 breaths per minute

INFECTION CONTROL AND TRANSDUCER CARE

The cycle of infection may be depicted as a succession of steps (Fig. 15-1). Sonographers should continually employ the use of standard precautions and good hygiene to prevent the spread of infection. Standard precautions have been established to reduce the risk of microorganism transmission in the clinical setting. Standard precautions, formerly referred to as universal precautions, include (1) hand hygiene, (2) the use of personal protective equipment, (3) safe injection practices, (4) safe handling of potentially

contaminated equipment and surfaces, and (5) respiratory hygiene and coughing etiquette. These precautions apply to blood, nonintact skin, mucous membranes, contaminated equipment, and all other body fluids, except for sweat.

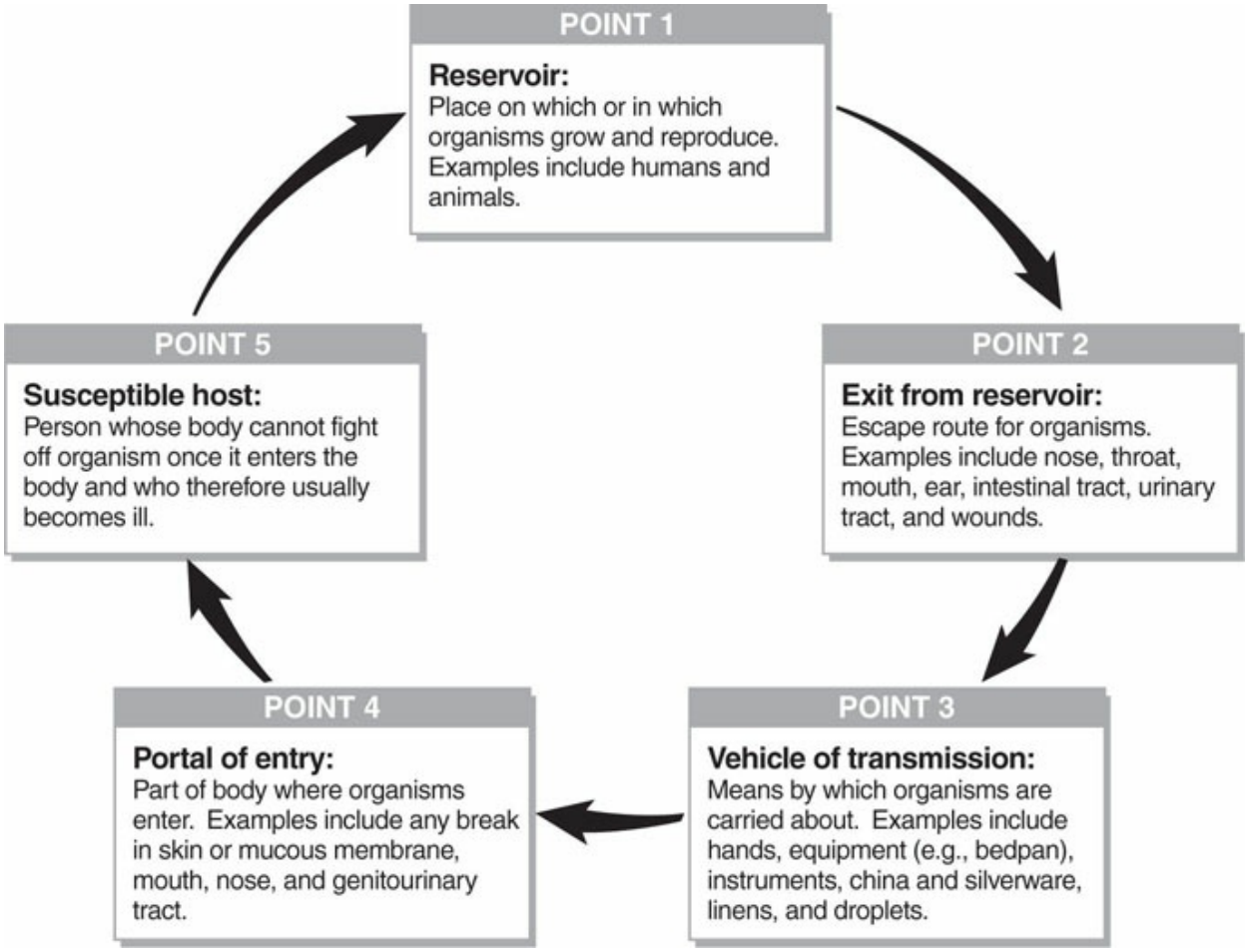


Figure 15-1 The cycle of infection.

The use of proper handwashing and handcleaning techniques is one of the most effective means of preventing the spread of infection. The Centers for Disease Control now recommends that health care workers employ the use of an alcohol-based handrub as the primary mode of hand hygiene in the clinical setting. Traditional handwashing should be used as well when time permits, especially in situations when the hands are visibly soiled. Sonographers should also utilize personal protective equipment, such as gloves, gowns, face shields, and masks, when clinically applicable. Gloves, which are made of latex, nonlatex, or other synthetic material, should be worn during the sonographic examination and should be changed between patients. Be mindful of the potential for patient latex allergies, and adapt accordingly by using another form of synthetic gloves.

Medical asepsis refers to the practices used to render an object or area free of pathogenic microorganisms. Although medical asepsis includes

handwashing, it also includes the use of disinfectants in the clinical setting, as well as the use of transducer or probe covers. Probe covers should be used for endocavity examinations, such as endovaginal and endorectal imaging. The use of sterile or nonsterile probe covers for these examinations is recommended by the institution. Transducers used during invasive procedures should be covered with a sterile probe cover, and sterile ultrasound gel should be utilized.

Following each examination, the transducer, ultrasound machine, stretcher, and any other equipment used during the examination should be thoroughly disinfected. The transducer should be cleaned with a disinfectant spray or wipe as recommended by the institution and manufacturer. Endovaginal transducers can be soaked in a high-level disinfectant, most likely a glutaraldehyde-based solution, and the specified manufacturer's instructions should be followed. Conversely, some institutions may utilize a tabletop unit that instead employs a hydrogen peroxide–based sterilization process. Because endovaginal imaging requires the transducer be placed into the vagina, a probe or transducer cover should be placed on the transducer, and it should be inserted into the vagina using sterile gel as a lubricant. In this regard, the sonographer should inquire about latex allergies, especially if a latex product is used, prior to the examination as well. Lastly, to prevent the spread of infection, sonographers should maintain good personal hygiene and health.

INVASIVE AND STERILE PROCEDURES

Patient preparation for invasive procedures varies among clinical facilities. However, informed consent from the patient and laboratory results are universally obtained. Laboratory findings, including an analysis of prothrombin time, partial thromboplastin time, international normalizing ratio, fibrinogen, and platelets, are used to evaluate the patient for coagulopathies. Sterile field preparation is performed prior to the sterile procedure as well, and sterile asepsis, also referred to as surgical asepsis, must be maintained (Table 15-5). Of course, sterile asepsis is always practiced in the surgical suite. Some invasive procedures that are commonly performed in the sonography department include the sonohysterogram, organ biopsies, mass biopsies, and abscess drainages. Biopsies can be performed using a freehand technique or under sonographic guidance using a needle guide that attaches to the transducer.

TABLE 15-5 Ten vital rules of surgical asepsis to remember

1. Always know which area and items are sterile and which are not.
2. If the sterility of an object is questionable, it is considered nonsterile.
3. If you recognize that an item has become nonsterile, act immediately.
4. A sterile field must never be left unmonitored. If a sterile field is left unattended, it is considered nonsterile.
5. A sterile person does not lean across a sterile field.
6. A sterile field ends at the level of the tabletop.
7. Cuffs of a sterile gown are not considered sterile.
8. The edges of a sterile wrapper are not considered sterile.
9. If one sterile person must pass another, they must pass back to back.
10. Coughing, sneezing, or excessive talking over a sterile field leads to contamination.

INSTRUMENTATION

Although a thorough physics review is beyond the scope of this book, there are several topics that must be addressed in preparation for the pelvic sonogram. Sonographic images are typically recorded and stored in a picture-archiving and communication system (PACS). PACS allows for both easy storage and comparison between sonographic findings and straightforward correlation between other imaging modality findings.

Pelvic imaging requires the use of a transducer that balances penetration with high-quality resolution. In general, the higher the frequency employed, the poorer the penetration abilities, but the better the resolution. Conversely, the lower frequencies provide better penetration with a sacrifice in resolution. Transducers that may be used for pelvic sonography include linear array, matrix array, curved or convex array, phased array, or the vector or sector array. Transabdominal transducers employ frequencies lower than 6 MHz, unless if the patient is thin. Endovaginal transducers also have varying frequencies, but are typically 7.5 MHz or higher. Higher frequency linear array transducers (7.5 to 18 MHz or higher when appropriate) may be used for superficial structures, such as the ovaries if needed. A standoff pad or a mound of gel may be used for imaging some superficial structures, such as protruding masses just below the skin surface. When applicable, sonographers should utilize technology including power Doppler, color Doppler, pulsed Doppler, harmonics imaging, compound imaging, extended field of view, and three-dimensional (3D) sonography to promote diagnostic accuracy.

SOUND OFF



↑Frequency = ↑Resolution = ↓Penetration
↓Frequency = ↓Resolution = ↑Penetration

When used separately or as an addition to routine two-dimensional (2D) sonography, 3D provides enhanced imaging of female pelvis. It is often used in the diagnosis of uterine malformations, to provide an accurate representation of the location of an intrauterine device, or to investigate the uterine cavity during sonohysterography. For ovarian imaging, 3D sonography is useful for evaluating complex ovarian masses and may be employed during ovarian follicular assessment as part of fertility treatment. The physics associated with 3D is beyond the scope of this text, although the sonographer should be familiar with the manner in which 3D images are acquired by the ultrasound machine that his or her institution utilizes.

ARTIFACTS IN PELVIC IMAGING

There are a few artifacts that may be seen during a routine pelvic sonogram.

It is important to know that artifacts exist and why they occur. Often, artifacts will be observed during real-time 2D and during Doppler imaging as well. A description can be found in Tables 15-6 and 15-7, and several representative figures can be found in Chapter 1 of this text.

PEDIATRIC GYNECOLOGIC SONOGRAPHY

Patient preparation for pediatric patients is similar for adults, although a smaller amount of water is warranted to distend the urinary bladder. Endovaginal imaging is contraindicated for virginal patients. Adolescent females may suffer from polycystic ovary syndrome, ovarian torsion, pelvic inflammatory disease, ectopic pregnancy, and, although rare, a malignant ovarian neoplasm. Although ovarian torsion has been known to occur in utero and in adulthood, it is much more common in adolescence. Adnexal or ovarian torsion can be associated with a large ovarian mass or cyst, or result from the excessive mobility of the adnexal structures. These topics are further discussed in subsequent chapters of this book (Chapters 15–21).

TABLE 15-6 Possible artifacts that may be noted during 2D pelvic sonography[a]

2D Artifact	Description	Example

Reverberation	Caused by a large acoustic interface and subsequent production of false echoes.	Echogenic region in the anterior aspect of the urinary bladder.
Mirror image	Produced by a strong specular reflector and results in a copy of the anatomy being placed deeper than the correct location.	May occur during endovaginal imaging and produce a (artificial) duplicate uterus.
Shadowing	Caused by attenuation of the sound beam.	Seen posterior to pelvic bones or a tooth within a cystic teratoma.
Ring-down artifact	Artifact that appears as a solid streak or a chain of parallel bands radiating away from a structure.	Gas or air within the endometrium secondary to endometritis.
Dirty shadowing	Caused by air or bowel gas.	Most often seen emanating from bowel; may be seen posterior to gas within an abscess.
Posterior (acoustic) enhancement or through transmission	Produced when the sound beam is barely attenuated through a fluid or a fluid-filled structure.	Posterior to the urinary bladder or simple ovarian cyst.

[a]Figures for these and other artifacts can be found in Chapter 1.

TABLE 15-7 Doppler artifacts[a]

Doppler Artifact	Explanation	Adjustment
Absent Doppler signal	Could be caused by low gain, low-frequency, high wall filter, or too high velocity scale.	• Decrease PRF • Turn up spectral gain • Decrease the wall filter • Open the sample gate
Aliasing	Occurs when the Doppler sampling rate (pulse-repetition frequency) is not high enough to accurately display the Doppler frequency shift.	• Increase the pulse-repetition frequency. • Adjust the baseline. • Switch to a lower frequency. • Increase the angle of insonation to decrease Doppler shift.
Doppler noise	Caused by inappropriately high Doppler settings.	Reduce color gain setting.

Flow directional abnormalities	Caused by the sound beam striking a vessel at a 90-degree angle, producing an area void of color.	Change the angle of insonation.
Twinkle artifact	Occurs behind strong, granular, and irregular surfaces like crystals, calculi, or calcifications.	Artifact that is actually useful at identifying small kidney or biliary stones.

[a]Figures for some of these artifacts can be found in Chapter 1.

Ambiguous genitalia, a condition in which the newborn's external genitalia are neither recognizably male nor female, is an indication for pelvic sonography for the newborn infant. The most common disorder of sex development is Turner syndrome, also referred to as Monosomy X. These patients suffer from gonadal dysfunction and have physical characteristics such as short stature, and webbing of the skin on the neck. The role of sonography for patients with ambiguous genitalia is to locate the gonads, to determine the presence or absence of the uterus, and to possible assess the adrenal glands for masses or swelling. Various gynecologic pathologies of the pediatric patient will be discussed in great detail in the following chapters.

EXTRAPELVIC PATHOLOGY ASSOCIATED WITH GYNECOLOGY

Ovarian and uterine masses may become large enough to obstruct the flow of urine from the kidney(s) to the bladder, resulting in hydronephrosis. Often, patients with pelvic disorders will have indistinct clinical findings suggestive of a bowel or renal disorders. For instance, uterine leiomyoma—benign tumors of the uterus that can grow fairly large—may cause clinical symptoms such as constipation and lower back pain. A pelvic kidney, which is a kidney located within the pelvis, may also be discovered during a pelvic sonogram and can mimic pathology.

A small amount of free fluid within the female pelvis is a common sonographic finding and is most often associated with a normal ovarian cycle. Ascites can collect in the pelvis in several peritoneal cavity spaces (Table 15-8). Massive amounts of pelvic ascites may be associated with some ovarian tumors, ectopic pregnancy, cirrhosis, and portal hypertension. Meigs syndrome (pelvic ascites, pleural effusion, and a benign ovarian mass) may also be suspected if there is an extensive amount of free fluid in the

pelvis. Malignant ovarian tumors may leak mucinous material, a condition known as pseudomyxoma peritonei, as in the case of a ruptured ovarian mucinous cystadenocarcinoma. The sonographic characterization of ascites is important. That is to say, the sonographer must not only note the presence of the pelvic ascites but also be able to assess the amount and describe whether there are septations, debris, or membranous components because these findings are more worrisome for malignancy.

TABLE 15-8 Location and significance of the peritoneal cavity spaces in the pelvis

Peritoneal Cavity Spaces	Location and Significant Points
Retropubic space	• Between the pubic bone and urinary bladder • Also referred to as the Space of Retzius
Paracolic gutters	• Extend alongside the ascending and descending colon on both sides of the abdomen
Posterior cul-de-sac	• Male: between the urinary bladder and rectum; also referred to as the rectovesical pouch • Female: between the uterus and rectum; also referred to as pouch of Douglas and rectouterine pouch
Anterior cul-de-sac	• Between the urinary bladder and uterus • Also called the vesicouterine pouch in females

ANALYZING A GYNECOLOGIC SONOGRAPHY REGISTRY QUESTION

Registry examinations can be intimidating. The following are a few steps that you can take to give you a better chance at answering these complex questions. Read the following question:

A 32-year-old multiparous patient presents to the sonography department with a history of abnormal uterine bleeding and dyspareunia. Sonographic findings include a diffusely enlarged uterus with notable thickening of the posterior myometrium. What is the most likely diagnosis?

A. Endometriosis
B. Adenomyosis
C. Posterior uterine leiomyoma

D.Endometrial carcinoma

Step 1: Read the question and try to answer it without looking at the answers provided.

The first step is to see if you know the answer without looking at the answers provided. If you have an idea, and your answer is one of the choices, then you are well on your way to answering the question correctly.

Step 2: If you do not know the answer right away, then break the question down.

Let us assume that you have no idea what the answer is. Then you move on to Step 2, which is breaking the question down. This step is complicated, but it will help.

The first part of the question provides the age of the patient, which is 32 years. Look at the answers provided. Is there one that you can eliminate solely on the patient's age? There is one: 32-year-old women rarely get endometrial carcinoma. Mark it off the list! You now have a 33% chance of answering the question correctly. We now move on to the next part of the patient's history, which is the word "multiparous"; this means that the patient has had several children. Look at the answers and see if there are any that you can eliminate that are linked with infertility. There is one definite choice and one possible choice. Endometriosis is definitely linked with infertility, and leiomyoma could possibly be linked with repeated abortion, but remember this patient has several children. Mark off the one that you know for certain is linked with infertility, endometriosis. Now, you have a 50% chance of getting the question correct. We now move on to the two patient complaints (and this is where the following chapters will help). You must know your clinical and sonographic findings to correctly answer these questions. In our sample question, the patient is complaining of abnormal uterine bleeding, which is common with both of our remaining answers. So we move on. Dyspareunia is the next complaint. This is where you must know your medical terminology. Dyspareunia is defined as painful intercourse, a common complaint with adenomyosis. So there is your answer! Not convinced? Look at the sonographic findings. Does it fit? The question lists the sonographic findings as "thickening of the posterior myometrium," which is a distinctive sonographic finding consistent with the sonographic diagnosis of adenomyosis.

REVIEW QUESTIONS

1. What term describes the echogenicity of a simple ovarian cyst?
   a. Anechoic
   b. Hypoechoic
   c. Echogenic
   d. Hyperechoic

2. The “S” in the STAR criteria stands for:
   a. Simple
   b. Sound
   c. Smooth walls
   d. Septations

3. Which of the following is defined as pain during intercourse?
   a. Dysuria
   b. Dysmenorrhea
   c. Dyspareunia
   d. Hirsutism

4. Which of the following is defined as excessive hair growth in women in areas where hair growth is normally negligible?
   a. Dyspareunia
   b. Hirsutism
   c. Meigs syndrome
   d. Polycystic ovary syndrome

5. Which of the following laboratory tests may be used as a tumor marker for an ovarian dysgerminoma?
   a. Lactate dehydrogenase
   b. Alpha-Fetoprotein
   c. Cancer antigen 125 (CA-125)
   d. Tamoxifen

6. All of the following are associated with acute pelvic pain except:
   a. Pelvic inflammatory disease
   b. Ruptured ovarian hemorrhagic cyst
   c. Perforated intrauterine contraceptive device
   d. Asherman syndrome

7. Which of the following is best defined as intermenstrual bleeding?
   a. Dysmenorrhea
   b. Menorrhagia
   c. Menometrorrhagia
   d. Metrorrhagia

8. Having the same echogenicity means:
   a. Anechoic
   b. Isoechoic
   c. Echogenic
   d. Hypoechoic

9. Which of the following would typically not be associated with amenorrhea?
   a. Asherman syndrome
   b. Polycystic ovarian disease
   c. Pregnancy
   d. Adenomyosis

10. Which of the following is best defined as difficult or painful menstruation?
    a. Dysmenorrhea
    b. Dyspareunia
    c. Dysuria
    d. Menorrhagia

11. What term relates to the number of pregnancies a patient has had?
    a. Para
    b. Menarche
    c. Menorrhagia
    d. Gravida

12. Which of the following definitions best describes the term adnexa?
    a. The area posterior to the uterus, between the uterus and rectum
    b. The area located posterior to the broad ligaments and adjacent to the uterus
    c. The area anterior to the uterus, between the uterus and urinary bladder
    d. The area lateral to the iliac crest and posterior to the pubic symphysis

13. All of the following statements are true of endovaginal imaging except:
    a. Endovaginal imaging requires a full urinary bladder.
    b. Endovaginal imaging leads to reduced waiting time for the patient and quicker medical management.
    c. Endovaginal imaging offers improved resolution of the endometrium, uterus, and ovaries, especially in the obese patient.
    d. Endovaginal imaging is contraindicated for pediatric patients, and for those with an intact hymen.

14. What laboratory value would be most useful to evaluate in a patient with suspected internal hemorrhage?
    a. White blood cells
    b. Lactate dehydrogenase
    c. Amylase
    d. Hematocrit

15. What abnormality results from the ovary twisting on its mesenteric connection?
    a. Pelvic inflammatory disease
    b. Fitz-Hugh–Curtis syndrome
    c. Ovarian torsion
    d. Ovarian hyperstimulation syndrome

16. Which of the following most often leads to an elevation of CA-125?
    a. Ovarian carcinoma
    b. Fitz-Hugh–Curtis syndrome
    c. Ovarian torsion
    d. Ovarian hyperstimulation syndrome

17. When does the Centers for Disease Control recommend that alcohol-based handrub not be used by the sonographer?
    a. After performing a sonogram
    b. Before performing a sonogram
    c. When your hands are visibly soiled
    d. Between patients

18. The best way to communicate with a patient who speaks a language other than your own is to:
    a. Use sign language
    b. Use proper body cues
    c. Use an online search engine
    d. Use a trained medical interpreter

19. What artifact would be seen posterior to a tooth within a cystic teratoma?
    a. Ring-down
    b. Reverberation
    c. Through transmission
    d. Shadowing

20. Which of the following is best described as an artifact that is produced by a strong reflector and results in a copy of the anatomy being placed deeper than the correct location?

a. Reverberation
b. Mirror image
c. Acoustic shadowing
d. Comet tail

21. Which of the following statements is not true concerning transabdominal pelvic imaging?
    a. Transabdominal imaging of the pelvis provides a global view of the entire pelvis.
    b. Transabdominal imaging lacks the detail of endovaginal imaging.
    c. Obese patients and patients with a retroverted or retroflexed uterus present a unique challenge to the transabdominal technique.
    d. Transabdominal imaging is contraindicated for pediatric patients.

22. Malignant ovarian tumors may leak mucinous material, and this condition is known as:
    a. Dandy–Walker syndrome
    b. Pseudomyxoma peritonei
    c. Asherman syndrome
    d. Fitz-Hugh–Curtis syndrome

23. All of the following are proper techniques for providing patient care for patients during a pelvic sonogram except:
    a. All transducers and their cords should be cleaned before performing a pelvic sonogram.
    b. Endovaginal transducers should be cleaned with a high-level disinfectant.
    c. A probe cover should be placed on the transducer for transabdominal imaging to prevent the spread of infection.
    d. Sterile jelly should be used as a lubricant for endovaginal imaging.

24. The breast cancer drug that inhibits the effects of estrogen in the breast is:
    a. CA-125
    b. Methotrexate
    c. RA-916
    d. Tamoxifen

25. Which of the following statements would be considered an acceptable disadvantage of endovaginal imaging?
    a. Endovaginal imaging has a limited field of view.
    b. The resolution of endovaginal imaging is reduced compared to

transabdominal imaging.

c. Endovaginal imaging is more time consuming than transabdominal imaging.
d. Endovaginal imaging can be performed only by female sonographers.

26. What artifact could be noted emanating from air or gas within the endometrium in a patient with endometritis?
a. Ring-down
b. Mirror image
c. Posterior enhancement
d. Dirty transmission

27. What Doppler artifact occurs when the Doppler sampling rate is not high enough to display the Doppler shift frequency?
a. Doppler noise
b. Aliasing
c. Twinkle artifact
d. Absent Doppler signal

28. Which of the following would be the least likely to cause abdominal distension?
a. Ascites
b. Multiple leiomyoma
c. Ovarian hyperstimulation syndrome
d. Polycystic ovarian disease

29. All of the following are common indications for a pelvic sonogram except:
a. Evaluation of congenital anomalies
b. Evaluation of pelvic anatomy immediately following a motor vehicle accident
c. Localization of an intrauterine contraceptive device
d. Postmenopausal bleeding

30. Precocious puberty is best defined as:
a. Pubertal development before the age of 8
b. Pubertal development before the age of 13
c. Excessive hair growth in girls in areas where hair growth is normally negligible
d. Changes within the female that are caused by increased levels of α-fetoprotein

31. Amenorrhea is defined as:
    a. The first menstrual cycle
    b. Excessive bleeding after the cycle
    c. Lack of menstrual flow
    d. Painful menstrual flow

32. Which of the following would most likely be associated with hirsutism?
    a. Polycystic ovary syndrome
    b. Meigs syndrome
    c. Adenomyosis
    d. Adenomyomatosis

33. Which of the following would be caused by a large acoustic interface and subsequent production of false echoes?
    a. Posterior shadowing
    b. Acoustic enhancement
    c. Mirror image
    d. Reverberation

34. Which of the following would be best defined as abnormally heavy menstrual flow?
    a. Menometrorrhagia
    b. Menorrhagia
    c. Metrorrhagia
    d. Hypomenorrhea

35. Which of the following would be best defined as regularly timed menses but light flow?
    a. Menometrorrhagia
    b. Menorrhagia
    c. Metrorrhagia
    d. Hypomenorrhea

36. All of the following would be relevant laboratory tests to evaluate before performing a routine pelvic sonogram except:
    a. Human chorionic gonadotropin
    b. Hematocrit
    c. White blood cell count
    d. Lipase

37. Which of the following could be described as an infection of the female genital tract that may involve the ovaries, uterus, and/or the fallopian tubes?

a. Pseudomyxoma peritonei
b. Pelvic inflammatory disease
c. Polycystic ovarian disease
d. Ovarian torsion

38. Which of the following diagnostic tests is used to evaluate emitted radiation from the patient to assess the function of organs?
a. Magnetic resonance imaging
b. Nuclear medicine
c. Radiography
d. Computed tomography

39. Endovaginal transducers may be cleaned by submerging in a(n) ___-based solution.
a. glutaraldehyde
b. ascites
c. formaldehyde
d. alcohol

40. Leukocytosis would most likely be associated with:
a. Multiple degenerating fibroids
b. Ovarian teratoma
c. Adenomyosis
d. Pelvic inflammatory disease

SUGGESTED READINGS

AIUM Practice Parameter for the Performance of an Ultrasound of the Female Pelvis. Available at: http://www.aium.org/resources/guidelines/femalePelvis.pdf

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Sanders RC, Hall-Terracciano B. Clinical Sonography: A Practical Guide. 5th Ed. Philadelphia: Wolters Kluwer, 2016:61–93 & 399.

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16

Anatomy of the Female Pelvis

Introduction

This chapter offers an overview of normal structures and their location within the female pelvis. Anatomic landmarks are provided as well as the anatomy routinely visualized on a pelvic sonogram. Bony pelvis anatomy, pelvic muscles, ligaments, normal vascular anatomy, and extrauterine pelvic spaces are all discussed. This chapter also provides the reader with an overview of the location of these structures in relationship to the uterus and ovaries.

Key Terms

abdominal aorta—major abdominal artery responsible for supplying the abdomen, pelvis, and lower extremities with oxygenated blood

adnexa—the area located posterior to the broad ligaments, adjacent to the uterus, which contains the ovaries and fallopian tubes

anterior cul-de-sac—peritoneal outpouching located between the bladder and the uterus; also referred to as the vesicouterine pouch

arcuate arteries—peripheral arteries of the uterus that lie at the edge of the myometrium

broad ligament—pelvic ligament that extends from the lateral aspect of the uterus to the side walls of the pelvis

cardinal ligament—pelvic ligament that extends from the lateral surface of the cervix to the lateral fornix of vagina and houses the uterine vasculature

coccygeus—pelvic muscle located posteriorly within the pelvis that helps support the sacrum

common iliac arteries—abdominal aortic bifurcation vessels

external iliac arteries—external branches of the common iliac arteries

false pelvis—superior portion of the pelvis

iliopsoas muscles—bilateral muscles located lateral to the uterus and anterior to iliac crest

internal iliac arteries—internal branches of the common iliac arteries

levator ani muscles—hammock-shaped pelvic muscle group located between the coccyx and pubis consisting of the iliococcygeus, pubococcygeus, and puborectalis

linea terminalis—imaginary line that separates the true pelvis from the false pelvis

obturator internus muscles—paired pelvic muscles located lateral to the ovaries

ovarian ligaments—pelvic ligaments that provides support to the ovary extending from the ovary to the lateral surface of the uterus

pelvic diaphragm—group of pelvic muscles consisting of the levator ani and coccygeous muscles that provide support to the pelvic organs

piriformis muscles—paired pelvic muscles located posteriorly that extends from the sacrum to the femoral greater trochanter

posterior cul-de-sac—see key term rectouterine pouch

pouch of Douglas—see key term rectouterine pouch

prolapse—(uterine prolapse) a condition that results from the weakening of the pelvic diaphragm muscles and allows for the displacement of the uterus, often through the vagina

radial arteries—arteries that supply blood to the deeper layers of the myometrium

rectouterine pouch—peritoneal outpouching located between the uterus and rectum; also referred to as the posterior cul-de-sac and pouch of Douglas

rectus abdominis muscles—paired anterior abdominal muscles that extend from the xiphoid process of the sternum to the pubic bone

space of Retzius—extraperitoneal space located between the bladder and symphysis pubis that contains fat

spiral arteries—tiny, coiled arteries that supply blood to the functional layer of the endometrium

straight arteries—uterine radial artery branch that supplies blood to the basal layer of the endometrium

suspensory ligament of the ovary—pelvic ligament that provides support to the ovary and extends from the ovaries to the pelvic side walls

true pelvis—inferior portion of the pelvis that contains the uterus, ovaries, fallopian tubes, urinary bladder, small bowel, sigmoid colon, and rectum

uterine arteries—branches of the internal iliac artery that supplies blood to the uterus, ovaries, and fallopian tubes

vesicouterine pouch—peritoneal outpouching located between the bladder and the uterus; also referred to as the anterior cul-de-sac

PELVIC STRUCTURE

Bony Pelvis and Location of the Female Genitalia

The bony pelvis consists of the sacrum, coccyx, and innominate bones. These bones mark the boundaries of the pelvic cavity. The posterior border of the pelvic cavity is marked by the sacrum and coccyx. The innominate bones consist of the ilium, ischium, and pubic symphysis. The boundaries of the female pelvis are considered to be from the iliac crest to a group of muscles known as the pelvic diaphragm, located at the base of the pelvis.

The pelvis can further be divided into a true pelvis (lesser pelvis) and false pelvis (major pelvis) by an imaginary line known as the linea terminalis (Fig. 16-1). The false pelvis is located more superiorly than the true pelvis, the latter of which contains the urinary bladder, small bowel, sigmoid colon, rectum, ovaries, fallopian tubes, and uterus.



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The true pelvis contains the urinary bladder, small bowel, sigmoid colon, rectum, ovaries, fallopian tubes, and uterus.

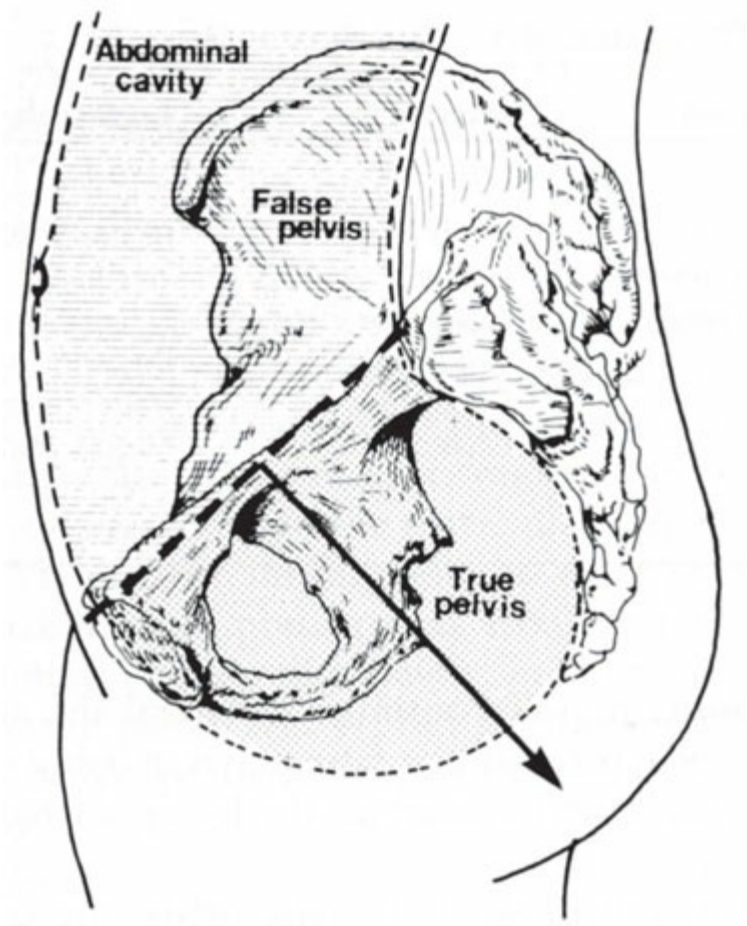


Figure 16-1 Relationship of the abdominal cavity to the true and false pelvis.

Within the pelvis, the nongravid uterus lies within the midline, posterior to the urinary bladder and anterior to the rectum (Fig. 16-2). The vagina extends inferiorly from the external os of the cervix to the external genitalia, where it is positioned posterior to the urethra. The fallopian tubes and ovaries are considered bilateral adnexal structures. However, the course of the fallopian tubes and location of the ovaries are relatively unpredictable.

Pelvic Muscles

Several pelvic muscles may be identified sonographically within the female pelvis (Table 16-1, Fig. 16-3). Muscles visualized on a sonogram include the rectus abdominis muscles, the iliopsoas muscles, obturator internus muscles, piriformis muscles, and a group of muscles known as the pelvic diaphragm, which is composed of the levator ani and coccygeus muscles (Figs. 16-4 to 16-6). The pelvic diaphragm muscles provide support to the pelvic organs. A weakening in the levator ani muscles could result in prolapse of the pelvic organs.

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The weakening of the pelvic diaphragm, which includes the levator

ani muscles, can lead to prolapse of the uterus.

Because pelvic muscles can be seen sonographically, sonographers must have an understanding of their locations and sonographic appearance in order to differentiate them from pelvic masses. For instance, the piriformis muscles or iliopsoas may be confused for the ovaries or adnexal masses because of their location within the pelvis. Pelvic muscles will appear as hypoechoic structures with varying degrees of hyperechoic, striated muscle fibers noted in the transverse and longitudinal scanning planes.

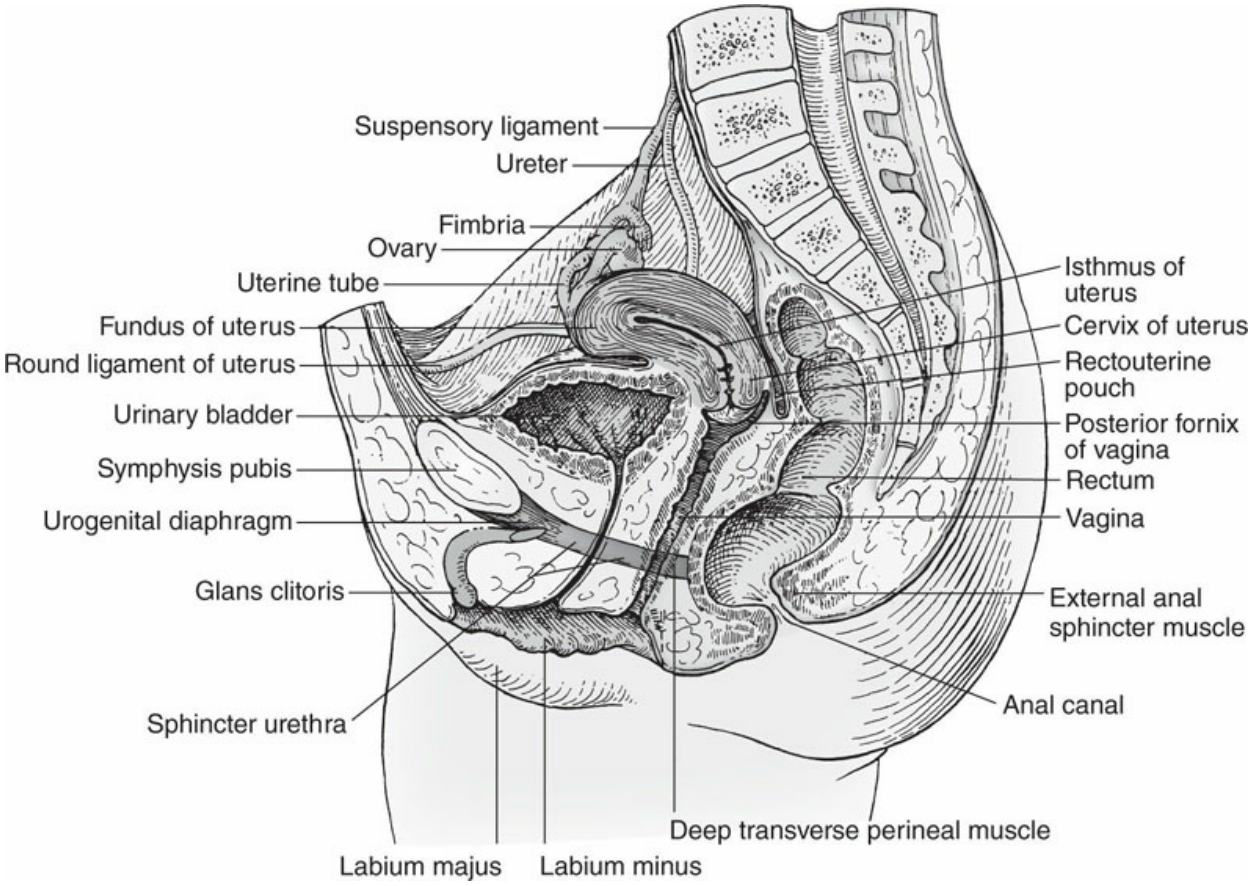


Figure 16-2 Organs of the female pelvis in the sagittal section.

Pelvic Ligaments

The ligaments of the pelvis provide support to the ovaries, uterus, and fallopian tubes (Table 16-2). The broad ligaments and suspensory ligament of the ovary are actually double folds of peritoneum. In addition to providing support, the suspensory ligament of the ovary contains the ovarian artery, ovarian vein, lymphatics, and ovarian nerves. Conversely, the cardinal ligaments house the vasculature of the uterus. The majority of pelvic ligaments are not identified during a routine sonographic examination of the pelvis. However, when surrounded by free fluid, the dense broad ligaments

may be identified as echogenic structures extending from the lateral borders of the uterus bilaterally (Fig. 16-7).

Pelvic Spaces

Pelvic ascites and free fluid may accumulate within potential spaces or recesses within the female pelvis. When filled with fluid, these regions can be easily identified sonographically. The vesicouterine pouch, or anterior cul-de-sac, is located anterior to the uterus and posterior to the urinary bladder. The rectouterine pouch, located between the rectum and uterus, may also be referred to as the posterior cul-de-sac or pouch of Douglas. The rectouterine pouch is considered the most dependent part of the peritoneal cavity, making it the most likely place for fluid to collect in the pelvis. Between the anterior wall of the urinary bladder and symphysis pubis lies the space of Retzius, or retropubic space, an area that contains extraperitoneal fat. Free fluid, when excessive, may also be noted within the adnexa, lower quadrants of the abdomen, and may serve the purpose of delineating the borders of pelvic organs.

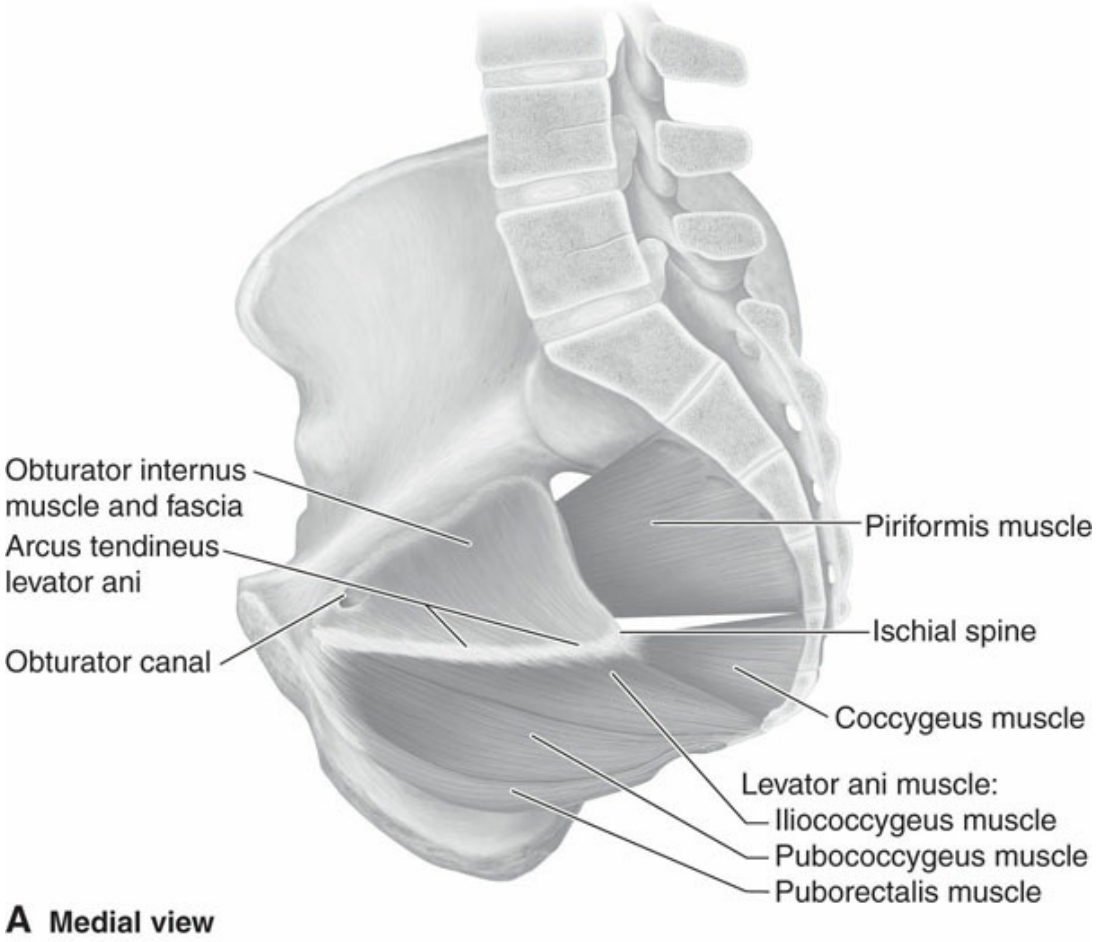
TABLE 16-1 Sonographically identifiable pelvic muscles

Sonographically Identifiable Pelvic Muscles	Location
Rectus abdominis muscle (2)	Anterior
Iliopsoas muscles (2)	Lateral and anterior to iliac crest
Obturator internus (2)	Lateral to ovaries
Piriformis (2)	Posterior
Pelvic diaphragm (levator ani and coccygeus muscles)	Inferior near the vagina in transverse

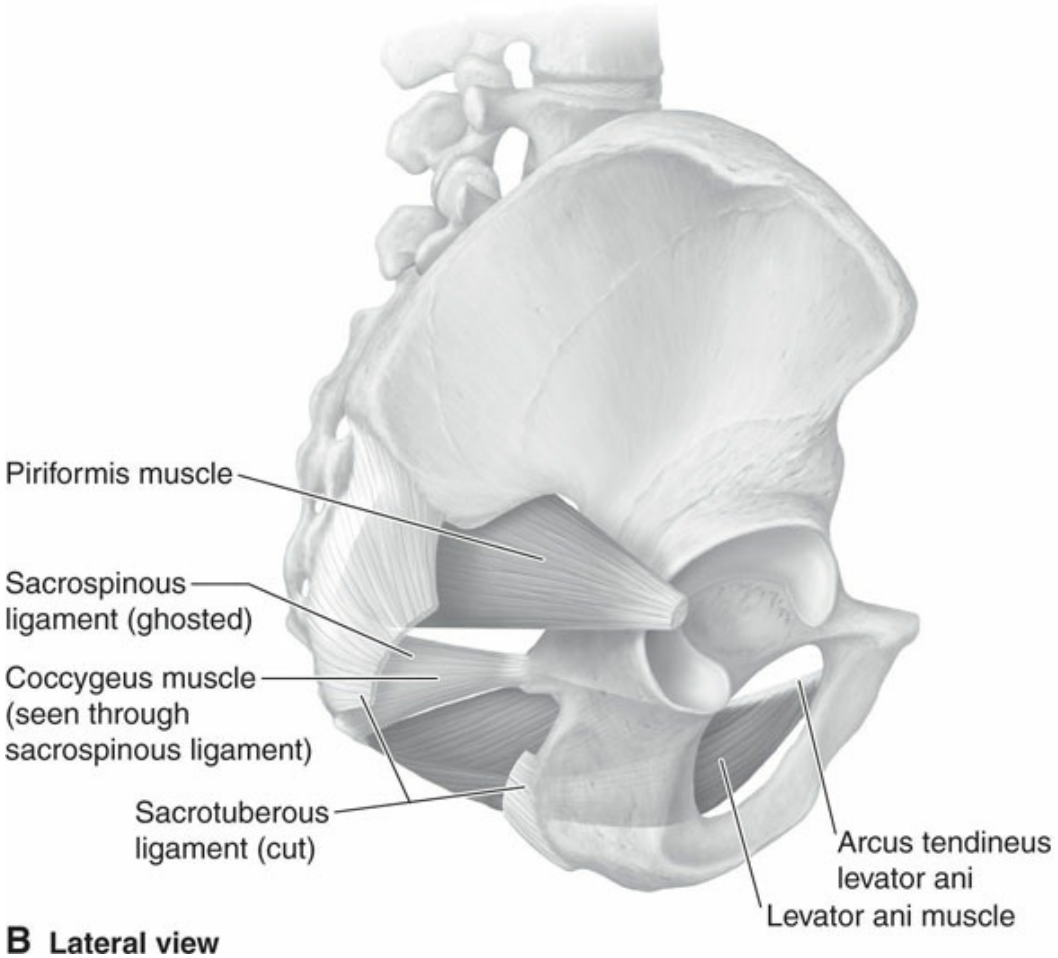


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The most dependent part of peritoneal cavity is the posterior cul-de-sac or pouch of Douglas, making it the most likely place for free fluid to collect in the pelvis.



A **Medial view**



B **Lateral view**

Figure 16-3 Medial view and lateral view of the several pelvic muscles.

PELVIC VASCULATURE

Arterial System of the Female Pelvis

Vascular structures can provide both important diagnostic information and landmarks during a sonographic examination of the female pelvis. The abdominal aorta supplies blood to the female genitalia. It branches into the paired common iliac arteries, typically near the umbilicus. The common iliac arteries then divide into the external iliac arteries and internal iliac arteries (Fig. 16-8). These vessels, along with their venous counterparts, provide useful landmarks for identifying the ovaries. The paired right and left uterine arteries are branches of the internal iliac arteries. They supply blood to the uterus, the fallopian tubes, and the ovaries, and course along the lateral aspect of the uterus within the folds of the broad ligaments.

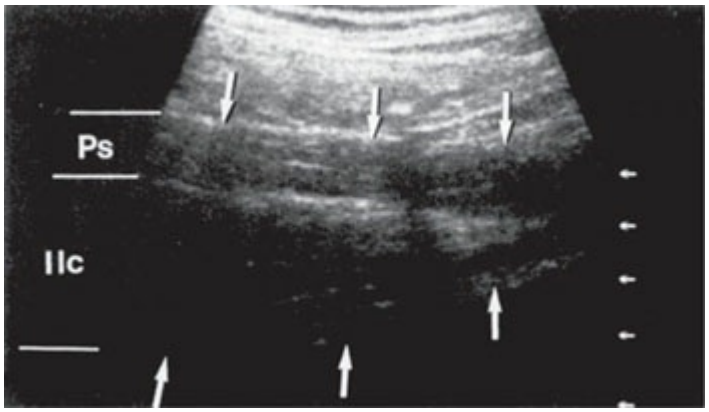


Figure 16-4 Sagittal scan of the psoas major (*Ps*) and the iliac muscle (*Ilc*).

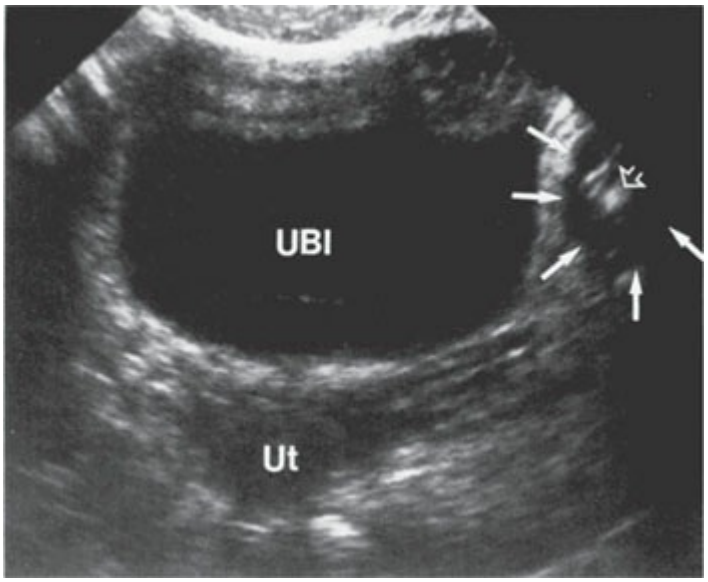


Figure 16-5 Transverse scan of the pelvis reveals the urinary bladder (*UBl*), uterus

(*Ut*), and left iliopsoas muscle (*arrows*).

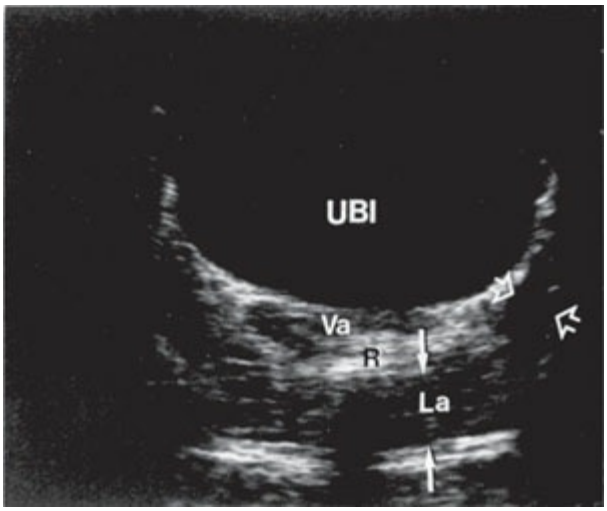


Figure 16-6 Transverse scan at the level of the vagina (*Va*), urinary bladder (*UBl*), and rectum (*R*) demonstrating the levator ani (*La*) muscle group (*solid white arrows*) and the obturator internus muscle (*open arrows*).

Branches of the uterine artery include the arcuate arteries, which may be visualized with Doppler interrogation along the lateral aspect of the myometrium. The arcuate vessels progress further within the uterus and eventually become the radial arteries, which supply blood to the deeper layers of the myometrium. The radial arteries then divide into the straight arteries and spiral arteries. The spiral arteries are the tiny, coiled vessels that supply blood to the functional or decidual layer of the endometrium. The ovarian arteries originate from the lateral aspect of the abdominal aorta. The ovaries have a dual blood supply. Each ovary receives its nourishment from an ovarian artery and a branch of the uterine artery.

TABLE 16-2 Location of pelvic ligaments and structures that they support

Pelvic Ligaments	Supports	Location
Broad ligaments	Uterus, tubes, ovaries	Extends from the lateral aspect of the uterus to the side walls of the pelvis
Round ligaments	Uterus (fundus)	Extends from uterine cornua to labia majora between the folds of the broad ligaments
Suspensory ligament of the ovaries	Ovaries and tubes	Extends from the ovaries to the pelvic side walls

(infundibulopelvic)		
Ovarian ligaments	Ovaries	Extends from ovary to lateral surface of the uterus
Cardinal ligament	Cervix	Extends from the lateral surface of the cervix to the lateral fornix of vagina
Uterosacral ligament	Uterus	Extends from uterus to sacrum

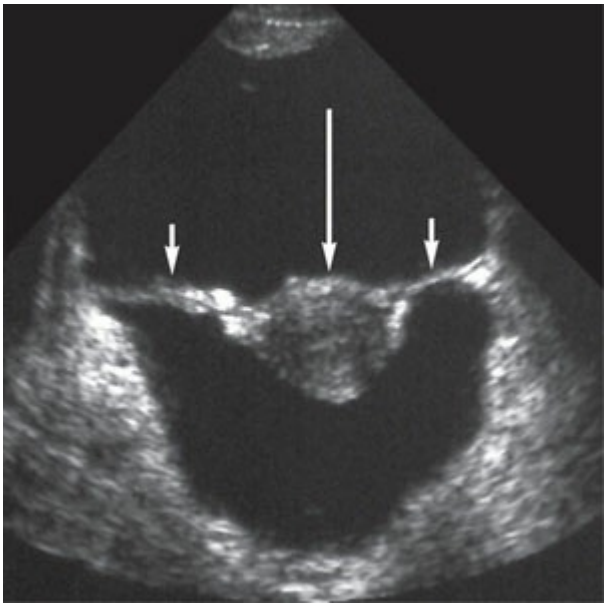


Figure 16-7 Broad ligament outlined by ascites. The bilateral broad ligaments (*short arrows*), outlined by ascites, are clearly noted in this transverse image. The longer arrow is identifying the uterus.

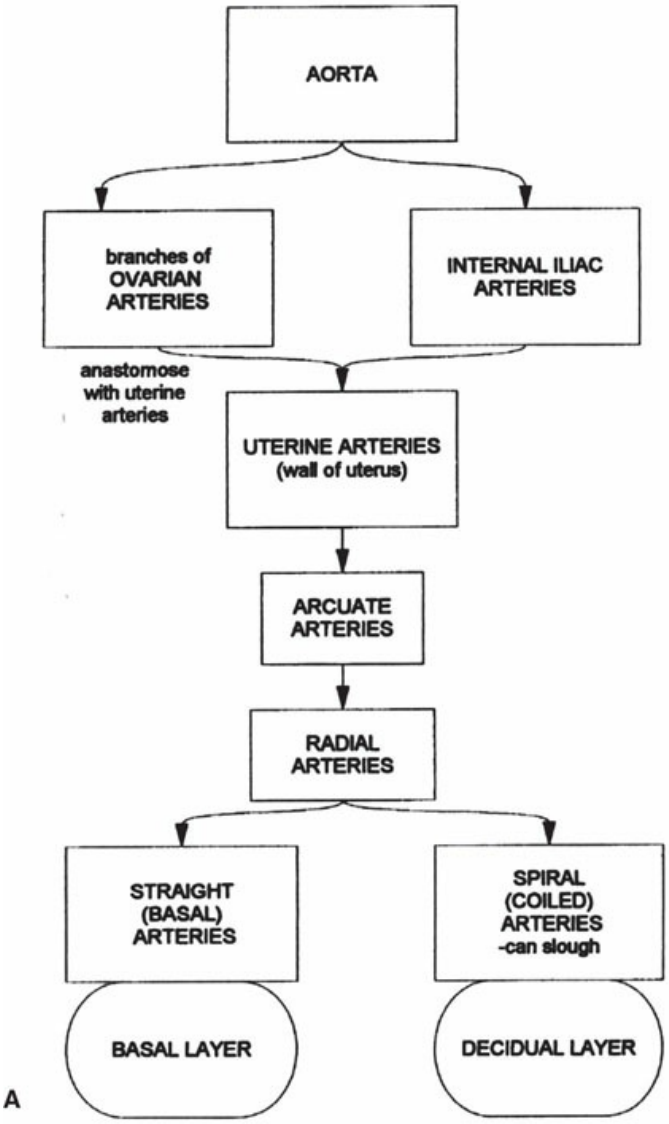
SOUND OFF
The spiral arteries are the tiny, coiled vessels that supply blood to the functional layer of the endometrium.

Venous System of the Female Pelvis

All venous structures mirror their arterial counterparts with the exception of the left ovarian vein, which instead of returning blood to the inferior vena cava, drains directly into the left renal vein (Fig. 16-9). The common iliac veins unite at almost the same level as the common iliac artery bifurcation to help form the inferior vena cava.

SOUND OFF
The left ovarian vein drains into the left renal vein.

VASCULATURE OF UTERUS

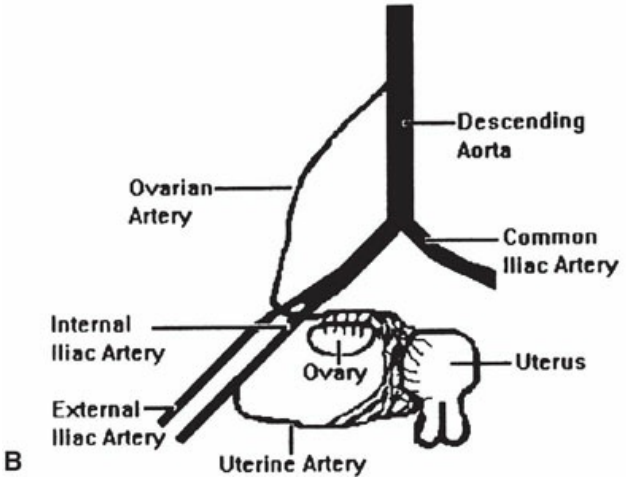


A

ARTERIAL CIRCULATION

-uterine artery runs medially off the internal iliac artery toward the cervix where it then ascends lateral to the uterus in the broad ligament to the cornua

-there it courses laterally toward the ovary to where it anastomoses with a branch of the ovarian artery



B

Figure 16-8 Arterial circulation within the female pelvis. **A.** Schematic of the arterial flow from the aorta to the uterus. **B.** Simple drawing of the branches of the abdominal aorta.

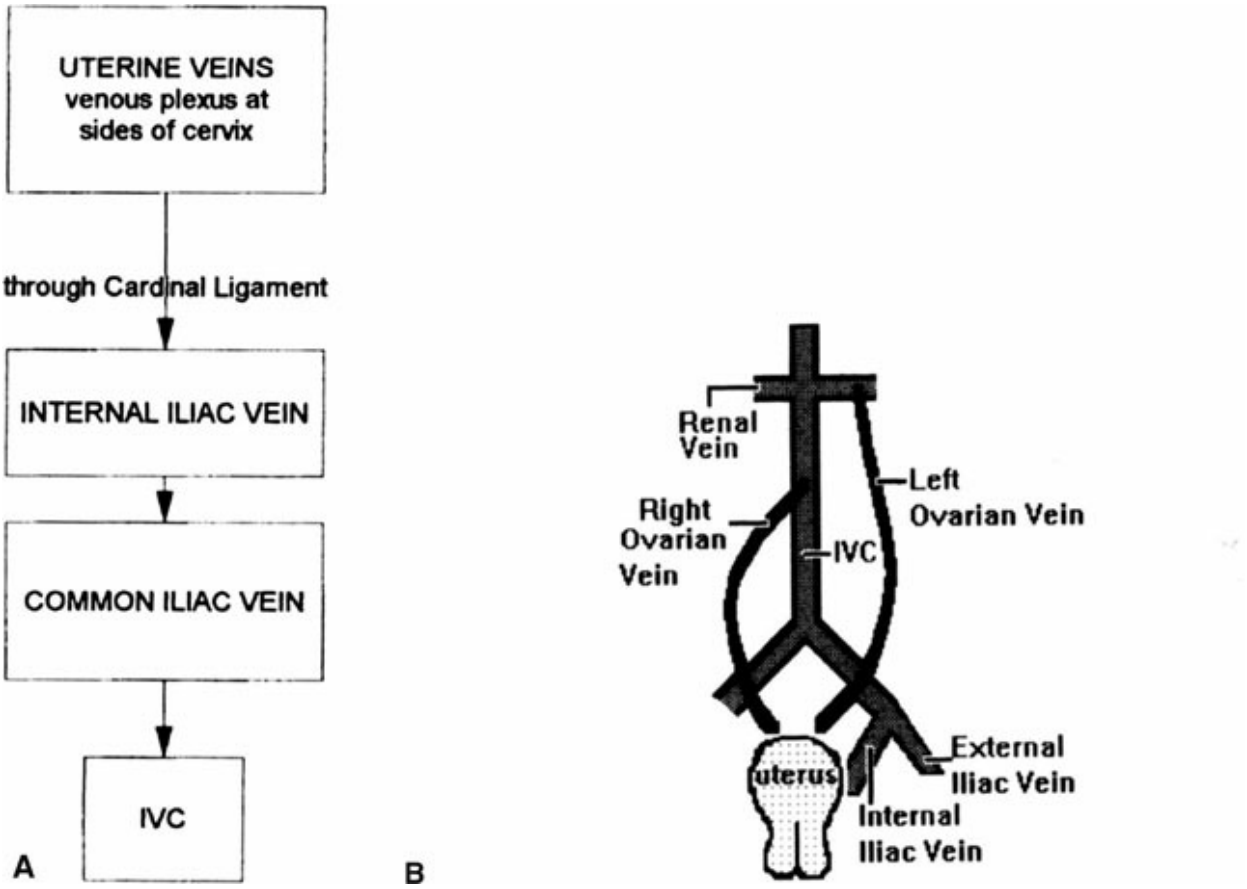


Figure 16-9 Venous circulation within the female pelvis. **A.** Schematic of the venous flow from the uterus to the inferior vena cava. **B.** Simple drawing of the venous return from the uterus and ovaries. Note the left ovarian vein attached to the left renal vein.

REVIEW QUESTIONS

1. What structure within the female pelvis lies posterior to the urinary bladder and anterior to the rectum?
   a. Broad ligament
   b. Rectus abdominus muscle
   c. Space of Retzius
   d. Uterus

2. Fluid noted posterior to the uterus would most likely be located within the:
   a. Space of Retzius
   b. Pouch of Douglas

c. Anterior cul-de-sac
d. Adnexa

3. Both the straight and spiral arteries are branches of the:
a. Common iliac artery
b. Radial artery
c. Arcuate artery
d. External iliac artery

4. The left ovarian vein drains directly into the:
a. Right renal vein
b. Inferior vena cava
c. Aorta
d. Left renal vein

5. Pelvic bones, when visualized on sonography, will produce:
a. Posterior shadowing
b. Posterior enhancement
c. Mirror image artifact
d. Minimal enhancement

6. The uterine arteries supply blood to all of the following except:
a. Fallopian tubes
b. Rectum
c. Ovaries
d. Uterus

7. The anterior cul-de-sac is also referred to as the:
a. Space of Retzius
b. Rectouterine pouch
c. Pouch of Douglas
d. Vesicouterine pouch

8. What is considered the most dependent part of the peritoneal cavity?
a. Space of Retzius
b. Anterior cul-de-sac
c. Pouch of Douglas
d. Rectovessicular pouch

9. The right ovarian vein drains directly into the:
a. Right renal vein
b. Aorta
c. Inferior vena cava

d. Common iliac vein

10. The innominate bones of the pelvis consist of the:
    a. Ischium, ilium, and pubic bones
    b. Ilium, sacrum, and coccyx bones
    c. Sacrum, coccyx, and pubic bones
    d. Sacrum, ischium, and ilium bones

11. What other term is used to describe the space of Retzius?
    a. Posterior cul-de-sac
    b. Anterior cul-de-sac
    c. Murphy pouch
    d. Retropubic space

12. The true pelvis is delineated from the false pelvis by the:
    a. Space of Retzius
    b. Adnexa
    c. Linea terminalis
    d. Iliac crest

13. The vagina is located __ to the uterus:
    a. anterior
    b. posterior
    c. inferior
    d. medial

14. The muscles that may be confused with the ovaries on a pelvic sonogram include the:
    a. Rectus abdominis and obturator internus muscles
    b. Levator ani and coccygeus muscles
    c. Obturator internus and levator ani muscles
    d. Piriformis and iliopsoas muscles

15. Which vessels supply blood to the deeper layers of the myometrium?
    a. Radial arteries
    b. Spiral arteries
    c. Straight arteries
    d. Arcuate arteries

16. Pelvic muscles appear:
    a. Echogenic
    b. Anechoic
    c. Hypoechoic

d. Complex

17. The abdominal aorta bifurcates into the:
    a. Internal iliac arteries
    b. Common iliac arteries
    c. Ovarian arteries
    d. External iliac arteries

18. Which of the following are the paired anterior abdominal muscles that extend from the xiphoid process of the sternum to the pubic bone?
    a. Iliopsoas muscles
    b. Rectus abdominis muscles
    c. Obturator interni muscles
    d. Piriformis muscles

19. Peritoneal spaces located posterior to the broad ligament are referred to as the:
    a. Rectouterine spaces
    b. Anterior cul-de-sacs
    c. Lateral cul-de-sacs
    d. Adnexa

20. The paired muscles that are located lateral to the uterus and anterior to the iliac crest are the:
    a. Iliopsoas muscles
    b. Rectus abdominis muscles
    c. Obturator interni muscles
    d. Piriformis muscles

21. Fluid noted anterior to the uterus would most likely be located within the:
    a. Pouch of Douglas
    b. Vesicouterine pouch
    c. Space of Retzius
    d. Rectouterine pouch

22. The bilateral muscles that are located posterior to and extend from the sacrum to the femoral greater trochanter are the:
    a. Levator ani muscles
    b. Rectus abdominis muscles
    c. Obturator internus muscles
    d. Piriformis muscles

23. The pelvic ligament that provides support to the ovary to the pelvic side

wall is the:
a. Cardinal ligament
b. Ovarian ligament
c. Broad ligament
d. Suspensory ligament of the ovary

24. The pelvic muscle group that is located between the coccyx and the pubis is the:
a. Levator ani muscles
b. Rectus abdominis muscles
c. Obturator internus muscles
d. Piriformis muscle

25. The sonographic pelvic examination of a female patient reveals an extensive amount of ascites. In the transverse plane, you visualize two echogenic structures extending from the side walls of uterus to the pelvic side walls bilaterally. These structures are most likely the:
a. Broad ligaments
b. Cardinal ligaments
c. Ovarian ligaments
d. Uterosacral ligaments

26. The space of Retzius is located:
a. Between the uterus and bladder
b. Between the bladder and ilium
c. Along the lateral aspect of the uterus
d. Between the bladder and pubic bone

27. The right ovarian artery branches off of the:
a. Aorta
b. Right renal artery
c. Uterine artery
d. Internal iliac artery

28. The muscle located lateral to the ovaries is the:
a. Iliopsoas muscle
b. Rectus abdominis muscle
c. Obturator internus muscle
d. Piriformis muscle

29. The arteries that directly supply blood to the functional layer of the endometrium are the:
a. Radial arteries

b. Spiral arteries
c. Straight arteries
d. Arcuate arteries

30. Another name for the rectouterine pouch is the:
    a. Space of Retzius
    b. Pouch of Retzius
    c. Pouch of Douglas
    d. Anterior cul-de-sac

31. A patient presents to the sonography department with a history of uterine prolapsed. Which of the following best describes this disorder?
    a. A condition that results from the weakening of the pelvic diaphragm muscles and allows for the displacement of the uterus, often through the vagina.
    b. A congenital anomaly that results in the duplication of the uterus.
    c. A condition that results in the abnormal invasion of the myometrium through the bladder wall leading to hematuria.
    d. An abnormality that describes the inversion of the myometrium and endometrium.

32. The pelvic ligament that extends from the lateral aspect of the uterus to the side walls of the pelvis is the:
    a. Broad ligament
    b. Ovarian ligament
    c. Piriformis ligament
    d. Round ligament

33. The uterine artery branches off of the:
    a. Abdominal aorta
    b. Uterine plexus
    c. Internal iliac artery
    d. External iliac artery

34. The peripheral arteries of the uterus are the:
    a. Radial arteries
    b. Spiral arteries
    c. Straight arteries
    d. Arcuate arteries

35. The urinary bladder, uterus, and ovaries are located within the:
    a. True pelvis
    b. False pelvis

36. The pelvic ligament that provides support to the ovary and extends from the ovary to the lateral surface of the uterus is the:
    a. Cardinal ligament
    b. Ovarian ligament
    c. Broad ligament
    d. Suspensory ligament of the ovary

37. Pelvic bones, when visualized on sonography, will appear:
    a. Anechoic
    b. Hypoechoic
    c. Dark
    d. Hyperechoic

38. The ligament that houses the vasculature of the uterus is the:
    a. Cardinal ligament
    b. Ovarian ligament
    c. Broad ligament
    d. Suspensory ligament of the ovary

39. The ovary is supplied blood by the:
    a. Ovarian artery
    b. Ovarian artery and uterine artery
    c. Uterine artery
    d. Arcuate artery

40. Prolapse of the pelvic organs most often involves the:
    a. Rectus abdominis and obturator internus muscles
    b. Levator ani and coccygeus muscles
    c. Obturator internus and levator ani muscles
    d. Piriformis and iliopsoas muscles

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17

The Uterus and Vagina

Introduction

This chapter provides the reader a review of both normal sonographic anatomy and pathology associated with the uterus and vagina. The discussion will continue in regard to endometrial pathology in upcoming chapters to include postmenopausal bleeding and also intracavitary masses that can lead to abnormal uterine bleeding.

Key Terms

adenomyoma—a focal mass of adenomyosis

adenomyosis—the benign invasion of endometrial tissue into the myometrium of the uterus

agenesis—failure of an organ or structure to grow during embryologic development

amenorrhea—the absence of menstruation

anteflexion—the uterine body tilts forward and comes in contact with the cervix, forming an acute angle between the body and the cervix

anteversion—the typical version of the uterus where the uterine body tilts forward, forming a 90-degree angle with the cervix

basal layer (endometrium)—the nonfunctional outer layer of the endometrium

bicornuate uterus—a common uterine anomaly in which the endometrium divides into two horns; also referred to as bicornis unicollis

boggy—limp

broad ligaments—pelvic ligament that extends from the lateral aspect of the uterus to the side walls of the pelvis

cervix—the rigid region of the uterus located between the isthmus and the vagina

congenital malformations—physical defects that are present in a person at birth; may also be referred to as congenital anomalies

cornua (uterus)—areas just inferior to the fundus of the uterus where the fallopian tubes are attached bilaterally

corpus (uterus)—the uterine body

dextroverted uterus—the long axis of the uterus deviating to the right of the midline

diethylstilbestrol (DES)—a drug administered to pregnant woman from the 1940s to the 1970s to treat threatened abortions and premature labor that has been linked with uterine malformation in the exposed fetus

dyschezia—difficult or painful defecation

dysmenorrhea—difficult or painful menstruation

dyspareunia—painful sexual intercourse

dysuria—painful or difficult urination

endometrial cavity—area that lies between the two layers of the endometrium; may also be referred to as the uterine cavity

endometrium—the inner mucosal layer of the uterus

external os—the inferior portion of the cervix that is in close contact with the vagina

fibroid—see key term leiomyoma

functional layer (endometrium)—the functional inner layer of the endometrium that is altered by the hormones of the menstrual cycle

fundus (uterus)—the most superior and widest portion of the uterus

Gartner duct cyst—a benign cyst located within the vagina

hematocolpos—blood accumulation within the vagina

hematometra—blood accumulation within the uterine cavity

hematometrocolpos—blood accumulation within the uterus and vagina

hydrocolpos—fluid accumulation within the vagina

hydrometrocolpos—fluid accumulation within the uterus and vagina

hysterectomy—the surgical removal of the uterus

hysterosalpingography—a radiographic procedure that uses a dye instilled into the endometrial cavity and fallopian tubes to evaluate for internal

abnormalities

hysteroscopic uterine septoplasty—the surgical repair of a uterine septum in a septate uterus using a hysteroscopy

imperforate hymen—a vaginal anomaly in which the hymen has no opening, therefore resulting in an obstruction of the vagina

internal os—the superior portion of the cervix closest to the isthmus

intracavitary (fibroid)—a leiomyoma located within the uterine cavity

intramural (fibroid)—location of leiomyoma within the myometrium of the uterus

isthmus (uterus)—area of the uterus between the corpus and the cervix

leiomyoma (uterine)—a benign, smooth muscle tumor of the uterus; may also be referred to as a fibroid or uterine myoma

leiomyosarcoma—the malignant manifestation of a leiomyoma

levoverted uterus—the long axis of the uterus deviating to the left of the midline

lower uterine segment—the term used for the isthmus of the uterus during pregnancy

magnetic resonance imaging-guided high-intensity focused ultrasound —a fibroid treatment that utilizes focused high-frequency, high-energy ultrasound guided by magnetic resonance imaging to heat and destroy fibroid tissue

menometrorrhagia—excessive and prolonged bleeding at irregular intervals

menorrhagia—abnormally heavy and prolonged menstruation

Müllerian ducts—paired embryonic ducts that develop into the female urogenital tract

multiparous—having birthed more than one child

myomectomy—the surgical removal of a myoma (fibroid) of the uterus

myometrium—the muscular layer of the uterus

nabothian cysts—benign cysts located within the cervix

neonatal—the first 4 weeks (28 days) after birth

parity—the total number of pregnancies in which the patient has given birth to a fetus at or beyond 20 weeks gestational age or an infant weighing more than 500 g

pedunculated—something that grows off of a stalk

perimetrium—the outer layer of the uterus; may also be referred to as the serosal layer

precocious puberty—pubertal development before the age of 8; the early development of pubic hair, breast, or genitals

pseudoprecocious puberty—secondary sexual development induced by sex steroids or from other sources such as ovarian tumors, adrenal tumors, or steroid use

retroflexion—the uterine body tilts backward and comes in contact with the cervix, forming an acute angle between the body and the cervix

retroversion—the uterine body tilts backward, without a bend where the cervix and body meet

saline infusion sonohysterography—a sonographic procedure that uses saline instillation into the endometrial cavity and possibly the fallopian tubes to evaluate for internal abnormalities; also referred to as sonohysterography

septate uterus—common congenital malformation of the uterus that results in a single septum that separates two endometrial cavities

serosal layer (uterus)—the outermost layer of the uterus; may also be referred to as the perimetrium

submucosal (fibroid)—a leiomyoma that distorts the shape of the endometrium

subseptate uterus—congenital malformation of the uterus that results in a normal uterine contour with an endometrium that branches into two horns

subserosal (fibroid)—location of a leiomyoma in which the tumor grows outward and distorts the contour of the uterus

torsion—twisting

unicornuate uterus—congenital malformation of the uterus that results in a uterus with one horn

uterine artery embolization—procedure used to block the blood supply to a leiomyoma (fibroid)

uterine myoma—see key term leiomyoma

uterus didelphys—congenital malformation of the uterus that results in the complete duplication of the uterus, cervix, and vagina

vaginal atresia—occlusion or imperforation of the vagina; can be congenital or acquired

vaginal cuff—the portion of the vagina remaining after a hysterectomy

vaginal fornices—recesses of the vagina

EMBRYOLOGIC DEVELOPMENT OF THE FEMALE UROGENITAL TRACT

During the embryonic period, the uterus and kidneys develop at essentially the same time. Therefore, it is safe to assume that when there are congenital

anomalies recognized on a routine sonogram of the uterus, coexisting anomalies may be present in the kidneys. For this reason, patients who present with uterine anomalies may also require a urinary tract sonogram.

The uterus, vagina, and fallopian tubes develop from the paired Müllerian ducts (paramesonephric ducts). Incomplete fusion, partial fusion, or agenesis of the Müllerian ducts will result in an anatomic variant of the uterus, cervix, and/or vagina that may be recognized sonographically. Thus, these anatomic variants may also be referred to as Müllerian anomalies or congenital malformations. Congenital malformations are discussed later in this chapter (see "Congenital Uterine Anomalies" section).

SOUND OFF
Congenital anomalies of the kidneys and uterus often coexist.

ANATOMY AND PHYSIOLOGY OF THE UTERUS AND VAGINA

The uterus is a pear-shaped, retroperitoneal organ that lies anterior to the rectum, posterior to the urinary bladder, and is bounded laterally by the broad ligaments (Fig. 17-1). Its primary function is to provide a place for the products of conception to implant and develop. The uterus can be divided into four major divisions: fundus, corpus, isthmus, and cervix (Fig. 17-2). The fundus is the most superior and widest portion of the uterus. Each fallopian tube attaches to the uterus at the level of the uterine horns called the cornua. The largest part of the uterus is the corpus, or body. The corpus is located inferior to the fundus. The isthmus is the area located between the corpus and the cervix. During pregnancy, the isthmus may be referred to as the lower uterine segment. The cervix is the rigid component of the uterus that is located inferior to the isthmus, and it is the portion of the uterus that projects into the vagina. The cervix is marked superiorly by the internal os, which is in contact with the isthmus, and inferiorly by the external os, which is in close contact with the vagina.

SOUND OFF
During pregnancy, the isthmus may be referred to as the lower uterine segment.

The vagina is a tubular organ that extends from the external os of the cervix to the external genitalia. The vaginal fornices (singular form is fornix) envelop the inferior aspect of the cervix. The vagina is composed of three

layers: inner mucosal layer, middle muscular layer, and an outer layer that may be referred to as the adventitia. Sonographically, the divisions of the uterus can be demonstrated (Fig. 17-3).

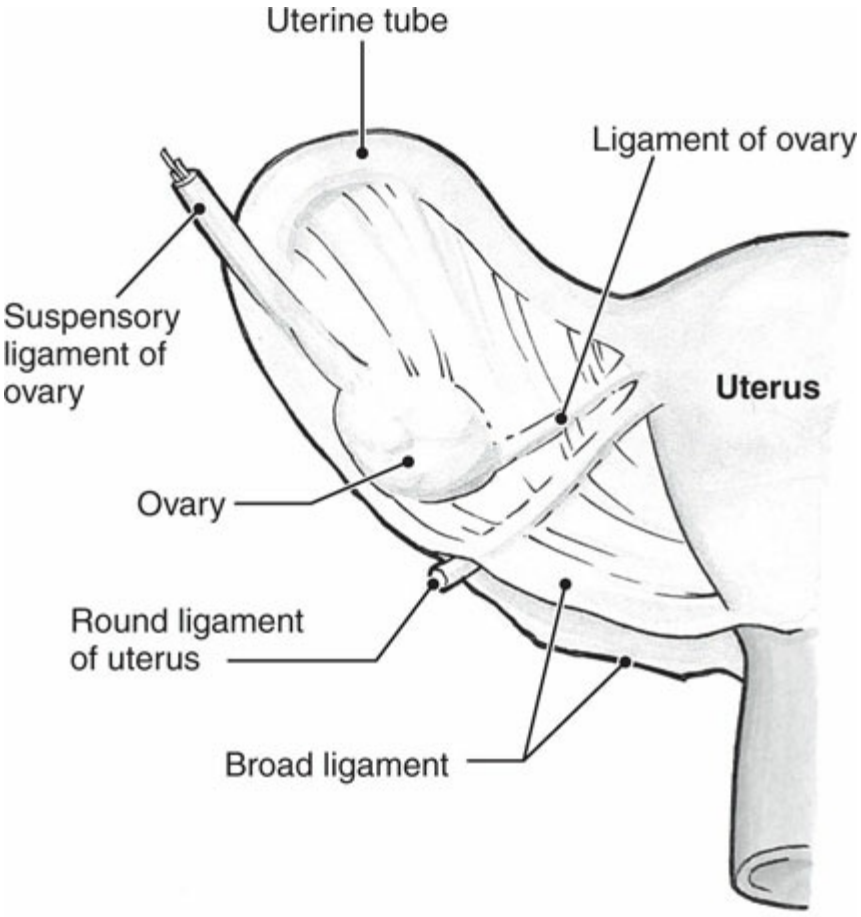


Figure 17-1 Schematic of the relationship of the uterus, ovary, and broad ligament.

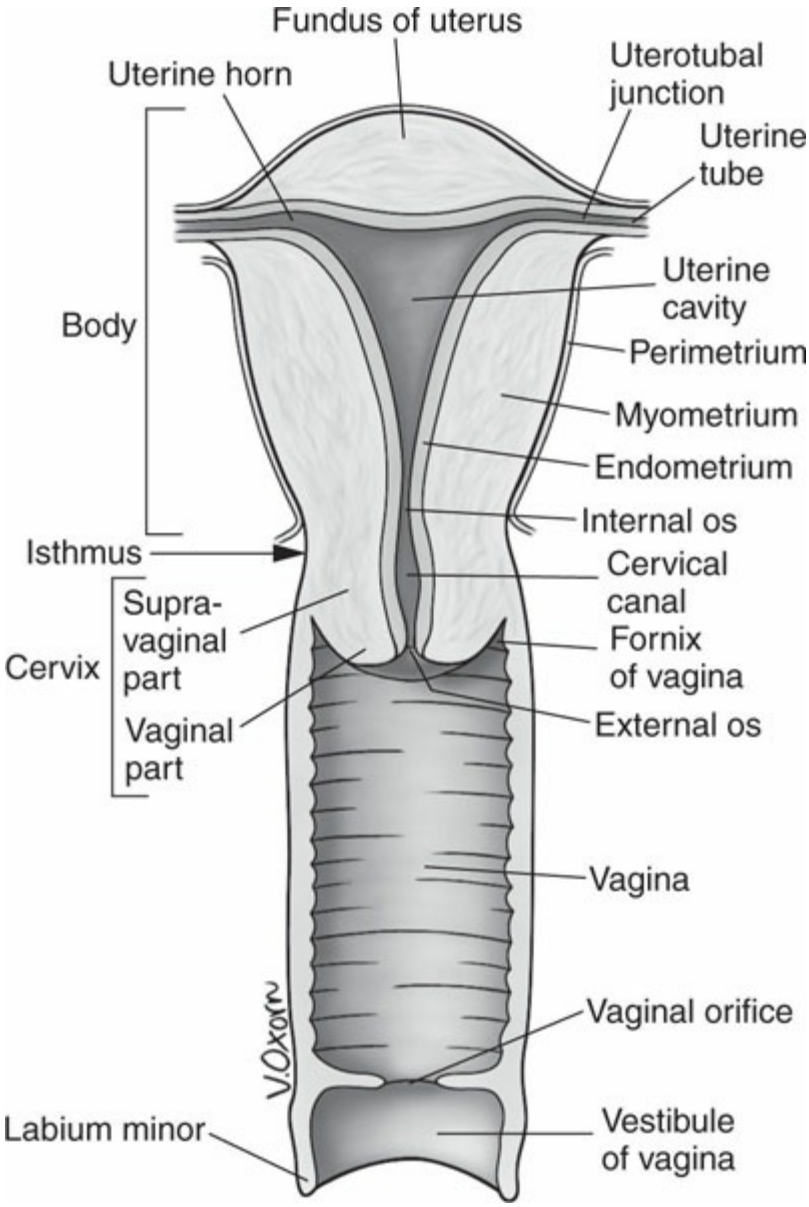


Figure 17-2 Coronal uterine anatomy.

The uterine wall consists of three layers (Fig. 17-4). The outermost layer is referred to as the serosal layer or perimetrium, which is continuous with the fascia of the pelvis. The middle layer is the myometrium or muscular layer, which constitutes the bulk of the uterine tissue, providing the area where contractile motion occurs. The inner mucosal layer of the uterus is referred to as the endometrium. The endometrium can be further divided into a deep or basal layer and a superficial or functional layer (Fig. 17-5).

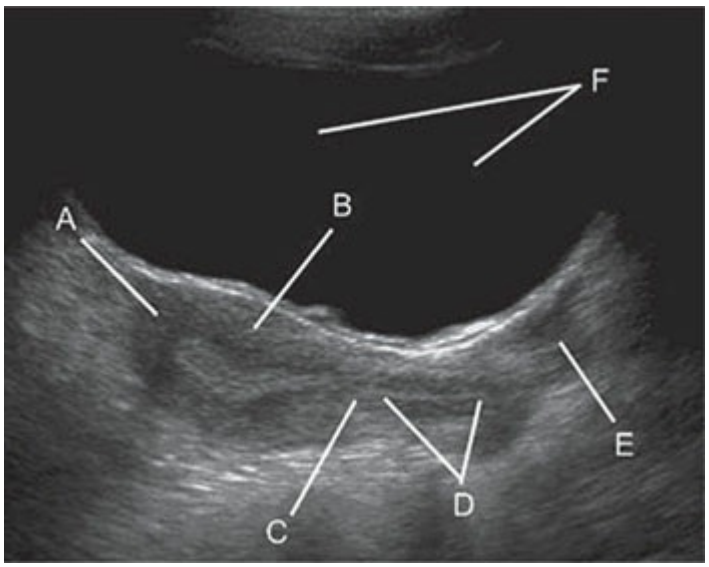


Figure 17-3 Sagittal transabdominal image of the uterus demonstrating posterior to the distended urinary bladder (*F*), the uterine fundus (*A*), uterine corpus (*B*), uterine isthmus (*C*), cervix (*D*), and vagina (*E*).

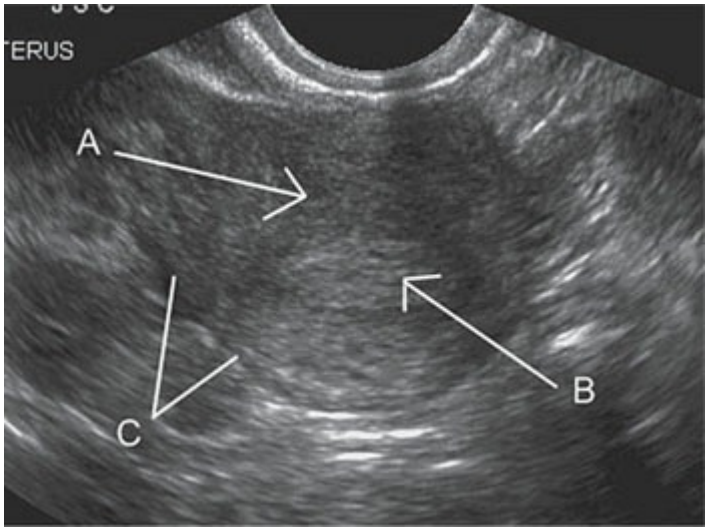


Figure 17-4 Endovaginal transverse image of the uterus demonstrating the myometrium (*A*), the endometrium (*B*), and the serosa (*C*).

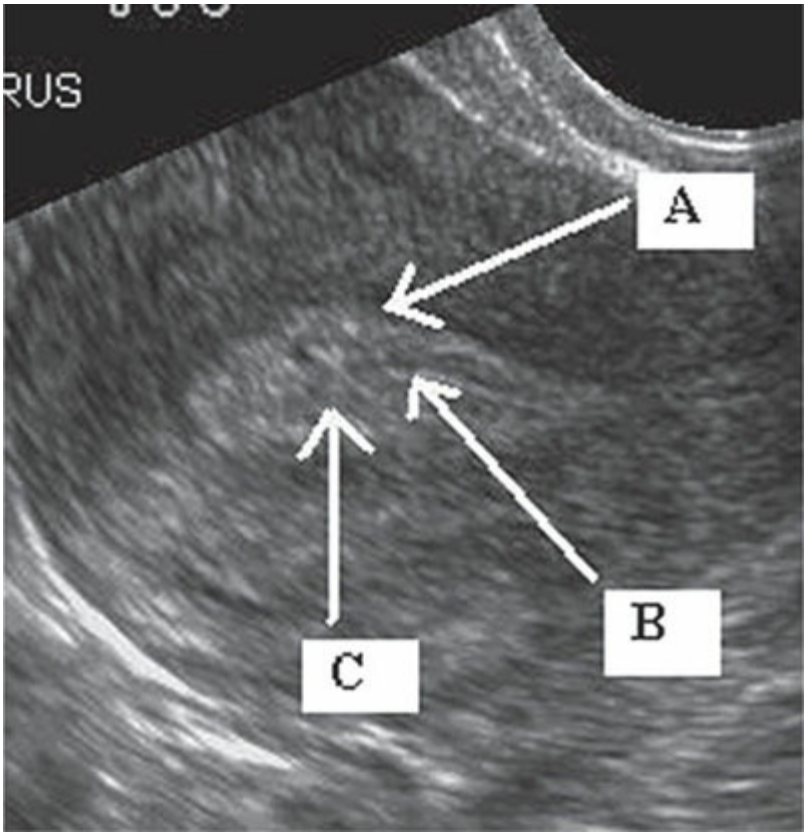


Figure 17-5 Sagittal endovaginal image of the endometrium demonstrating the outermost basal layer (*A*), the innermost echogenic stripe of the uterine cavity (*B*), and the functional layer (*C*).

The thickness of the basal layer is typically consistent, although minimal changes may occur throughout the menstrual cycle. The functional layer of the endometrium is the component that is shed during menstruation; thus, the thickness of the functional layer of endometrium will vary during the menstrual cycle as a result of hormonal stimulation. The endometrial cavity, also referred to as the uterine cavity, is located between the two functional layers of the endometrium. This cavity is contiguous with the lumen of the fallopian tubes laterally, and the cervix inferiorly.

SOUND OFF
The endometrial cavity, also referred to as the uterine cavity, is located between the two functional layers of the endometrium.

Uterine Size and Shape

The size and shape of the uterus depends on the age of the patient, parity, and the presence of pathology or congenital anomalies that may alter its contour. The normal neonatal uterus is tubular in appearance and may exhibit distinct endometrial echoes in the first week of life as a result of maternal hormone stimulation. Following the neonatal period, the cervical anteroposterior

diameter is equal to or slightly greater than that of the uterine fundus. The normal prepubertal uterus has a cervix to uterus ratio of 2:1. The uterus grows minimally during prepubertal years, whereas after puberty, the uterine fundus becomes much larger than the cervix, consequently providing the pear-shaped appearance of the normal adult uterus. Following menopause, the uterus typically becomes much smaller than the premenopausal uterus (Figs. 17-6 and 17-7).

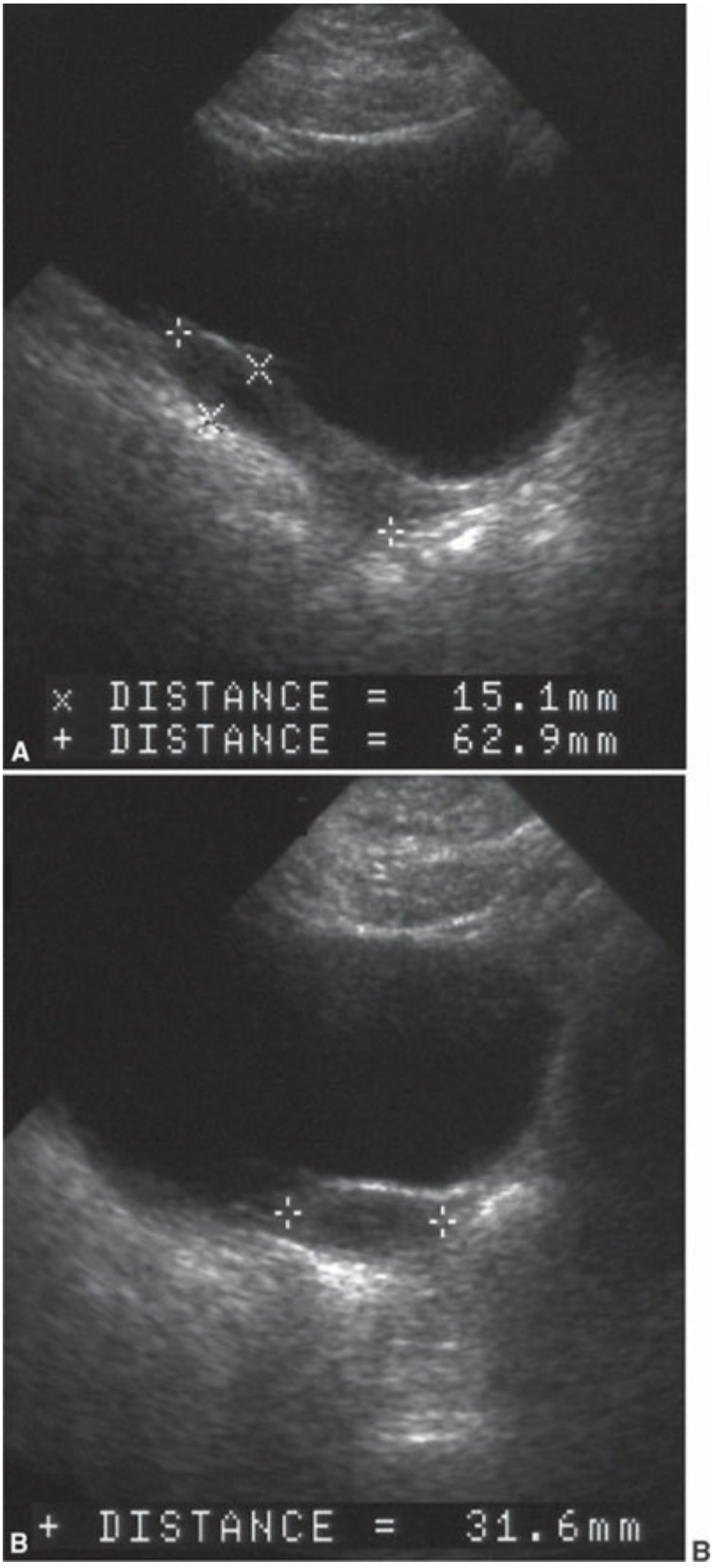


Figure 17-6 Postmenopausal uterus. Sagittal **(A)** and transverse **(B)** views demonstrating an atrophic postmenopausal uterus (*between calipers*).

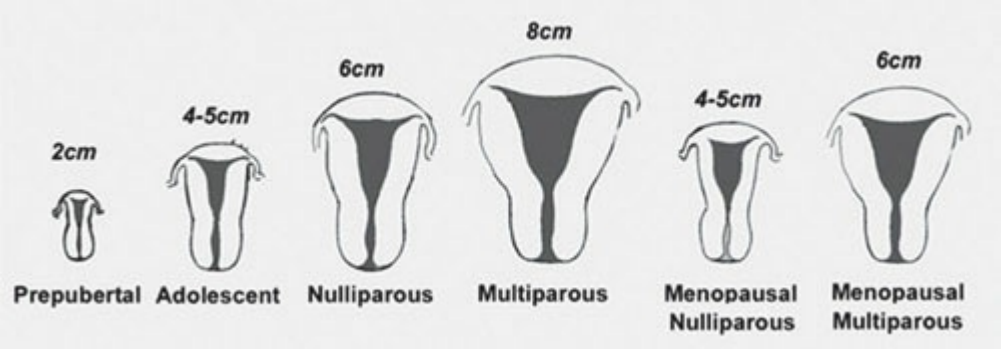


Figure 17-7 Changes in uterine size with age.

SOUND OFF
A newborn baby girl may have a thickened endometrium. This is caused by the stimulation of the baby's endometrium by maternal hormones.

Uterine Positions

The uterine position within the pelvis is variable (Fig. 17-8). The normal position of the uterus is considered to be anteversion or anteflexion. Anteversion describes the uterine position in which the body tilts forward or anteriorly, forming a 90-degree angle with the vagina. Anteflexion of the uterus denotes the position in which the uterine body folds forward, possibly coming in contact with the cervix. Retroversion of the uterus is the position in which the uterine body tilts backward or posteriorly, without a bend where the cervix and body meet. Retroflexion is the uterine position that results in the uterine body tilting backward and actually coming in contact with the cervix. The uterus may also be oriented more to the left or right of the midline, resulting in a variation between anatomic midline and functional midline. The uterus that is located more on the left is referred to as a levoverted uterus, whereas the uterus that is located on the right is referred to as dextroverted uterus.

SOUND OFF
The normal position of the uterus is considered to be anteversion or anteflexion.

Congenital Uterine Anomalies

As stated earlier, uterine malformations are a result of fusion anomalies of the Müllerian ducts. For this reason, they may also be referred to as Müllerian ducts anomalies. Agenesis of the uterus is uncommon. A bicornuate uterus, also referred to as bicornis unicollis, is a common uterine

anomaly that is present when the endometrium divides into two endometrial cavities with one cervix, with a prominent concavity noted in the outline of the uterine fundus (Fig. 17-9). The unicornuate uterus is present when the uterus has only one horn. The septate uterus, which is also a common Müllerian duct anomaly, describes a uterus that has two complete separate uterine cavities separated by an anteroposterior septum (Fig. 17-10). The subseptate uterus, which is characterized by an incomplete septum, has a normal uterine contour with an endometrium that branches into two horns. The arcuate uterus is a subtle variant in which the endometrium has a concave contour at the uterine fundus. The uterus didelphys is complete duplication of the vagina, cervix, and uterus (Fig. 17-11).

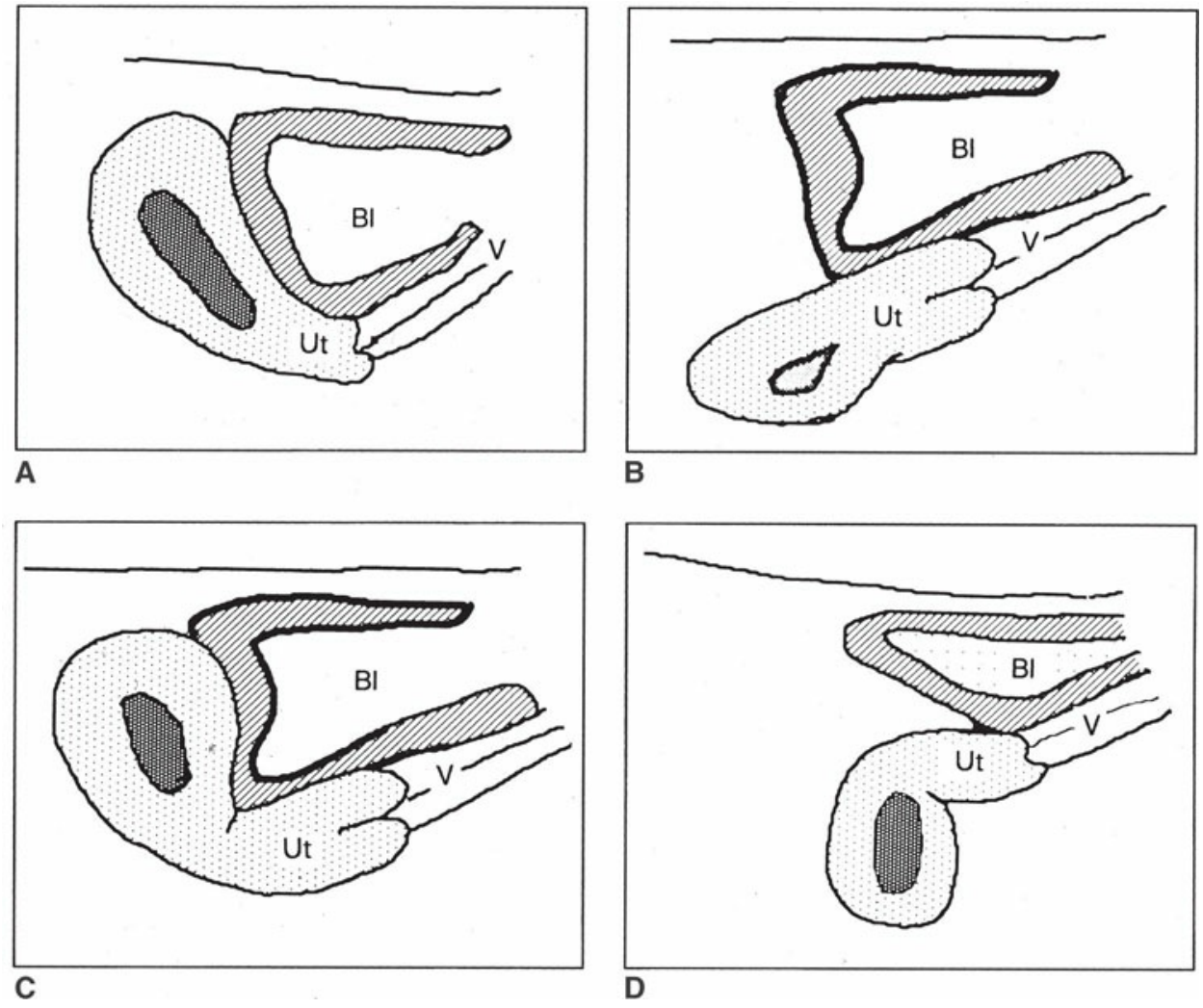


Figure 17-8 Various uterine positions: (**A)** anteverted, (**B**) retroverted, (**C**) anteflexed, and (**D**) retroflexed. The relationship of the bladder (*Bl*), uterus (*Ut*), and vagina (*V*) can be seen.

SOUND OFF

The word part “colli” refers to the neck or cervix of the uterus, whereas the word part “cornu” refers to the horn of the uterus. For example,

bicornis unicollis is interpreted as two horns with a cervix, whereas bicornis bicollis is interpreted as two horns with a double cervix.

Some studies claim that intrauterine exposure to diethylstilbestrol (DES) has resulted in the formation of congenital malformation of the uterus (Fig. 17-12). DES was a drug administered to pregnant woman from the 1940s to the 1970s to treat threatened abortions and premature labor. The female fetus exposed to DES in utero had an increased likelihood of developing a congenital uterine malformation. Congenital malformations have been linked to menstrual disorders, infertility, and obstetric complications. Specifically, the septate uterus has an explicit connection with spontaneous abortion.

In the past, hysterosalpingography, which is a radiographic study that utilizes contrast to evaluate the uterine cavity and fallopian tubes, was often performed on women with suggested congenital uterine malformations or who are suffering from infertility (Fig. 17-13). But most recently, sonography has become a valuable tool as well. Two-dimensional ultrasound can be helpful in identifying the presence of possible uterine malformations that involve variants of the endometrium during routine examinations. However, three-dimensional (3D) ultrasound, with an accuracy rate of greater than 90% for detecting uterine malformations, has become exceedingly useful (Fig. 17-14). Saline infusion sonohysterography, which may also be referred to as simply sonohysterography, can be used to provide additional helpful information in regard to congenital uterine malformations. For patients with a septate uterus, sonography can also aid in the resection of the septum during a hysteroscopic uterine septoplasty. Other imaging modalities and techniques, such as computed tomography, magnetic resonance imaging (MRI), and laparoscopy, may be utilized to identify and further investigate evidence of congenital uterine malformations.

SOUND OFF

The septate uterus is said to be one of the most common Müllerian duct anomalies.

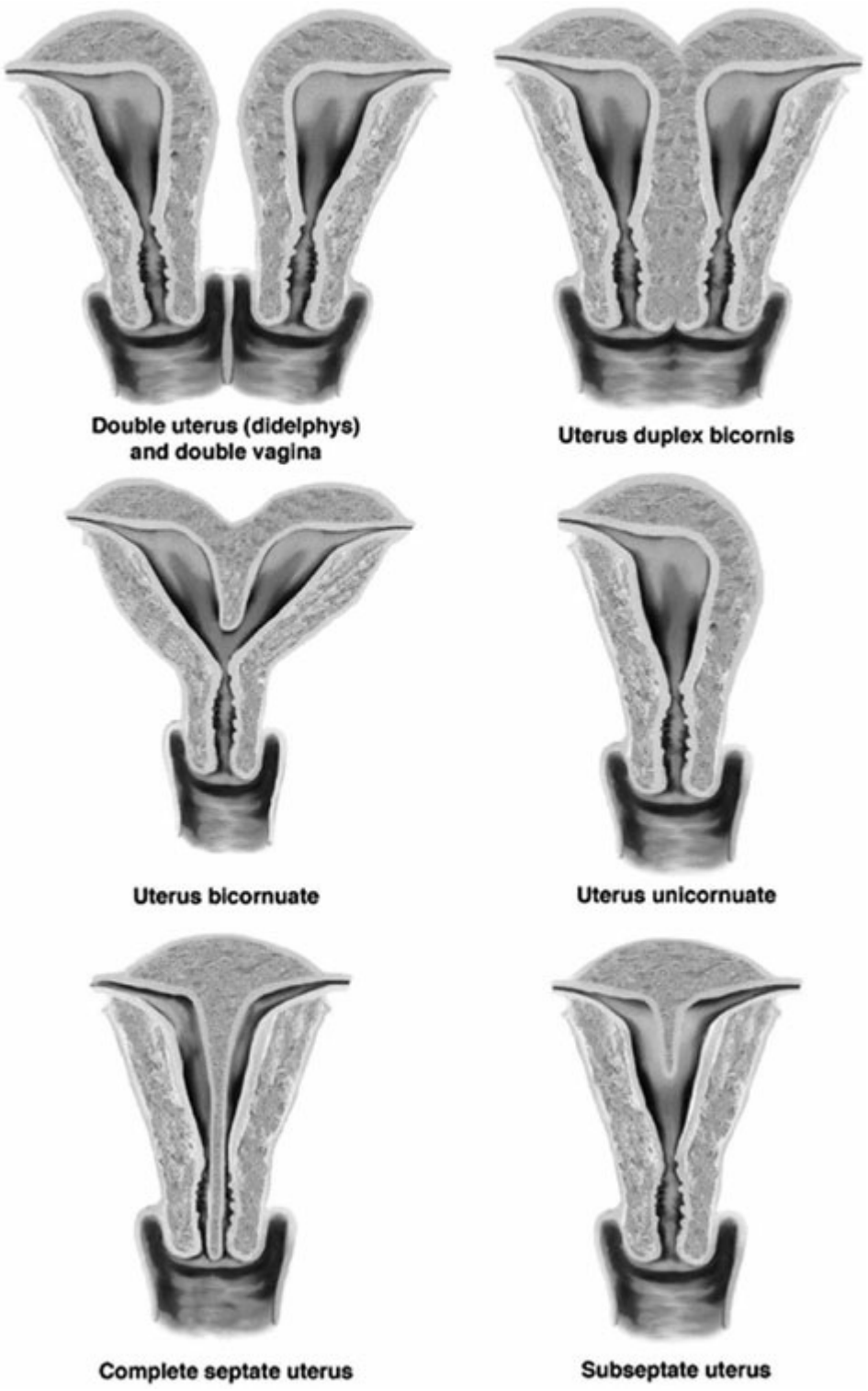


Figure 17-9 Congenital uterine anomalies.

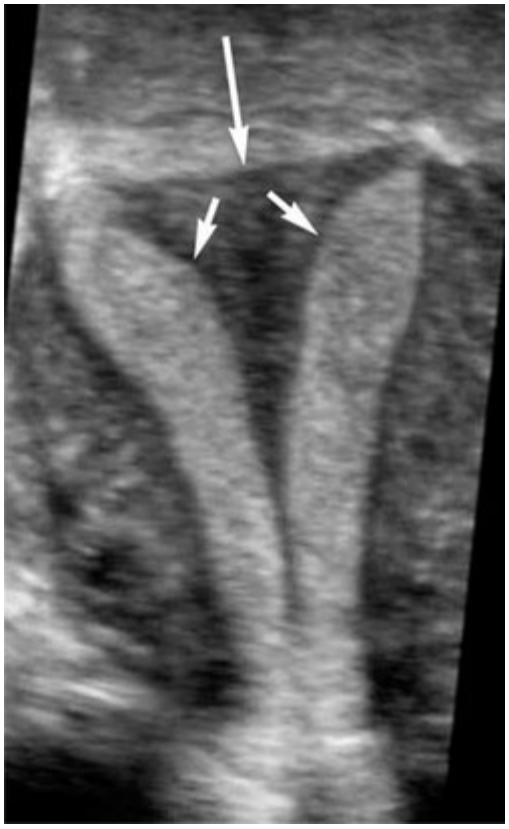


Figure 17-10 Septate uterus. Three-dimensional reformatting of a septate uterus in the coronal plane demonstrating the presence of two separate endometriums *(short arrows)* within the fundus *(long arrow)* of the uterus.

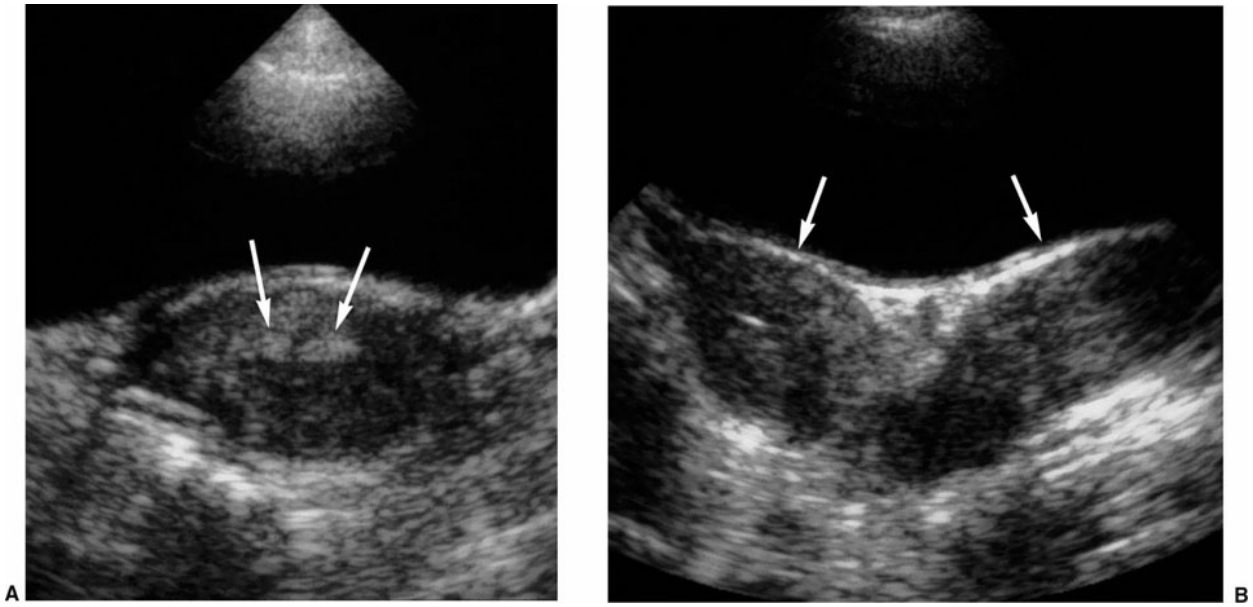


Figure 17-11 Didelphic uterus. **A.** Transverse transabdominal image of the cervix revealing two separate endocervical canals *(arrows)*. **B.** Transverse transabdominal image of the upper uterus demonstrating a separate right and left uterine horn *(arrows)*.

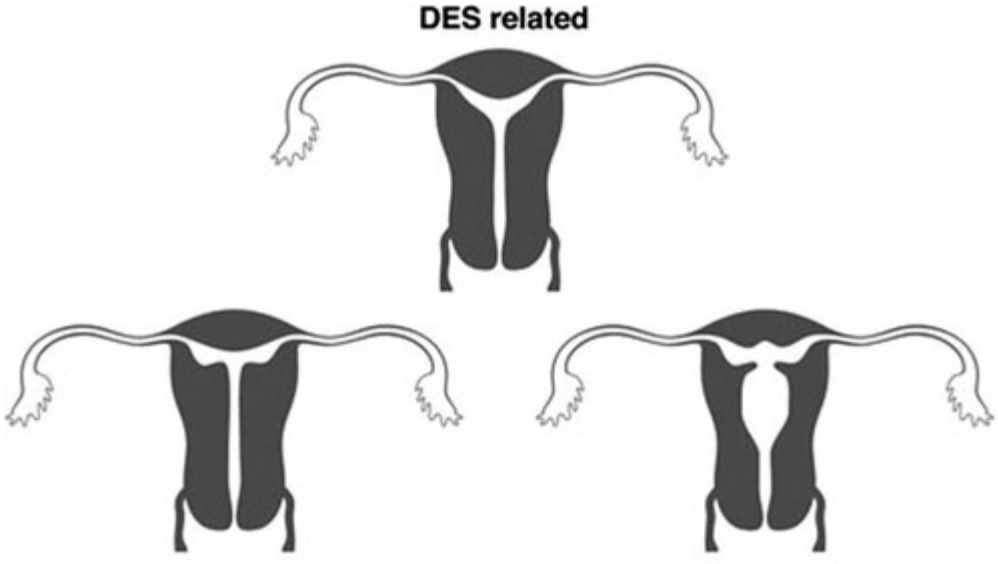


Figure 17-12 DES anomalies. Uterine anomalies associated with in utero diethylstilbestrol (DES) exposure. The classic anomaly is a T-shaped uterus.

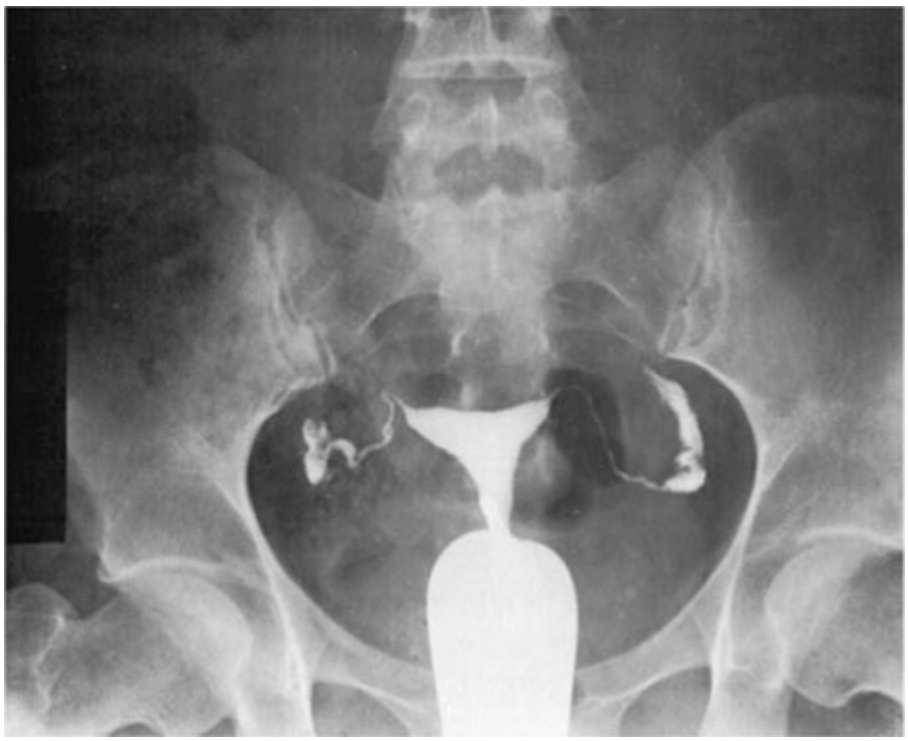


Figure 17-13 Normal hysterosalpingogram. Radiograph of the female pelvis after the installation of a radiopaque compound into the uterine cavity.

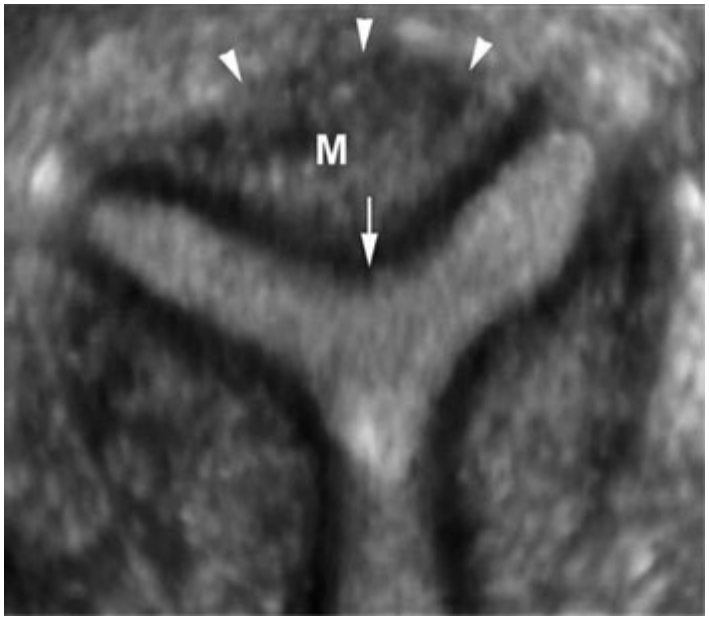


Figure 17-14 3D of arcuate uterus. True coronal view of the uterus, obtained by reconstruction using 3D sonography, demonstrating the myometrium (*M*) in the uterine fundus dips down with a rounded configuration (*arrow*) into the endometrium, indicating an arcuate uterus. The fundus had a normal shape (*arrowheads*).

Congenital Malformation of the Vagina

Congenital malformations of the vagina can lead to the accumulation of fluid within the female genital tract secondary to an obstruction. The obstruction can be the result of vaginal atresia, a vaginal septum, or an imperforate hymen. The consequence of this obstruction could lead to the distension of the vagina, cervix, uterus, and fallopian tubes with fluid or blood.

Hydrocolpos describes the condition in which the vagina is distended with simple, anechoic fluid, and is seen more often in the neonatal period (Fig. 17-15). As the vagina distends with fluid, excessive amounts may lead to further accumulation of the fluid into the uterus, a condition known as hydrometrocolpos. Clinically, neonatal patients with vaginal obstructions present with a palpable pelvic or abdominal mass as a result of an excessive buildup of vaginal secretions in utero.

Patients may have blood components from menstruation retained in the uterine cavity or vagina, termed hematometra and hematocolpos, respectively (Figs. 17-16 and 17-17). They may also have hematometrocolpos, a condition when both the uterine cavity and vagina are filled with blood. This obstruction is frequently associated with the presence of an imperforate hymen in young girls. Clinically, these patients will present with amenorrhea, cyclic abdominal pain, an abdominal mass, enlarged uterus, and possibly urinary retention.

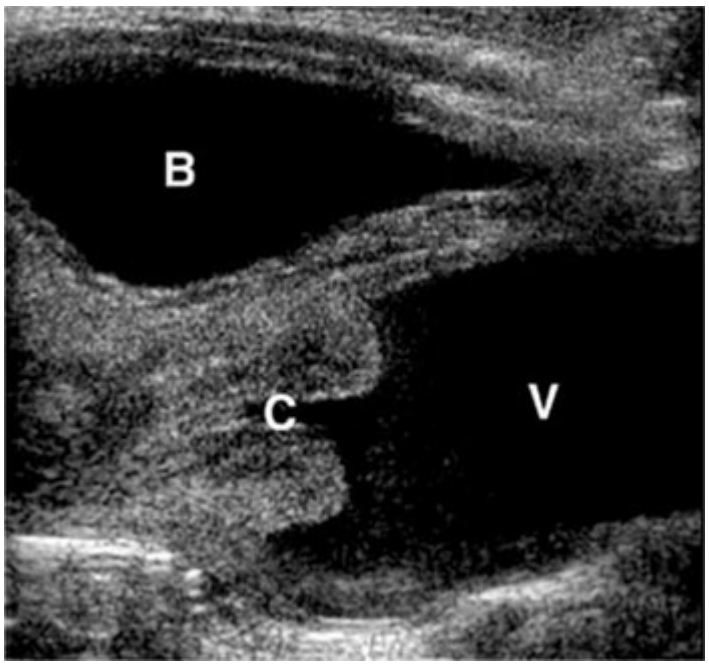


Figure 17-15 Hydrocolpos. Simple appearing fluid is noted posterior to the urinary bladder (*B*) and inferior to the cervix (*C*) within the vagina (*V*) in this sagittal image of the neonatal pelvis.

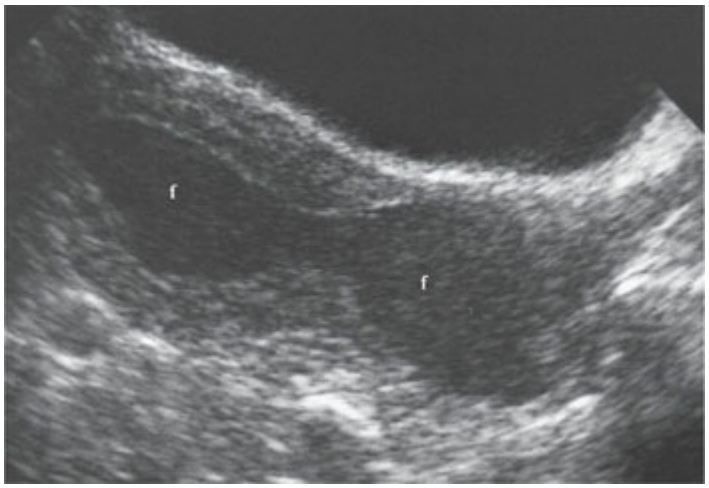


Figure 17-16 Hematometra. The uterus is distended with echogenic fluid *(f)* representing blood.

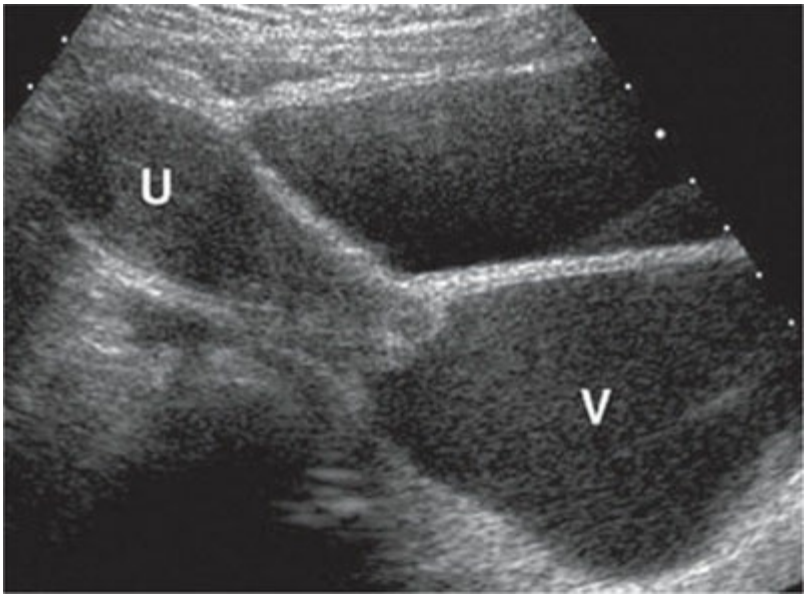


Figure 17-17 Hematocolpos. Sagittal image of a 12-year-old girl with cyclic pain demonstrating a blood-filled distended vagina (*V*).

SOUND OFF

The word part "colpo" refers to the vagina, whereas the word part "metra" refers to the uterus. Thus, hydrocolpos is interpreted as fluid in the vagina, whereas hydrometrocolpos refers to fluid in both the uterus and the vagina.

CLINICAL FINDINGS OF VAGINAL OBSTRUCTIONS

1. Cyclic pelvic pain (often at the time of menses in adolescent girls)
2. Enlarged uterus
3. Abdominal pain
4. Urinary retention
5. Amenorrhea (adolescent girls)

SONOGRAPHIC FINDINGS OF VAGINAL OBSTRUCTIONS

1. Distension of the uterus, vagina, or both with anechoic or complex fluid

UTERINE PATHOLOGY

Adenomyosis

Adenomyosis is the invasion of endometrial tissue into the myometrium. For unknown reasons, endometrial tissue is allowed to invade the myometrium. The basal layer of the endometrium can often extend into the myometrium at depths of at least 2.5 mm. The involvement of adenomyosis may be either

focal or diffuse and is typically found more often within the fundus and posterior portion of the uterus (Fig. 17-18). Focal adenomyosis in the form of a mass is termed an adenomyoma. Sonographically, the uterus will appear diffusely enlarged and heterogeneous. There may be indistinct hypoechoic or echogenic areas scattered throughout the myometrium, with small myometrial cysts noted as well (Fig. 17-19). Thickening of the posterior myometrium can also be recognized. Adenomyosis is often present in the uterus afflicted with fibroid tumors. Up to 20% of patients with adenomyosis suffer from endometriosis as well.

SOUND OFF
Adenomyosis is often present in the uterus afflicted with fibroid tumors.

The clinical presentation of adenomyosis is varied and nonspecific, with most women experiencing dyschezia, dysmenorrhea, menometrorrhagia, pelvic pain, and dyspareunia. Patients often have a boggy, enlarged, and tender uterus upon physical examination. Although sonography is steadily becoming a valuable diagnostic instrument in the diagnosis of adenomyosis, MRI appears to provide important diagnostic information. Treatment for adenomyosis is hysterectomy or hormone therapy, with the latter often producing limited, if any, relief from symptoms. An important differentiation should be made between endometriosis and adenomyosis. Patients with endometriosis tend to be younger and have fertility troubles, whereas those with adenomyosis are often older and multiparous.

CLINICAL FINDINGS OF ADENOMYOSIS

1. Uterine enlargement
2. Boggy, tender uterus
3. Dysmenorrhea
4. Menometrorrhagia
5. Pelvic pain
6. Dyschezia
7. Dyspareunia
8. Multiparous

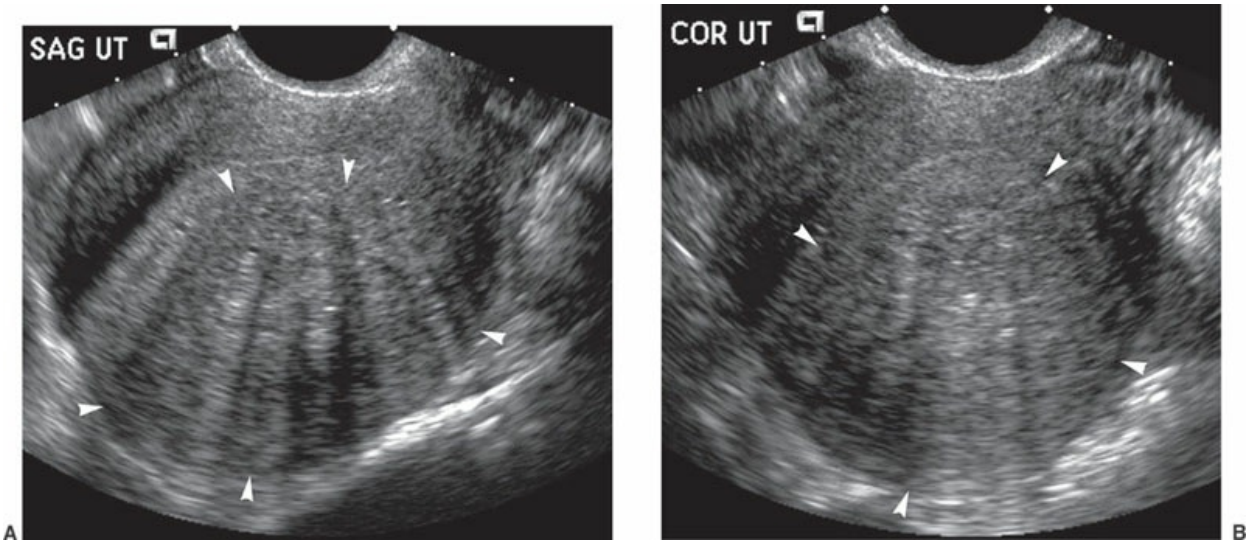


Figure 17-18 Adenomyosis. Sagittal **(A)** and coronal **(B)** of a uterus demonstrating adenomyosis *(arrowheads)* involving the posterior myometrium.

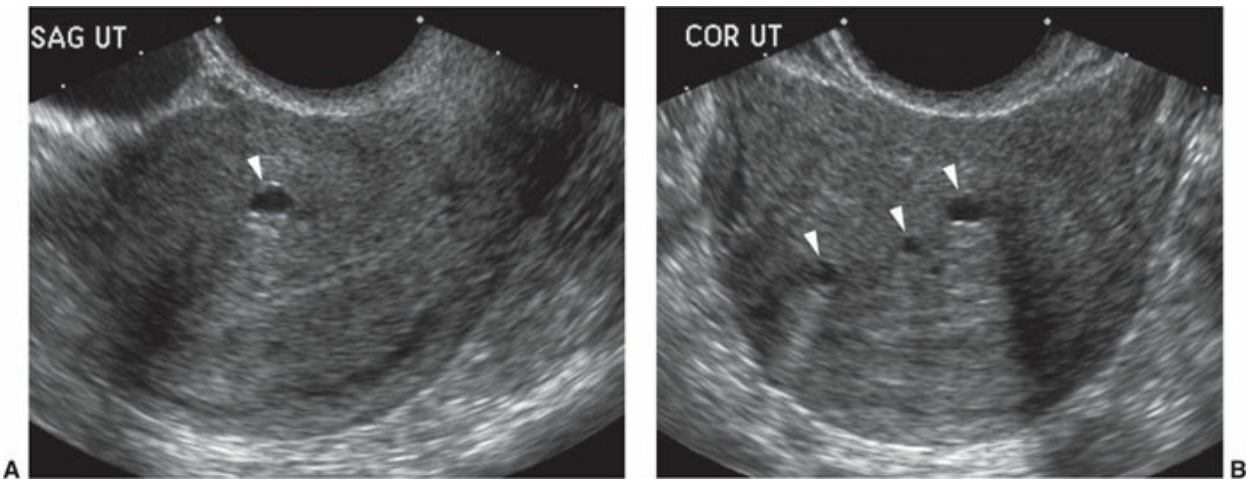


Figure 17-19 A. Myometrial cyst (*arrowhead*) associated with adenomyosis. **B.** Myometrial cysts *(arrowheads)* are noted throughout the uterus in a patient who is suffering from adenomyosis.

SONOGRAPHIC FINDINGS OF ADENOMYOSIS

1. Diffusely enlarged uterus
2. Hypoechoic or echogenic areas adjacent to endometrium
3. Heterogeneous myometrium
4. Myometrial cysts
5. Ill-defined interface between myometrium and endometrium
6. Thickening of the fundus or posterior myometrium

Uterine Leiomyoma

The leiomyoma is a benign, smooth muscle tumor of the uterus that may also be referred to as a fibroid or uterine myoma. Leiomyomas (leiomyomata) are the most common benign gynecologic tumors and the leading cause of

hysterectomy and gynecologic surgery. These tumors can vary in size and may alter the shape of the uterus and have varying sonographic appearances. Those who are at greater risk for the development of fibroids are women who are obese, black, nonsmokers, and perimenopausal. Clinical findings include pelvic pressure, menorrhagia, palpable abdominal mass, enlarged uterus, urinary frequency, dysuria, constipation, and possibly infertility.

Sonographically, fibroids often appear as solid, hypoechoic masses that produce posterior shadowing. Degenerating fibroids may have calcifications or cystic components, whereas multiple fibroids may cause diffuse uterine enlargement and heterogeneity. A uterus that is distorted by multiple leiomyomas may be referred to as a fibroid uterus.

SOUND OFF
Leiomyomas are the most common benign gynecologic tumors and the leading cause of hysterectomy and gynecologic surgery.

Fibroids are also described by their location (Figs. 17-20 and 17-21). The most common location for fibroids is intramural, or within the myometrium. A subserosal fibroid grows outward and distorts the contour of the uterus. Subserosal fibroids that are pedunculated (on a stalk), or those associated with the broad ligament, could resemble adnexal masses. Pedunculated fibroids may undergo torsion as well, thus cutting off the blood supply to the mass. This lack of blood supply results in necrosis, and clinically, the patient will present with acute, localized pelvic pain. Submucosal fibroids are located adjacent to the endometrial cavity and often distort the shape of the endometrium. Intracavitary fibroids, the fibroids located within the uterine cavity, and submucosal fibroids usually lead to abnormal uterine bleeding because of their location in relationship to the endometrium. Some fibroids may also extend into the cervix when pedunculated and may prolapsed into the vagina as well.

SOUND OFF
Pedunculated fibroids may undergo torsion, thus cutting off the blood supply to the mass. This lack of blood supply results in necrosis, and clinically, the patient will present with acute, localized pelvic pain.

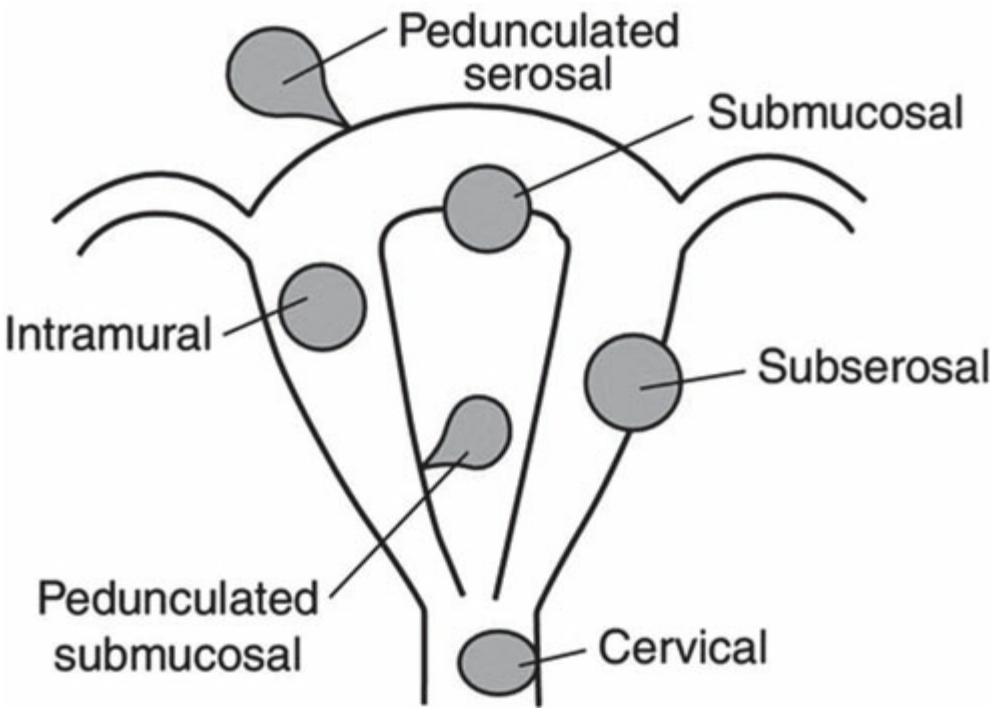


Figure 17-20 Diagram of fibroid locations.

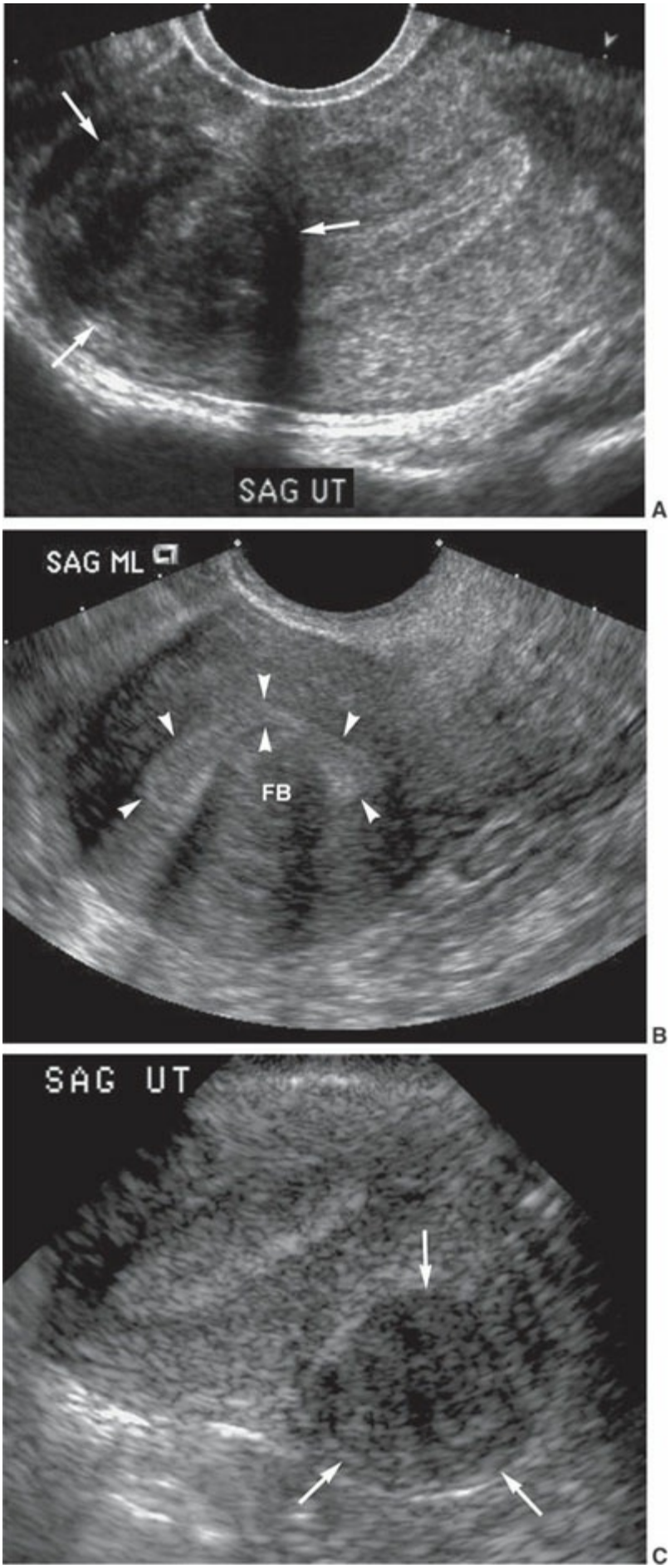


Figure 17-21 Fibroid locations with sonography. **A.** Sagittal endovaginal view

demonstrating an intramural fibroid (*between arrows*). **B.** Sagittal endovaginal view demonstrating a submucosal fibroid (*FB*). Note the distortion of the endometrium (*arrowheads*). **C.** Sagittal endovaginal view showing a subserosal fibroid *(long arrows).*

Fibroid growth has been associated with estrogen stimulation, and consequently, their size may increase during pregnancy and reduce after menopause. Fibroids may also impact fertility if they are intracavitary or submucosal, because the location of these fibroids may result in a higher incidence of spontaneous abortion. Fibroids may also affect the contractile motion of the uterus, thus leading to interference with sperm migration. A concurrent intrauterine pregnancy and fibroid can be sonographically identified, although often this occurrence does not result in preterm labor or early pregnancy loss. Alternatively, fibroids may prevent cervical dilation during pregnancy, thus often requiring a cesarean section to be performed at the time of delivery.

SOUND OFF

Fibroids may impact fertility if they are intracavitary or submucosal, because the location of these fibroids may result in a higher incidence of spontaneous abortion.

The medical treatment for fibroids is hormone therapy, which typically results in a reduction in tumor size. Surgical treatment may either be hysterectomy or myomectomy. Myomectomy is the surgical removal of a fibroid and may be performed abdominally or laparoscopically. Another alternative treatment for fibroids involves uterine artery embolization, which is used to obstruct the blood supply to the mass. Uterine artery embolization, which is performed under fluoroscopic guidance, results in a reduction in the size of the mass and also in a decline in the associated clinical symptoms. Magnetic resonance imaging-guided high-intensity focused ultrasound offers an additional noninvasive management of fibroids that uses focused high-frequency, high-energy ultrasound guided by MRI to heat and destroy fibroid tissue.

CLINICAL FINDINGS OF A UTERINE LEIOMYOMA

1. Pelvic pressure
2. Menorrhagia
3. Palpable pelvic mass
4. Enlarged, bulky uterus (if multiple)
5. Urinary frequency

6. Dysuria
7. Constipation
8. Infertility

SONOGRAPHIC FINDINGS OF A UTERINE LEIOMYOMA

1. Hypoechoic mass within the uterus
2. Posterior shadowing from the mass
3. Degenerating fibroids may have calcifications or cystic components
4. Multiple fibroids appear as an enlarged, irregularly shaped, diffusely heterogeneous uterus

Leiomyosarcoma

Leiomyosarcoma is the malignant counterpart of the normally benign leiomyoma. Although not specific, these masses are characterized by a rapid increase in growth over a short period of time (Fig. 17-22). They are also more commonly found in perimenopausal or postmenopausal woman. Their sonographic appearance is variable, and they may appear similar to a benign fibroid, with some evidence of degeneration. Clinically, patients with leiomyosarcoma may be asymptomatic or may present with the same symptoms as the benign leiomyoma.

CLINICAL FINDINGS OF LEIOMYOSARCOMA

1. Pelvic pressure
2. Menorrhagia
3. Palpable abdominal mass
4. Enlarged, bulky uterus
5. Urinary frequency
6. Dysuria
7. Constipation
8. Infertility

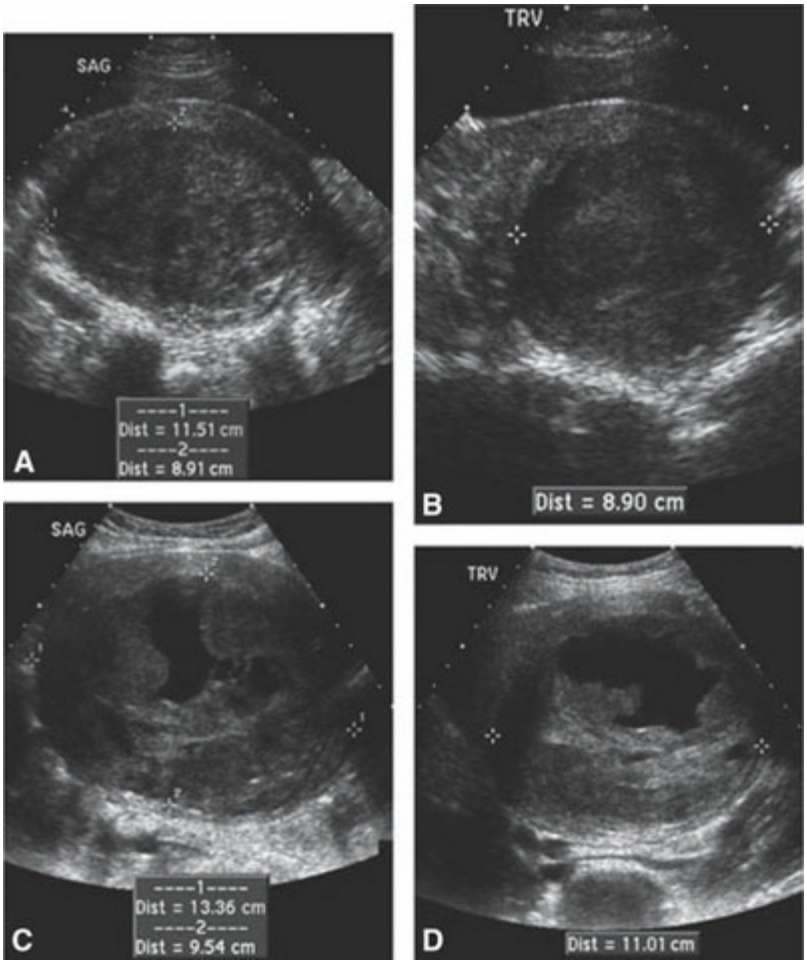


Figure 17-22 Leiomyosarcoma. Sagittal **(A)** (*SAG*) and **(B)** transverse (*TRV*) transabdominal views of the uterus in a postmenopausal woman demonstrating a hypoechoic mass (*calipers*) in the uterus. This mass was initially diagnosed as a fibroid. Sagittal **(C)** and transverse **(D)** views 5 months later showing the mass has grown substantially. Pathology following a hysterectomy revealed the diagnosis of leiomyosarcoma.

SONOGRAPHIC FINDINGS OF LEIOMYOSARCOMA

1. Rapidly growing mass within the uterus
2. Hypoechoic mass within the uterus
3. Posterior shadowing from the mass
4. Degenerating fibroids may have calcifications or cystic components
5. Multiple fibroids appear as an enlarged, irregularly shaped, diffusely heterogeneous uterus

Nabothian Cyst

Nabothian cysts are common findings on routine sonographic examinations. These benign retention cysts are located within the cervix and may cause cervical enlargement on physical examination. Nabothian cysts are classically simple but may have some internal debris or septations, which

may represent hemorrhage or infection. Nabothian cysts are typically asymptomatic and may be multiple (see Fig. 17-23).

CLINICAL FINDINGS OF A NABOTHIAN CYST

1. Asymptomatic

SONOGRAPHIC FINDINGS OF A NABOTHIAN CYST

1. Anechoic mass within the cervix
2. May be multiple
3. May be complex

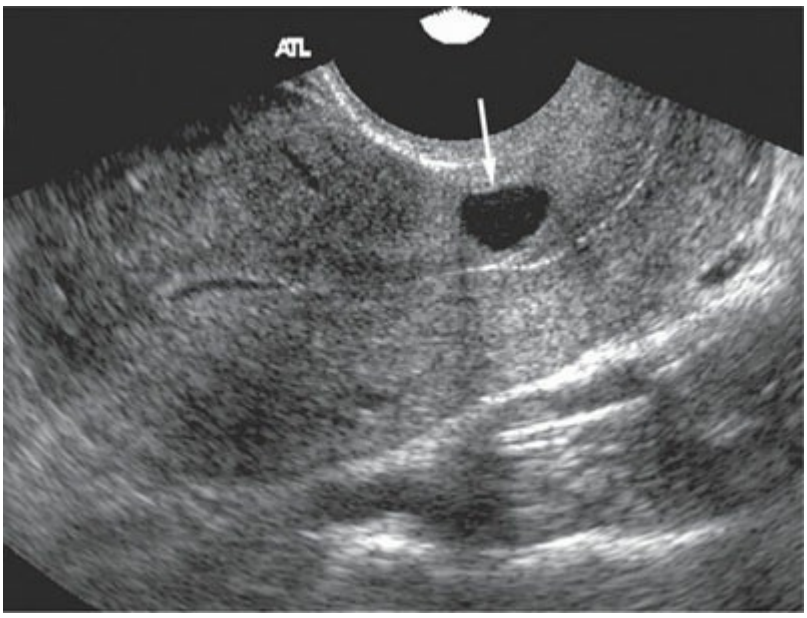


Figure 17-23 Nabothian cyst. Sagittal endovaginal view of the uterus revealing a cyst with the cervix *(arrow)*, which is highly specific for a Nabothian cyst.

PATHOLOGY OF THE CERVIX

Cervical Carcinoma and Cervical Stenosis

Cervical carcinoma is the most common female malignancy in women younger than age 50. Although cervical carcinoma is not routinely diagnosed with sonography, when seen, it may present as an inhomogeneous, bulky, enlarged cervix or as a focal mass within the cervix. Loss of the normal cervical canal may occur as well. The cervical width should not exceed 4 cm.

Transvaginal and transrectal imaging are methods in which sonography can be used to better visualize the cervix. Masses may be large enough to obstruct the cervix, thus leading to hydrometra or hematometra. In patients who have had a hysterectomy, the cervical remnant should not exceed 4.4 cm

in the anteroposterior plane and 4.3 cm in length. Patients who have undergone an abdominal hysterectomy may have no cervical remnant, but rather a vaginal cuff. This cuff should not exceed 2 cm. Enlargement or a notable mass in the area of the cervical remnant or vaginal cuff will most likely lead to more imaging and possible a biopsy.

Cervical stenosis, which is the narrowing of the endocervical canal, often leads to an abnormal quantity of fluid in the endocervical or endometrial canals. It can be the result of a tumor in the cervix, cervical fibroid, cervical polyp, cervical infection, cervical atrophy, or scarring of the cervix following radiation treatment for cancer. Clinically, women with cervical stenosis may be asymptomatic, whereas those who are still menstruating may present with absent menstrual flow when expected. In some women, an enlarged uterus may be noted during a physical examination as well.



SOUND OFF

Cervical stenosis can be the result of an obstructing tumor, fibroid, or polyp in the cervix. In addition, cervical infection, cervical atrophy, or scarring of the cervix following radiation treatment for cancer can result in stenosis of the cervix.

PATHOLOGY OF THE VAGINA

Gartner Duct Cyst

The vagina can be imaged well with transabdominal imaging. A Gartner duct cyst may be noted within the vagina. They are typically small and located along the wall of the vagina. Gartner duct cysts are often asymptomatic.

CLINICAL FINDINGS OF A GARTNER DUCT CYST

1. Asymptomatic

SONOGRAPHIC FINDINGS OF A GARTNER DUCT CYST

1. Anechoic mass within the vagina

PRECOCIOUS PUBERTY

Precocious puberty is pubertal development before the age of 8 (Table 17-1). Delayed puberty is described as absent or incomplete breast development after the age of 12. The diagnosis of precocious puberty typically constitutes

an endocrinologic workup to evaluate gonadotropin levels. True precocious puberty is associated with intracranial tumors or may simply be idiopathic. Pseudoprecocious puberty, also referred to as peripheral pseudosexual precocity or gonadotropin-independent precocious puberty, has been linked with ovarian, adrenal, and liver tumors. Therefore, patients who present with the indication of precocious puberty should perhaps be sonographically assessed for ovarian, hepatic, and adrenal gland tumors. The uterus may appear enlarged with a postpubertal shape and contain a prominent endometrial stripe. The ovary or ovaries may be enlarged, and a functional ovarian cyst or ovarian mass may be seen.

TABLE 17-1 Terms associated with precocious puberty

Term	Description
Isosexual precocity	Early development of secondary sexual characteristics with menses, ovulation, and elevated gonadotropin levels
Premature adrenarche	Characterized by isolated pubic hair development and increased levels of adrenal androgens
Premature thelarche	Characterized by isolated breast development with normal prepubertal hormones
Secondary sexual characteristics	Body changes typically occurring at puberty such as enlargement of breasts and growth of pubic hair
Virilization	A condition in which a female develops physical changes that are associated with males hormones (androgens) such as hair growth



SOUND OFF

True precocious puberty is associated with intracranial tumors or may simply be idiopathic. Pseudoprecocious puberty has been linked with ovarian, adrenal, and liver tumors.

REVIEW QUESTIONS

1. Which of the following fibroid locations would most likely result in abnormal uterine bleeding because of its relationship to the endometrium?
   a. Submucosal
   b. Intramural

c. Subserosal
d. Subserosal pedunculated

2. All of the following are sonographic findings consistent with adenomyosis except:
   a. Diffuse, enlarged uterus
   b. Myometrial cysts
   c. Hypoechoic areas adjacent to the endometrium
   d. Complex adnexal mass

3. The largest part of the uterus is the:
   a. Corpus
   b. Isthmus
   c. Cervix
   d. Fundus

4. Which of the following would be most indicative of a leiomyosarcoma?
   a. Vaginal bleeding
   b. Rapid growth
   c. Dysuria
   d. Large hypoechoic mass

5. The inferior portion of the cervix closest to the vagina is the:
   a. Cornu
   b. Internal os
   c. External os
   d. Inferior fornix

6. The inner mucosal lining of the uterus is the:
   a. Myometrium
   b. Endometrium
   c. Serosal layer
   d. Perimetrium

7. Difficult or painful intercourse is referred to as:
   a. Dysuria
   b. Dysmenorrhea
   c. Dyspareunia
   d. Hydrocolpos

8. What congenital malformation of the uterus is common and has a clear association with an increased risk for spontaneous abortion?
   a. Anteflexed uterus

b. Levoverted uterus
c. Dextroverted uterus
d. Septate uterus

9. Absence of a menstruation is referred to as:
   a. Dysuria
   b. Dysmenorrhea
   c. Amenorrhea
   d. Menorrhagia

10. The invasion of endometrial tissue into the myometrium of the uterus is referred to as:
    a. Amenorrhea
    b. Endometriosis
    c. Adenomyomatosis
    d. Adenomyosis

11. Pseudoprecocious puberty may be associated with all of the following except:
    a. Ovarian tumor
    b. Adrenal tumor
    c. Liver tumor
    d. Brain tumor

12. The layer of the endometrium that is significantly altered as a result of hormonal stimulation during the menstrual cycle is the:
    a. Myometrium
    b. Endometrial cavity
    c. Functional layer
    d. Basal layer

13. The most superior and widest portion of the uterus is the:
    a. Corpus
    b. Isthmus
    c. Cervix
    d. Fundus

14. A 24-year-old female patient presents to the sonography department for a pelvic sonogram with an indication of pelvic pain. Upon sonographic interrogation, the sonographer notes an anechoic mass within the vagina. This mass most likely represents a:
    a. Nabothian cyst
    b. Gartner duct cyst

c. Dandy-Walker cyst
d. Ovarian cyst

15. What section of the uterus is also referred to as the lower uterine segment?
a. Cervix
b. Isthmus
c. Fundus
d. Cornu

16. The outer layer of the endometrium is the:
a. Myometrium
b. Endometrial cavity
c. Functional layer
d. Basal layer

17. Which of the following would be considered the more common uterine anomaly?
a. Bicornis univernus
b. Bicornis bicollis
c. Uterus didelphys
d. Septate uterus

18. The rigid region of the uterus located between the vagina and the isthmus is the:
a. Cornu
b. Corpus
c. Cervix
d. Fundus

19. Upon sonographic evaluation of a patient complaining of abnormal distention, you visualize a large, hypoechoic mass distorting the anterior border of the uterus. What is the most likely location of this mass?
a. Intramural
b. Subserosal
c. Submucosal
d. Intracavitary pedunculated

20. A simple fluid accumulation within the vagina secondary to an imperforate hymen is:
a. Hydrometrocolpos
b. Hydrocolpos
c. Hematometra

d. Hematocolpos

21. The uterine position in which the corpus tilts forward and comes in contact with the cervix describes:
    a. Anteflexion
    b. Anteversion
    c. Retroflexion
    d. Retroversion

22. What leiomyoma location would have an increased risk to undergo torsion?
    a. Subserosal
    b. Intracavitary
    c. Pedunculated
    d. Submucosal

23. A 13-year-old girl presents to the sonography department with a history of cyclic pain, abdominal swelling, and amenorrhea. Sonographically, you visualize an enlarged uterus and a distended vagina that contains anechoic fluid with debris. What is the most likely diagnosis?
    a. Cervical stenosis
    b. Adenomyosis
    c. Endometriosis
    d. Hematocolpos

24. All of the following are clinical findings associated with leiomyoma except:
    a. Myometrial cysts
    b. Infertility
    c. Palpable pelvic mass
    d. Menorrhagia

25. The surgical removal of a fibroid is termed:
    a. Hysterosonogram
    b. Total abdominal hysterectomy
    c. Myomectomy
    d. Uterine artery embolization

26. Which of the following is typically not a clinical complaint of women who are suffering from adenomyosis?
    a. Amenorrhea
    b. Dysmenorrhea
    c. Dyspareunia

d. Menometrorrhagia

27. The paired embryonic ducts that develop into the female urogenital tract are the:
    a. Fallopian ducts
    b. Wolffian ducts
    c. Gartner ducts
    d. Müllerian ducts

28. Precocious puberty is defined as the development of pubic hair, breasts, and the genitals before the age of:
    a. 13
    b. 8
    c. 5
    d. 10

29. Abnormally heavy and prolonged menstrual flow between periods is termed:
    a. Menometrorrhagia
    b. Menarche
    c. Menorrhagia
    d. Dysmenorrhea

30. Leiomyomas that project from a stalk are termed:
    a. Submucosal
    b. Intramural
    c. Subserosal
    d. Pedunculated

31. Congenital malformation of the uterus that results in complete duplication of the genital tract is:
    a. Unicornuate uterus
    b. Bicornis bicollis
    c. Uterus didelphys
    d. Subseptate uterus

32. A 38-year-old female patient presents to the sonography department for a pelvic sonogram with an indication of pelvic pain. Upon sonography interrogation, the sonographer notes an anechoic mass within the cervix. This mass most likely represents a:
    a. Nabothian cyst
    b. Benign follicular cyst
    c. Dermoid cyst

d. Gartner duct cyst

33. Leiomyosarcoma of the uterus denotes:
    a. The benign invasion of endometrial tissue into the myometrium
    b. The ectopic location of endometrial tissue in the adnexa
    c. The malignant counterpart of a fibroid
    d. An anechoic, simple cyst located within the cervix

34. The location of a fibroid within the myometrium is termed:
    a. Submucosal
    b. Intracavitary
    c. Subserosal
    d. Intramural

35. The superior portion of the cervix is the:
    a. Cornu
    b. Corpus
    c. Internal os
    d. External os

36. Anechoic fluid noted distending the uterus and vagina within a pediatric patient is termed:
    a. Hydrocolpos
    b. Hydrometrocolpos
    c. Hydrometra
    d. Hematometrocolpos

37. The normal position of the uterus is:
    a. Retroverted
    b. Retroflexed
    c. Anteverted
    d. Dysverted

38. The area of attachment of the fallopian tubes to the uterus is the:
    a. Fundus
    b. Corpus
    c. Isthmus
    d. Cornua

39. The recesses of the vagina are the:
    a. Cornu
    b. Isthmi
    c. Fornices

d. Parity

40. A patient presents to the sonography department for a pelvic sonogram with a history of adenomyosis that was diagnosed following an MRI of the pelvis. What are the most likely sonographic findings?
    a. Complex, bilateral adnexal masses
    b. Myometrial cysts with enlargement of the posterior uterine wall
    c. Endometrial thinning and cervical dilation
    d. Uterine atrophy with bilateral ovarian cysts

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18

The Ovaries and Fallopian Tubes

Introduction

This chapter discusses the anatomy and physiology of the ovaries and fallopian tubes. Benign conditions of the ovary are the most frequently encountered processes during the sonographic examination of the female pelvis. It is important to note that sonographers must be capable of describing, in sonographic terminology, the characteristics of ovarian masses, because there are often overlapping benign and malignant sonographic signatures. Fallopian tube pathology is discussed in this chapter and revisited in Chapter 21.

Key Terms

adnexa—the area located posterior to the broad ligaments and adjacent to the uterus, which contains the ovaries and fallopian tubes

ampulla—the longest and most tortuous segment of the fallopian tube

androblastoma—see key term Sertoli-Leydig cell tumor

anterior cul-de-sac—peritoneal outpouching located between the bladder and the uterus; also referred to as the vesicouterine pouch

ascites—excessive fluid in the peritoneal cavity

Brenner tumors—small benign ovarian tumors

CA 125—a protein that may be increased in the blood of women with ovarian cancer and other abnormalities

chocolate cysts—another name for endometriomas

cilia—hairlike projections within the fallopian tube

corpus albicans—the remaining structure of the corpus luteum after its deterioration

corpus luteum—temporary endocrine gland that results from the rupture of the Graafian follicle after ovulation

corpus luteum cyst—physiologic cyst that develops after ovulation has occurred

corpus luteum of pregnancy—the corpus luteum that is maintained during an early pregnancy for the purpose of producing estrogen and primarily progesterone

cumulus oophorus—structure that contains the developing oocyte

cystic teratoma—benign ovarian mass that is composed of the three germ cell layers; also referred to as a dermoid cyst

daughter cyst—a small cyst within a large cyst

dermoid cyst—another name for a cystic teratoma

dermoid mesh—mass of hair within a cystic teratoma

dermoid plug—part of a dermoid tumor that contains various tissues and may produce posterior shadowing during a sonographic examination

dyspareunia—painful sexual intercourse

ectoderm—the outer germ cell layer of the embryo that develops into the skin, hair, and nails, and other structures

endoderm—the germ cell layer of the embryo that develops into the gastrointestinal and respiratory tracts

endometrioid tumor—a typically malignant ovarian tumor that is often associated with a history of endometrial cancer, endometriosis, and endometrial hyperplasia

endometrioma—benign, blood-containing tumor that forms from the implantation of ectopic endometrial tissue; tumor associated with endometriosis

endometriosis—functional ectopic endometrial tissue located outside the uterus

fibroma—an ovarian sex cord-stromal tumor found in middle-aged women

fimbria—the fingerlike extension of the fallopian tube located on the infundibulum

follicle stimulating hormone—hormone of the anterior pituitary gland that causes the development of multiple follicles on the ovaries

follicular cyst—ovarian cyst that forms as a result of the failure of the Graafian follicle to ovulate

germ cell tumor—a type of neoplasm derived from germ cells of the gonads; may also be found outside the reproductive tract

gestational trophoblastic disease—a disease associated with an abnormal proliferation of the trophoblastic cells during pregnancy; may also be referred to as a molar pregnancy

Graafian follicle—the name for the dominant follicle prior to ovulation

hematosalpinx—blood within the fallopian tube

hemorrhagic cyst—a cyst that contains blood

hirsutism—excessive hair growth in women in areas where hair growth is normally negligible

human chorionic gonadotropin—hormone produced by the trophoblastic cells of the early placenta; may also be used as a tumor marker in nongravid patients and males

hydrosalpinx—the abnormal accumulation of fluid within the fallopian tube

hyperemesis—excessive vomiting

hysterosalpingography—a radiographic procedure that uses a dye instilled into the endometrial cavity and fallopian tubes to evaluate for internal abnormalities

infundibulum—the distal segment of the fallopian tube

interstitial—the segment of the fallopian tube that lies within the uterine horn (cornu)

isthmus—tube: the segment of the fallopian tube that is located between the interstitial and ampulla; uterus: area of the uterus between the corpus and the cervix

Krukenberg tumor—malignant ovarian tumor that metastasizes from most likely the gastrointestinal tract

lysis—destruction or breaking down (i.e., hemolysis, the breaking down of blood components)

malignant degeneration—developing into cancer

Meigs syndrome—ascites and pleural effusion in the presence of a benign ovarian tumor

menorrhagia—abnormally heavy and prolonged menstruation

mesoderm—the germ cell layer of the embryo that develops into the circulatory system, muscles, reproductive system, and other structures

mittelschmerz—pelvic pain at the time of ovulation

multiloculated—having more than one internal cavity

oogenesis—the creation of an ovum

ovarian cystectomy—the surgical removal of an ovarian cyst

ovarian hyperstimulation syndrome—a syndrome resulting from hyperstimulation of the ovaries by fertility drugs; results in the development of multiple, enlarged follicular ovarian cysts

ovarian torsion—an abnormality that results from the ovary twisting on its mesenteric connection, consequently cutting off the blood supply to the ovary

ovulation—the release of the mature egg from the ovary

papillary projections—a small protrusion of tissue

pedunculated uterine leiomyoma—leiomyoma (fibroid) that extends from the uterus on a stalk

pelvic inflammatory disease—infection of the female genital tract that may involve the ovaries, uterus, and/or the fallopian tubes

peristalsis—contractions that move in a wavelike pattern to propel a substance

peritonitis—inflammation of the peritoneal lining

pseudomyxoma peritonei—intraperitoneal extension of mucin-secreting cells that result from the rupture of a malignant mucinous ovarian tumor or possibly a malignant tumor of the appendix

pseudoprecocious puberty—secondary sexual development induced by sex steroids or from other sources like ovarian tumors, adrenal tumors, or steroid use

pyosalpinx—the presence of pus within the fallopian tube

salpingitis—inflammation of the fallopian tubes

sebum—an oily substance secreted by the sebaceous glands

septations—a partition separating two or more cavities

Sertoli–Leydig cell tumor—malignant sex cord-stromal ovarian neoplasm that is associated with virilization

serum lactate dehydrogenase—tumor marker that is elevated in the presence of an ovarian dysgerminoma and other abdominal abnormalities

sex cord-stromal tumors—ovarian tumors that arise from the gonadal ridges

sonohysterography—a sonographic procedure that uses saline instillation into the endometrial cavity and fallopian tubes to evaluate for internal abnormalities

theca lutein cysts—functional ovarian cysts that are found in the presence of elevated levels of human chorionic gonadotropin; also referred to as a theca luteal cyst

thecoma—benign ovarian sex cord-stromal tumor that produces estrogen in

older women

“tip of the iceberg” sign—denotes the sonographic appearance of a cystic teratoma (dermoid) when only the anterior element of the mass is seen, while the greater part of the mass is obscured by shadowing

true pelvis—inferior portion of the pelvis that contains the uterus, ovaries, fallopian tubes, urinary bladder, small bowel, sigmoid colon, and rectum

unilocular—having only one internal cavity

virilization—(female) changes within the female that are typically associated with males; caused by increased androgens and may lead to deepening of the voice and hirsutism

“whirlpool” sign—an indicator of the torsed ovarian pedicle adjacent to the ovary, appearing as a round mass with concentric hypoechoic and hyperechoic rings that demonstrates a swirling color Doppler signature

yolk sac tumor—(ovary) malignant germ cell tumor of the ovary

ANATOMY AND PHYSIOLOGY OF THE OVARY

The ovaries form in the upper abdomen and descend into the pelvis in utero. They are paired, oval-shaped, intraperitoneal organs that have a dual blood supply from both the ovarian artery and ovarian branches of the uterine arteries. It is important to remember that the ovarian arteries are branches of the abdominal aorta. Also, whereas the right ovarian vein drains into the inferior vena cave, the left ovarian vein drains into the left renal vein. As endocrine glands, the ovaries are responsible for releasing estrogen and progesterone in varying amounts throughout the menstrual cycle. They may be located anywhere within the true pelvis, excluding the anterior cul-de-sac. The ovarian fossa is located posterior to the ureter and internal iliac artery and superior to the external iliac artery.

The ovary consists of an outer cortex and an inner medulla (Fig. 18-1). The medulla contains the ovarian vasculature and lymphatics, whereas the cortex involves the mass of the ovary and is the site of oogenesis. The ovaries are stimulated by follicle-stimulating hormone, released by the anterior pituitary gland, to develop multiple follicles during the first half of the menstrual cycle (follicular phase). The cells surrounding the tiny follicles produce estrogen that stimulates the endometrium to thicken. Only one of these follicles will become the dominant follicle, or Graafian follicle, prior to ovulation, while all other follicles will undergo atrophy.



SOUND OFF

Only one follicle will become the dominant follicle, or Graafian

follicle, prior to ovulation, while all other follicles undergo atrophy.

The ovum is contained within the cumulus oophorus of the dominant follicle. The cumulus oophorus may be seen within the ovary during a sonographic examination, with the sonographic appearance resembling that of a daughter cyst. At approximately day 14 of the menstrual cycle, ovulation occurs when the dominant follicle ruptures, releasing the mature ovum and a small amount of follicular fluid into the peritoneal cavity. Mittelschmerz, which means middle pain, describes pain at the time of ovulation, typically on the side of the dominant follicle.

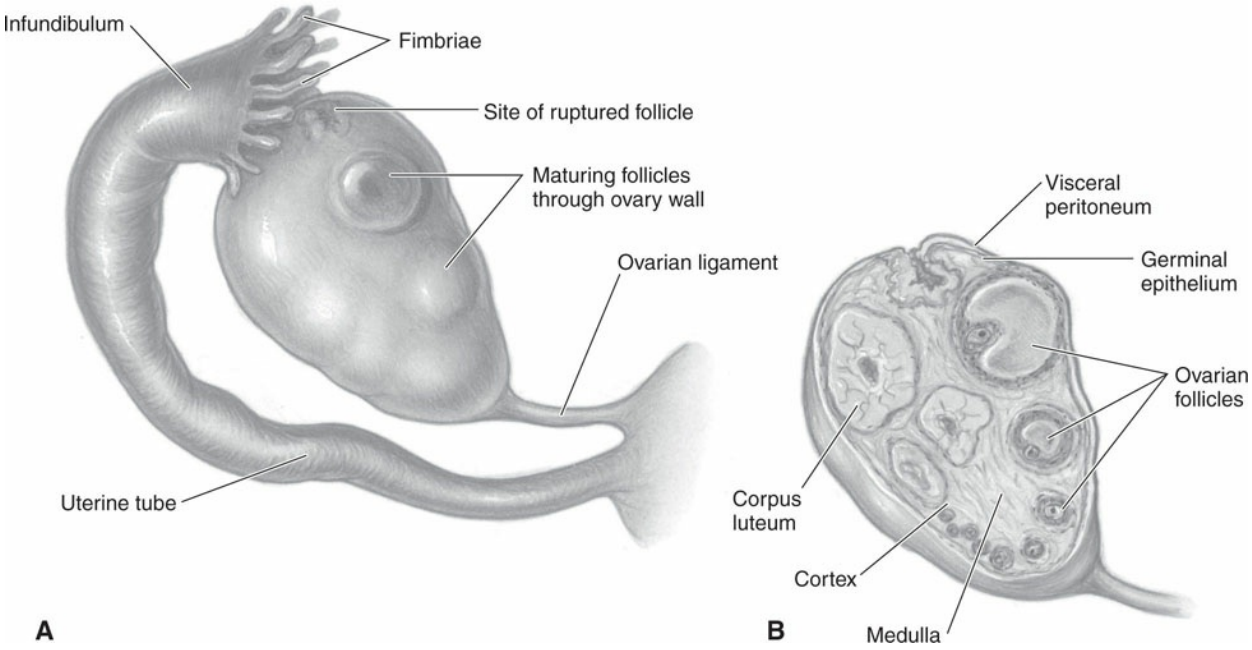


Figure 18-1 Ovarian anatomy. **A.** External structure of the ovary. **B.** Cross-sectioned ovary demonstrating the cortex, medulla, and ovarian follicle maturation.

The fluid from the ruptured follicle most often will settle in the rectouterine pouch (pouch of Douglas), the most dependent portion of the peritoneal cavity. After the Graafian follicle has ruptured, its structure is converted into the corpus luteum. During the second half of the menstrual cycle (luteal phase), the corpus luteum produces progesterone and, in small amounts, estrogen. If fertilization occurs, the corpus luteum is maintained and becomes the corpus luteum of pregnancy. If fertilization does not occur, the corpus luteum regresses and becomes the corpus albicans. The ovarian cycle is further discussed in Chapter 19.

SOUND OFF

After the Graafian follicle has ruptured, its structure is converted into the corpus luteum.

SONOGRAPHIC APPEARANCE OF THE OVARY

Sonographically, the normal ovary is homogeneous with a medium- to low-level echogenicity (Fig. 18-2). Multiple follicles may be noted with sonography during the neonatal and prepubertal ages. In addition, follicles on the ovaries, of varying sizes, may be seen throughout the normal menstrual cycle during reproductive years.

Color and spectral Doppler should be used to evaluate the ovaries. Typical ovarian flow varies throughout the menstrual cycle. During the early follicular phase and late luteal phase (days 0 to 7 and 18 to 28, respectively), the ovarian artery will demonstrate a high-resistive pattern, with increased impedance, and absent or low end-diastolic velocity. During the late follicular and early luteal phase (days 7 to 17), the ovary will demonstrate a low-resistive pattern, with low impedance and higher levels of diastolic flow (Fig. 18-3; Table 18-1). The size of the ovary depends on the physiologic state and age of the patient. Ovarian volume can be determined sonographically by utilizing the following formula: volume = length × width × height × 0.5233. It is important to note that the postmenopausal ovaries undergo atrophy and are often difficult to locate sonographically.



SOUND OFF

Typical ovarian flow is said to be high resistant during the early follicular phase and late luteal phase, and low resistant during the late follicular phase and early luteal phase.

PATHOLOGY OF THE OVARY

Benign Ovarian Disease

Follicular Cysts

Should the Graafian follicle fail to ovulate, it could continue to enlarge and result in a follicular cyst. Follicular cysts range in size from 3 to 8 cm; however, larger cysts have been documented. Their sonographic appearance is most often described as anechoic, thin walled, and unilocular (Fig. 18-4). Most follicular cysts regress and are asymptomatic, but some may lead to pain, resulting in frequent, follow-up sonographic examinations. In addition, surgical intervention or drainage may be warranted because a large cyst increases the risk for ovarian torsion. The surgical removal of an ovarian cyst is referred to as ovarian cystectomy.

SOUND OFF
A large mass or cyst on the ovary increases the patient's risk for ovarian torsion.

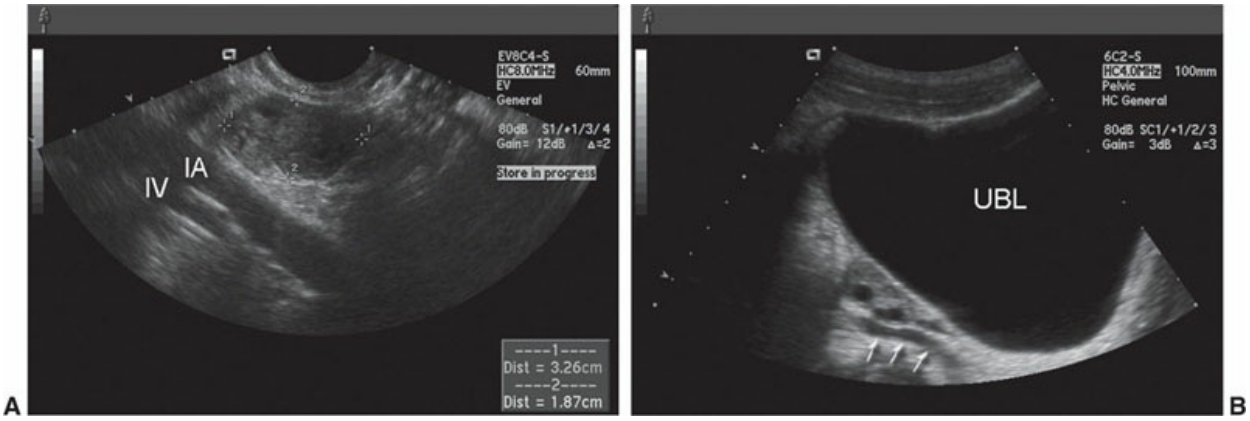


Figure 18-2 Normal sonographic appearance of the ovary. **A.** In this longitudinal endovaginal image of the pelvis, the ovary (*between calipers*) is noted adjacent to the iliac artery (*IA*) and iliac vein (*IV*). **B.** A normal ovary can be seen in this longitudinal transabdominal image of the pelvis between the urinary bladder (*UBL*) and prominent ureter *(arrows)*.

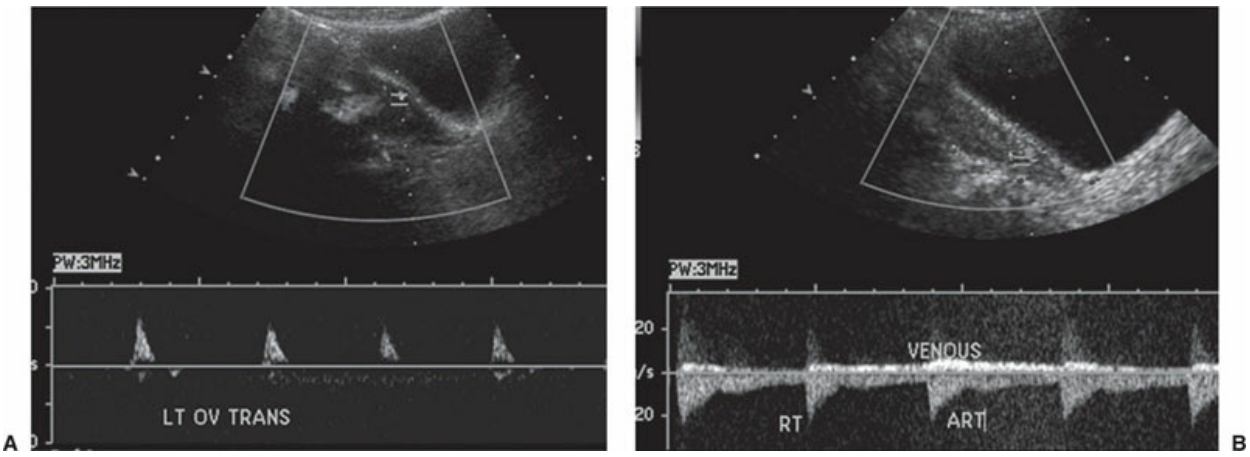


Figure 18-3 Normal ovarian flow. **A.** Transverse image of the ovary on day 5 of the menstrual cycle revealing a high-impedance waveform. **B.** Transverse image of the ovary during day 10 of the menstrual cycle revealing a low-impedance waveform pattern with more diastolic flow. (*Color image provided online*.)

TABLE 18-1 Ovarian arterial flow throughout the menstrual cycle

Ovarian Arterial Flow Throughout the Menstrual Cycle		
Early follicular phase	High impedance (resistance) with absent or low end-diastolic velocity	Resistive index = 1.0
Late follicular phase	Low impedance (resistance) with increased end-diastolic flow	Resistive index = 0.5

Early luteal phase	Low impedance (resistance) with increased end-diastolic flow	Resistive index = 0.5
Late luteal phase	High impedance (resistance) with absent or low end-diastolic velocity	Resistive index = 1.0

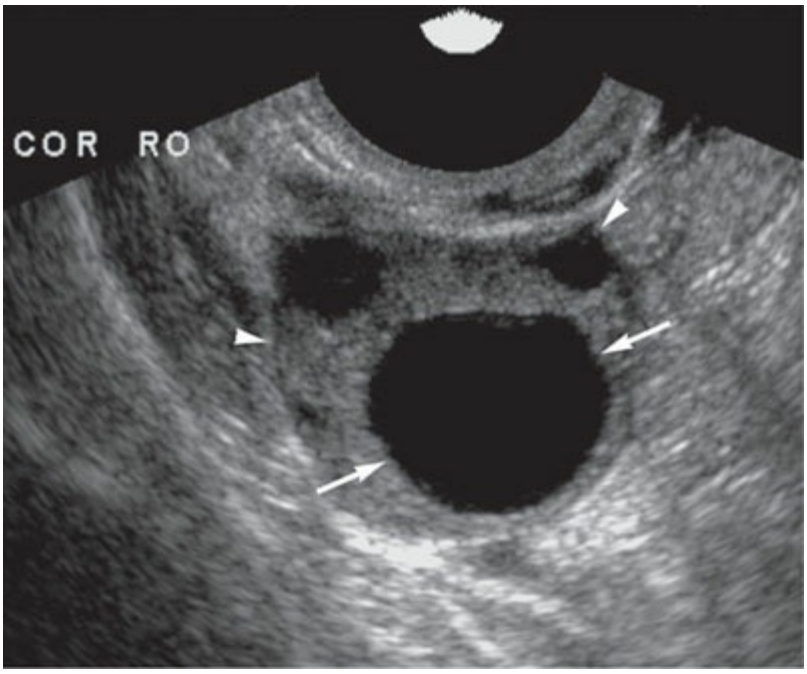


Figure 18-4 Simple ovarian cyst. Coronal image of the right ovary demonstrating a simple ovarian cyst *(arrows)*, surrounded by normal ovarian tissue *(arrowheads)*.

Hyperstimulation of the ovaries, or ovarian hyperstimulation syndrome, from fertility treatment will also result in the development of multiple, enlarged follicular cysts. A follicular cyst that contains blood is referred to as a hemorrhagic cyst, and it most often appears complex or completely echogenic depending on the hemorrhagic component present and the stage of lysis (Fig. 18-5). The sonographic manifestation of a hemorrhagic cyst may be described as demonstrating a weblike or lacy appearance.

CLINICAL FINDINGS OF FOLLICULAR CYSTS

1. Asymptomatic
2. Pain associated with hemorrhage and enlargement of cyst

Corpus Luteum Cysts (Corpus Luteal Cysts)

The corpus luteum cyst is a physiologic (functional) cyst that develops after ovulation has occurred. The corpus luteum is formed as a result of the rupture of the Graafian follicle and is responsible for producing progesterone, thereby maintaining the endometrium during an early

pregnancy in preparation for implantation. Thus, the corpus luteum will normally regress if fertilization does not occur but may rarely be maintained and continue to enlarge. When regression takes place, a small, echogenic structure may be noted within the ovary, representing the corpus albicans.

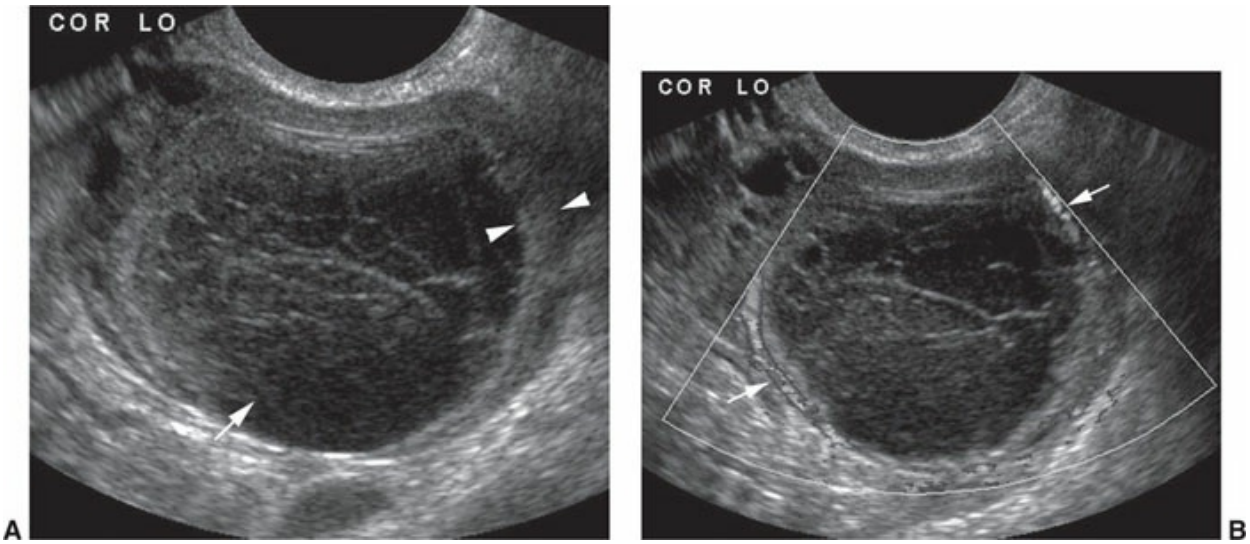


Figure 18-5 Hemorrhagic ovarian cyst. **A.** Coronal image of the ovary demonstrating a hemorrhagic ovarian cyst *(arrow)* with a weblike appearance and focal thickening of the wall *(arrowheads)*. **B.** Color Doppler image of the same hemorrhagic cyst depicts flow within the peripheral ovarian tissue (*arrows*). (Color image provided online.)

SONOGRAPHIC FINDINGS OF FOLLICULAR CYSTS

1. Simple cyst–anechoic, thin walled, unilocular, round, posterior enhancement
2. Hemorrhagic cyst—variable appearances, including complex components or entirely echogenic, depending on the amount of blood and the stage of lysis; may have a weblike or lacy appearance as well

SOUND OFF

The sonographic manifestation of a hemorrhagic cyst may be described as demonstrating a weblike or lacy appearance.

Corpus luteum cysts may reach sizes up to 8 cm, with resolution of the cyst taking place within 1 to 2 months in menstruating patients. Pain is associated with enlargement of the cyst, hemorrhage, and rupture. If the cyst is large, it increases the risk for ovarian torsion.

In the presence of a pregnancy, and thus the production of human chorionic gonadotropin (hCG) by the trophoblastic cells of the pregnancy, the corpus luteum is preserved. In this case, the cyst may be referred to as the corpus luteum of pregnancy. These cysts are considered the most common

pelvic masses seen during a first-trimester sonographic examination. They may even reach sizes up to 10 cm, although most often they resolve by 16 weeks gestation and do not exceed 3 cm. They tend to appear as simple cysts, although they may also have thick walls and may be difficult to differentiate from other solid and cystic adnexal masses (Fig. 18-6).

Patients with large corpus luteum cysts may present with pelvic pain if the cyst has ruptured or if hemorrhage within the cyst has occurred. Often, complex or thick-walled corpus luteum cysts can resemble an ectopic pregnancy, so precaution to establish the presence of an intrauterine pregnancy should be taken in this regard, as well as careful consideration of the entire clinical picture.



SOUND OFF

A complex or thick-walled corpus luteum cyst can resemble an ectopic pregnancy, so precaution to establish the presence of an intrauterine pregnancy should be taken in this regard, as well as careful consideration of the entire clinical picture.

CLINICAL FINDINGS OF CORPUS LUTEUM CYSTS AND CORPUS LUTEUM OF PREGNANCY

1. Asymptomatic
2. Pain associated with hemorrhage and enlargement of cyst
3. Corpus luteum of pregnancy accompanies a pregnancy

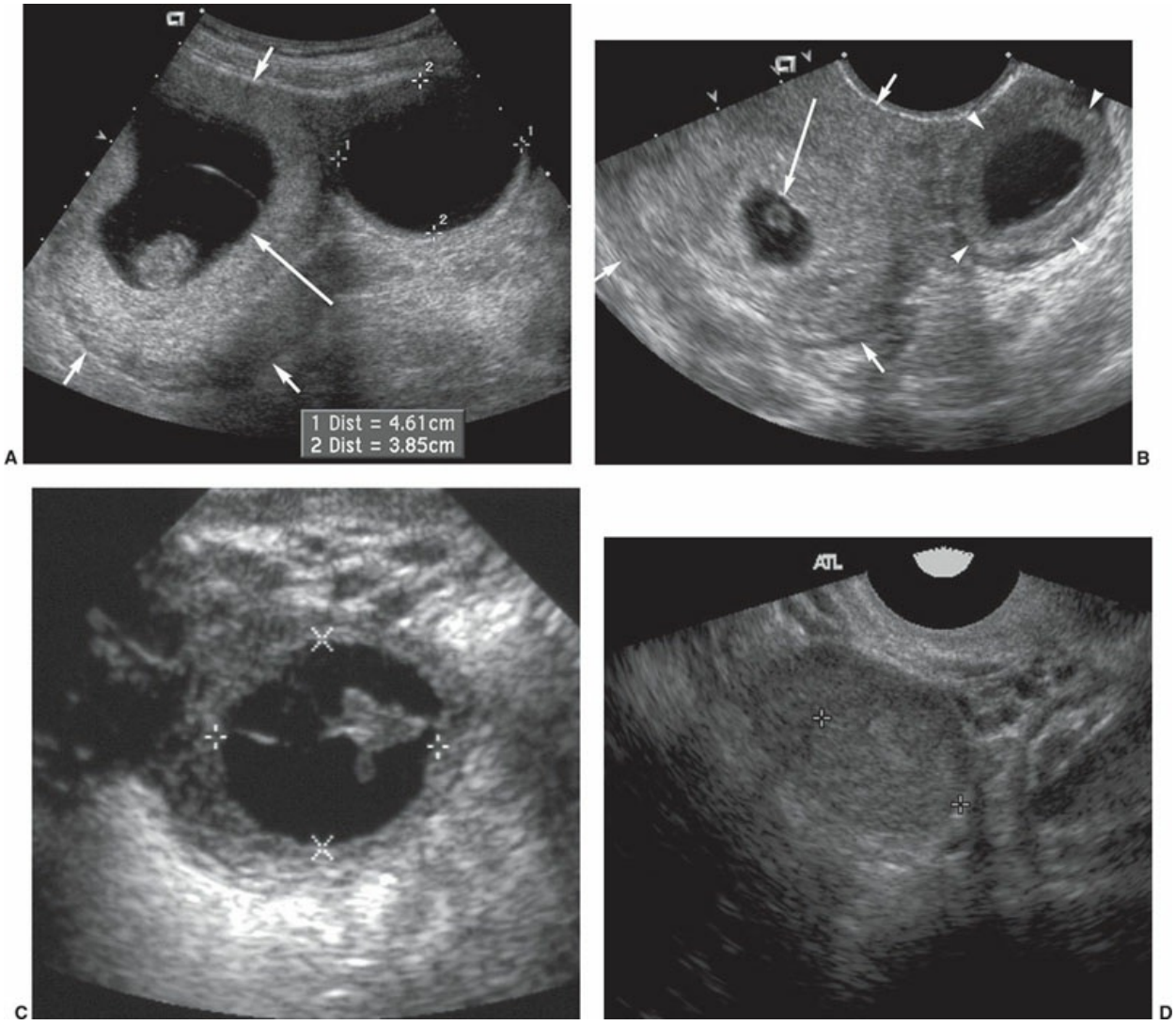


Figure 18-6 Corpus luteum. The range of sonographic appearances of the corpus luteum includes that of a thin-walled unilocular cyst **(A)**, a thick-walled cyst **(B)**, a complex cyst with septations **(C)**, and structure that contains diffuse internal echoes **(D)**. On images **(A)** and **(B)**, the corpus luteum is seen adjacent to a gestational sac *(long arrows)* within the uterus *(short arrows)*.

SONOGRAPHIC FINDINGS OF CORPUS LUTEUM CYSTS AND CORPUS LUTEUM OF PREGNANCY

1. Simple cyst appearance
2. May have a thick wall, be completely echogenic, and may be difficult to differentiate from other solid and cystic adnexal masses
3. Hemorrhagic components may appear complex or have a weblike or lacy appearance depending on the amount of blood and stage of lysis

Theca Lutein Cysts

Theca lutein cysts are the largest and least common of the functional cysts. They are found in the presence of elevated levels of hCG, often exceeding 100,000 mIU per mL. Therefore, gestational trophoblastic disease (molar

pregnancy) and ovarian hyperstimulation syndrome are common conditions associated with theca lutein cysts. Certainly, multiple gestations would also have higher levels of hCG and therefore increase the likelihood of developing theca lutein cysts. Patients with such high levels of hCG may suffer from hyperemesis and complain of pelvic fullness. These large cysts are frequently bilateral and multiloculated, and may reach sizes up to 15 cm (Fig. 18-7). Fortunately, they tend to regress after the high level of circulating hCG diminishes.

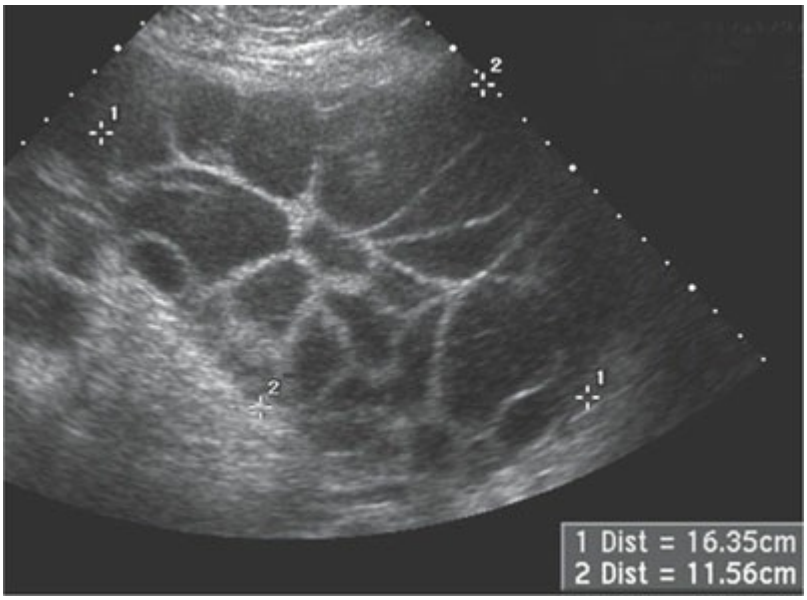


Figure 18-7 Theca lutein cysts. Transabdominal image of an enlarged ovary (*between calipers*) is seen in the patient with theca lutein cysts. This patient was undergoing infertility therapy and had a markedly elevated human chorionic gonadotropin blood level.

CLINICAL FINDINGS OF THECA LUTEIN CYSTS

1. Markedly elevated levels of hCG (as seen in cases of gestational trophoblastic disease, ovarian hyperstimulation, and twin gestations)
2. Nausea and vomiting
3. Pelvic fullness
4. Pain associated with hemorrhage, rupture, and ovarian torsion

SONOGRAPHIC FINDINGS OF PAROVARIAN CYSTS

1. Simple cyst located adjacent, but not attached, to the ovary
2. If hemorrhagic, will appear complex

SOUND OFF

Theca lutein cysts are large, bilateral, multiloculated ovarian cystic

masses that result from high levels of hCG as seen in patients with twins, and those suffering from gestational trophoblastic disease or ovarian hyperstimulation syndrome.

Parovarian Cysts

Parovarian cysts are small cysts located adjacent to the ovary, and most likely arise from the fallopian tubes or broad ligaments (Fig. 18-8). They may contain small amounts of hemorrhage and septations. Because these cysts can range in size from 1.5 to 19 cm, clinical presentation varies, with patients who have larger cysts presenting with pelvic pain and increased lower abdominal girth. Larger parovarian cysts may cause ovarian torsion.

SONOGRAPHIC FINDINGS OF THECA LUTEIN CYSTS

1. Large, bilateral, multiloculated ovarian cystic masses
2. May contain hemorrhagic components

CLINICAL FINDINGS OF PAROVARIAN CYSTS

1. Asymptomatic
2. If cyst is large, patients may present with pelvic pain and increased lower abdominal girth

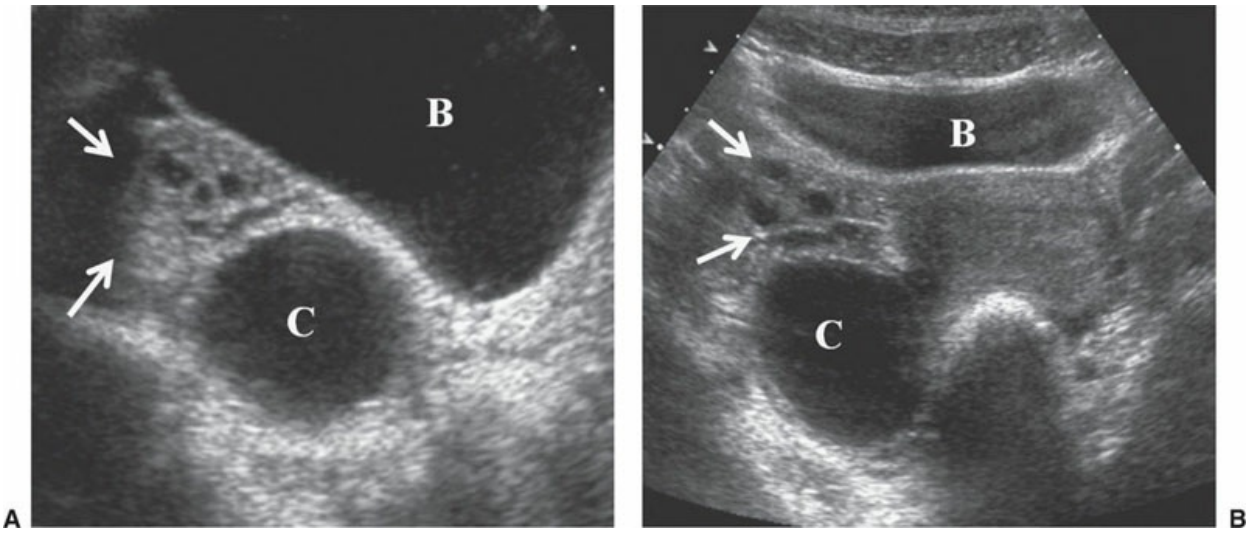


Figure 18-8 Paraovarian cyst. **A.** A simple appearing cyst (*C*) is noted adjacent to the ovary *(arrows)* and posterior to the urinary bladder (*B*) in this longitudinal image. **B.** The same patient in transverse.

Cystic Teratoma (Dermoid)

The most common benign ovarian tumor is the ovarian cystic teratoma, also referred to as a dermoid cyst. Dermoids result from the retention of an

unfertilized ovum that differentiates into the three germ cell layers. Therefore, these germ cell tumors are composed of ectoderm, mesoderm, and endoderm. As a result of the combination of these germ cells, a cystic teratoma may contain any number of tissues, including glandular thyroid components, bone, hair, sebum, fat, cartilage, and digestive elements. They frequently will contain fully formed or rudimentary teeth as well. Dermoids are commonly found in the reproductive-aged group but may also be found in postmenopausal patients. Patients are most often asymptomatic but may suffer from pain associated with torsion or rupture of the mass, the latter of which can lead to peritonitis. Dermoids also have the capability of malignant degeneration, but this is rare.

SOUND OFF
The most common benign ovarian tumor is the ovarian cystic teratoma, also referred to as a dermoid cyst.

The sonographic appearance of a cystic teratoma has been well documented, and it has most often been described as a complex or partially cystic mass in the ovary that includes one or more echogenic structures. These echogenic components may produce posterior shadowing (Fig. 18-9). The "tip of the iceberg" sign denotes the sonographic appearance of the mass when only the anterior element of the mass is seen, while the greater part of the mass is obscured by shadowing (Fig. 18-10). This occurs as a result of complete attenuation of the sound beam by the dense tissue components of the mass. Often, dermoid tumors contain a "dermoid plug." The dermoid plug contains various tissues that will be a source of posterior shadowing. The "dermoid mesh" has been used to describe the visualization of hair within the mass. Hair will appear as numerous linear interfaces within the cystic area of a dermoid. A fluid–fluid level may also be visualized, in which case there is a clear demarcation between serous fluid and sebum.

CLINICAL FINDINGS OF A CYSTIC TERATOMA

1. Often asymptomatic
2. If torsion or rupture occurs, the patient may present with acute pelvic pain

SONOGRAPHIC FINDINGS OF A CYSTIC TERATOMA

1. Complex, partially cystic mass in the ovary that includes one or more echogenic structures that may shadow
2. "Tip of the iceberg" sign–only the anterior element of the mass is seen, while the greater part of the mass is obscured by shadowing

3. Dermoid plug–produces posterior shadowing
4. Dermoid mesh–produced by hair and will appear as numerous linear interfaces within the cystic area of the mass

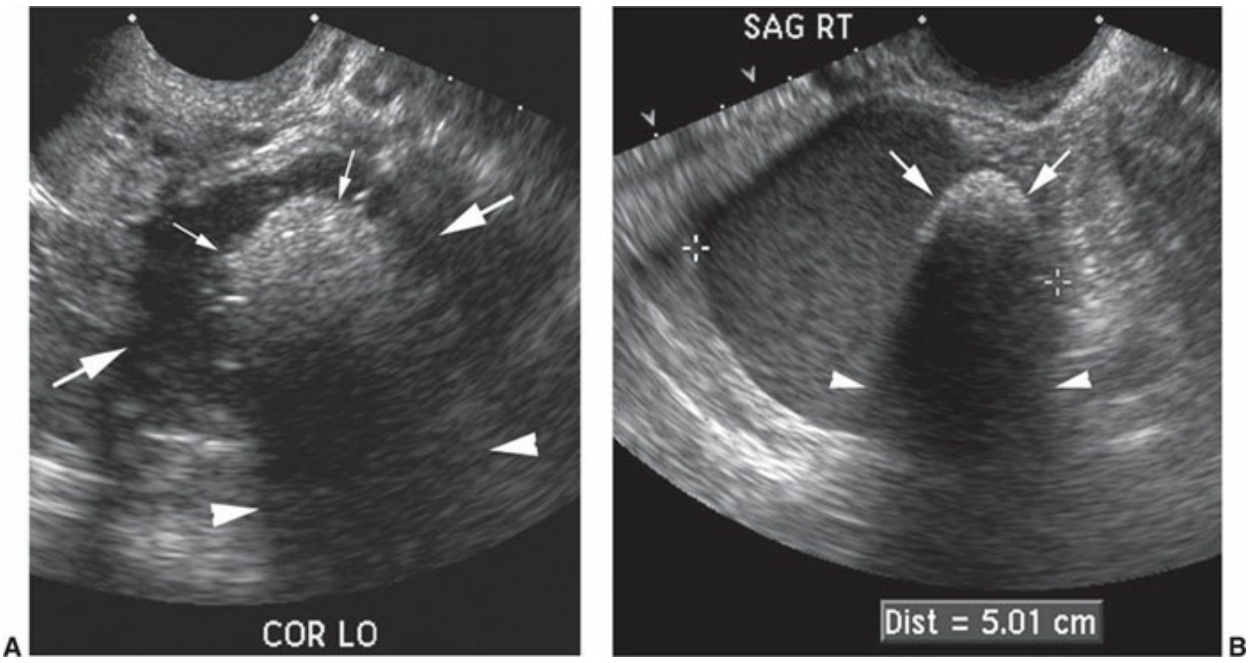


Figure 18-9 Cystic teratoma. **A.** A coronal image of the female pelvis demonstrating a complex ovarian mass (*between large arrows*) with several typical sonographic characteristics of a dermoid, including the dermoid plug *(small arrows)* and the posterior shadowing (*between arrowheads*) from the plug. **B.** In the sagittal plane, this dermoid (*between arrows*) reveals a solid *(arrows)* shadowing (*between arrowheads*) structure within its borders.

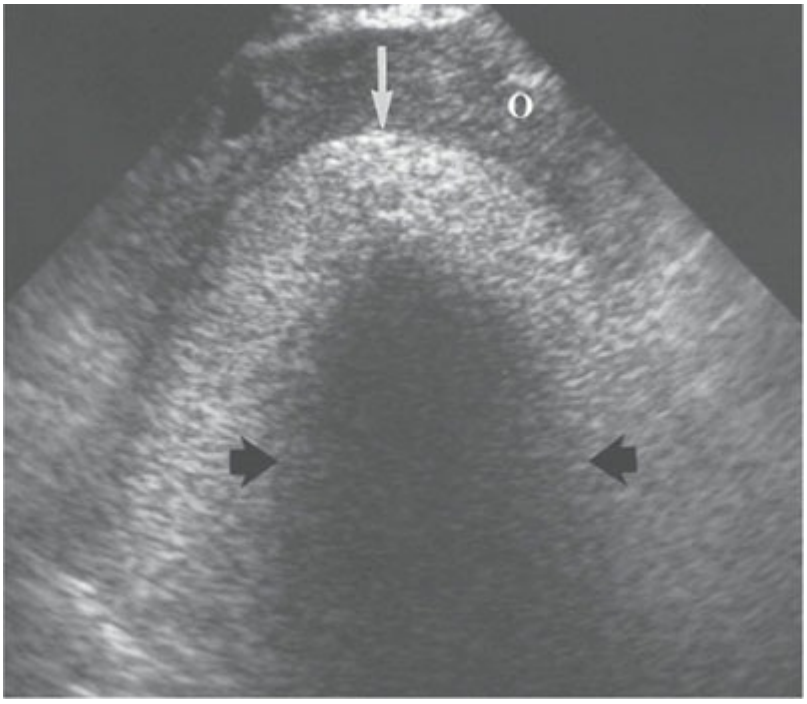


Figure 18-10 Cystic teratoma and the “tip of the iceberg” sign. The dermoid plug is

seen as a highly echogenic mass *(white arrow)* attached to the ovary (*O*). Acoustic shadowing *(black arrows)* is produced as a result of the sound absorption.

Thecoma

A thecoma is a benign ovarian sex cord-stromal tumor. Thecomas are most often found in postmenopausal women and may be associated with Meigs syndrome. Meigs syndrome describes the condition of a having a benign ovarian tumor with ascites and pleural effusion. Thecomas are estrogen-producing tumors; therefore, patients often complain of postmenopausal vaginal bleeding associated with the unconstrained estrogen stimulation upon the endometrium. As the term denotes, these tumors are masses that are composed of multiple ovarian thecal cells. A thecoma will sonographically appear as a hypoechoic, solid mass with posterior attenuation. They are most often unilateral and may appear similar to a pedunculated uterine leiomyoma.

CLINICAL FINDINGS OF A THECOMA

1. May be asymptomatic
2. Postmenopausal vaginal bleeding or abnormal vaginal bleeding secondary to estrogen stimulation
3. Meigs syndrome (ascites and pleural effusion)

SONOGRAPHIC FINDINGS OF A THECOMA

1. Hypoechoic, solid mass with posterior attenuation
2. No posterior enhancement
3. If large, it may mimic a pedunculated leiomyoma



SOUND OFF

A thecoma produces estrogen and can therefore lead to postmenopausal vaginal bleeding. It often appears as a hypoechoic mass, which can simulate the sonographic appearance of uterine fibroid.

Granulosa Cell Tumors

The granulosa cell tumor, also referred to as the granulose theca cell tumor, is considered to be the most common estrogenic tumor. It is also a sex cord-stromal tumor like the thecoma. These tumors typically occur unilaterally and are more commonly seen in the postmenopausal female, but they can also be found in younger patients. Because of its estrogen-producing potential, a granulosa cell tumor will present clinically much like the thecoma. Consequently, because of the estrogen interaction upon the endometrium, postmenopausal patients may present with vaginal bleeding,

whereas adolescent patients may present with pseudoprecocious puberty findings. As a result of consistent estrogen stimulation, postmenopausal patients with granulosa cell tumors have approximately a 10% to 15% chance of developing endometrial carcinoma. The sonographic findings of a granulosa cell tumor is unpredictable, with appearances ranging from that of a solid, hypoechoic mass to one that has some cystic components (Fig. 18-11). Granulosa cell tumors can reach sizes up to 40 cm and do have malignant potential.

CLINICAL FINDINGS OF GRANULOSA CELL TUMORS

1. Adolescence–pseudoprecocious puberty
2. Reproductive-aged and postmenopausal women will have abnormal vaginal bleeding

SONOGRAPHIC FINDINGS OF GRANULOSA CELL TUMORS

1. Solid, hypoechoic mass
2. Complex or partially cystic mass



SOUND OFF

In pediatric patients, the granulosa cell tumor is associated with pseudoprecocious puberty.

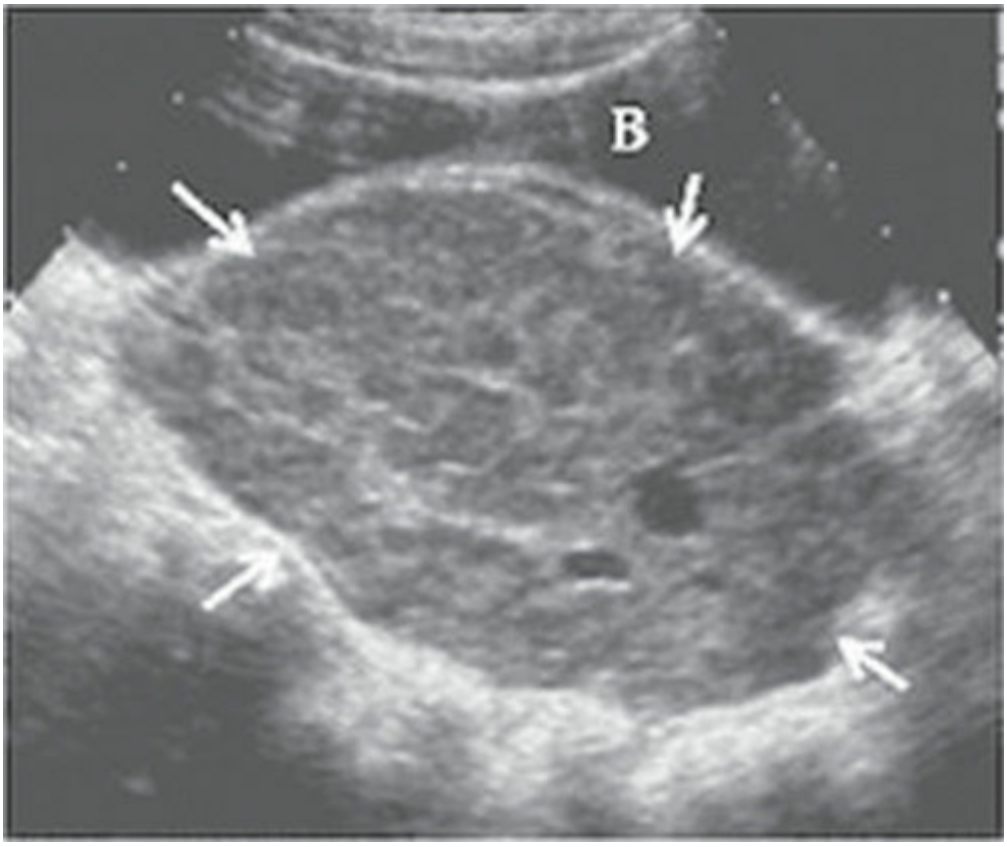


Figure 18-11 Granulosa cell tumor. Longitudinal image of a 3-year-old girl suffering from premature breast development demonstrating a granulosa cell tumor (*between arrows*) located posterior to the urinary bladder (*B*).

Fibroma

An ovarian fibroma is also considered a sex cord-stromal tumor. Unlike thecomas and granulosa cell tumors however, fibromas are not associated with estrogen production. Fibromas are most often found in middle-aged women. They are benign ovarian masses that may be complicated by Meigs syndrome as well. The sonographic appearance of a fibroma is that of a hypoechoic, solid mass with posterior attenuation (Fig. 18-12). Often, fibromas, like thecomas, may mimic pedunculated uterine leiomyoma. The ascites and pleural effusions associated with Meigs syndromes usually resolve after resection of the tumor.

CLINICAL FINDINGS OF A FIBROMA

1. May be asymptomatic
2. Meigs syndrome (ascites and pleural effusion)

SONOGRAPHIC FINDINGS OF A FIBROMA

1. Hypoechoic, solid mass with posterior attenuation
2. No posterior enhancement

3. If large, it may mimic a pedunculated leiomyoma

Brenner Tumor (Transitional Cell Tumor)

Brenner tumors, or transitional cell tumors, are most often small, solid, hypoechoic unilateral tumors that may contain calcifications. Consequently, their sonographic appearance may be similar to that of a uterine leiomyoma, thecoma, and fibroma. They are almost always benign, but they can undergo malignant degeneration. Patients may be asymptomatic or may present with a palpable mass or pain, and possibly signs of Meigs syndrome.

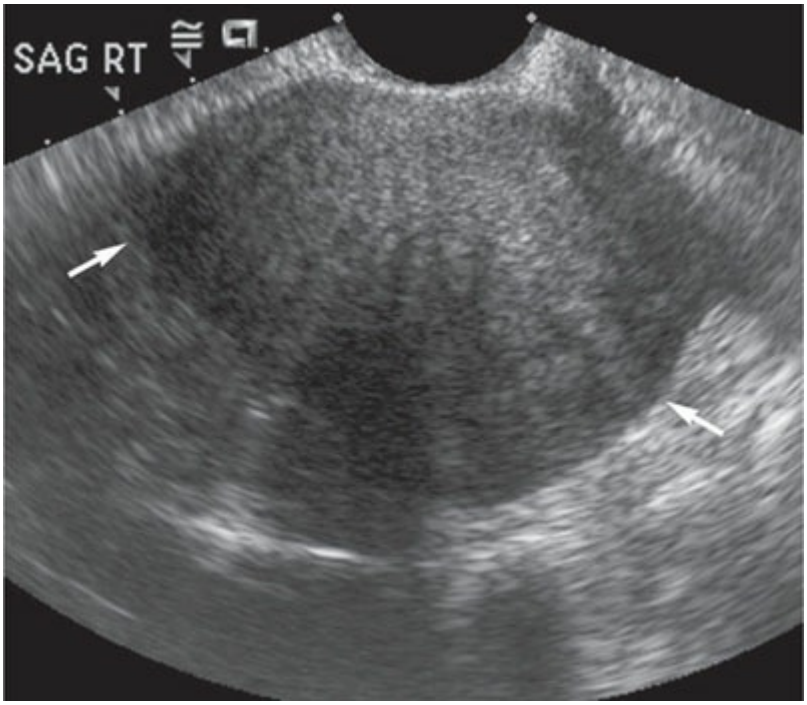


Figure 18-12 Ovarian fibroma. Sagittal image of the right ovary demonstrating a solid mass *(arrows)* with a homogeneous echotexture.

CLINICAL FINDINGS OF A BRENNER TUMOR

1. May be asymptomatic
2. Meigs syndrome (ascites and pleural effusion)

SONOGRAPHIC FINDINGS OF A BRENNER TUMOR

1. Small, solid, hypoechoic mass
2. May contain calcifications

Endometrioma (Chocolate Cyst)

An endometrioma is a benign, blood-containing tumor that is associated with endometriosis and forms from the implantation of ectopic endometrial tissue.

This ectopic endometrial tissue is functional. Therefore, the hormones of menstruation act on this tissue just as if it were located within the uterus, causing it to hemorrhage. It is this hemorrhage that forms into focal areas of bloody tumors—endometriomas. Consequently, they have been nicknamed "chocolate cysts" because they appear as dark, thick bloody masses during gross examination.

Endometriomas can be located anywhere outside the endometrial cavity, including on any other pelvic organ, such as the bladder and bowel, but are more commonly found on the ovary. Most often, these masses are multiple and seen more often in the reproductive years. Patients typically complain of pelvic pain, menorrhagia, dyspareunia, painful bowel movements (dyschezia), and possibly infertility.

The cause of endometriosis is still unknown; however, several hypotheses exist. One theory suggests that implantation of this ectopic tissue is a result of endometrial tissue being passed through the fallopian tubes during menstruation, whereas another proposes that scaring from surgery, such as a cesarean section, leads to endometriosis and the subsequent development of endometriomas. In fact, endometriomas can be found within the cesarean section scar and present as a palpable mass that may change shape throughout the menstrual cycle in relation to hormone alterations.

The sonographic appearance of an endometrioma is that of a predominately cystic mass with low-level echoes that resembles the sonographic appearance of a hemorrhagic cyst (Fig. 18-13). Endometriomas may also demonstrate a fluid–fluid level. They are discussed further in Chapter 21 of this text.

CLINICAL FINDINGS OF ENDOMETRIOMAS

1. Patient may be asymptomatic
2. Pelvic pain
3. Infertility
4. Dysmenorrhea
5. Menorrhagia
6. Dyspareunia
7. Painful bowel movements (dyschezia)

SONOGRAPHIC FINDINGS OF ENDOMETRIOMAS

1. Predominantly cystic mass with low-level internal echoes (may resemble a hemorrhagic cyst)
2. Anechoic or complex, mostly cystic mass with posterior enhancement and may have a fluid–fluid level

SOUND OFF
Endometriomas are also referred to as “chocolate cysts.”

Cystadenoma (Serous and Mucinous)

Together, serous cystadenomas and cystic teratomas comprise most neoplasms of the ovary. Approximately 50% to 70% of serous cystadenomas are benign, occurring more often in women in their forties and fifties as well as during pregnancy. Patients are often asymptomatic. These types of ovarian neoplasms are often large and bilateral. The sonographic appearance of a serous cystadenoma is that of a predominately anechoic lesion that contains septations and/or papillary projections (Fig. 18-14).

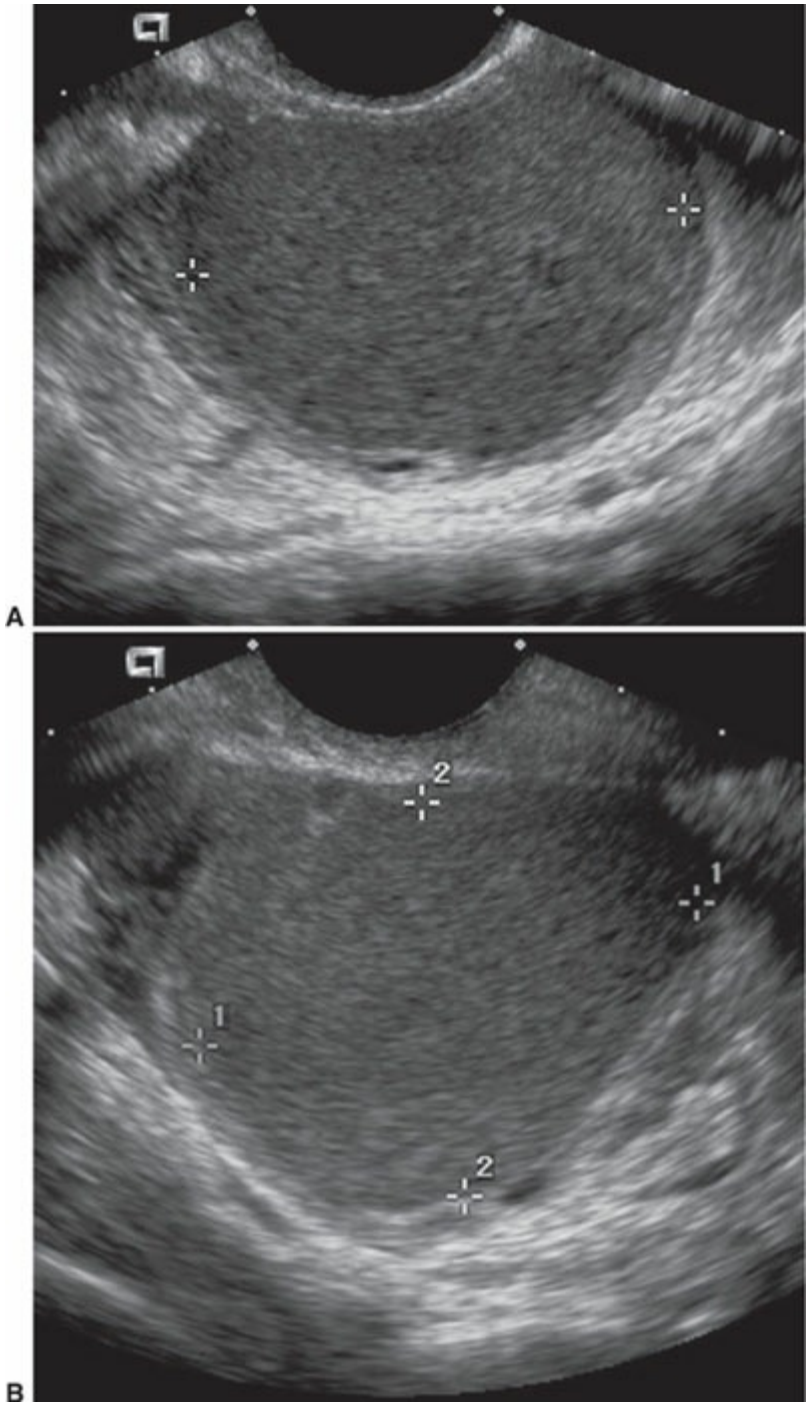


Figure 18-13 Endometrioma filled with homogeneous echoes. (**A** and **B**) Images of cystic adnexal mass (*calipers*) filled with homogeneous echoes consistent with the sonographic findings of an endometrioma.

Mucinous cystadenomas are often larger than serous cystadenomas and can even reach sizes up to 50 cm. Mucinous cystadenomas also tend to have septations and papillary projections like serous cystadenomas, but are not as often bilateral. A supportive sonographic distinguishing factor is the presence of internal debris within the mucinous cystadenoma, secondary to the solid components of the material contained within it (Fig. 18-15).

The clinical presentation of these masses is unpredictable, with patients

often complaining of pelvic pressure and swelling, secondary to the large size of the mass. Additional clinical symptoms include abnormal uterine bleeding, gastrointestinal symptoms, and acute abdominal pain secondary to rupture or ovarian torsion.

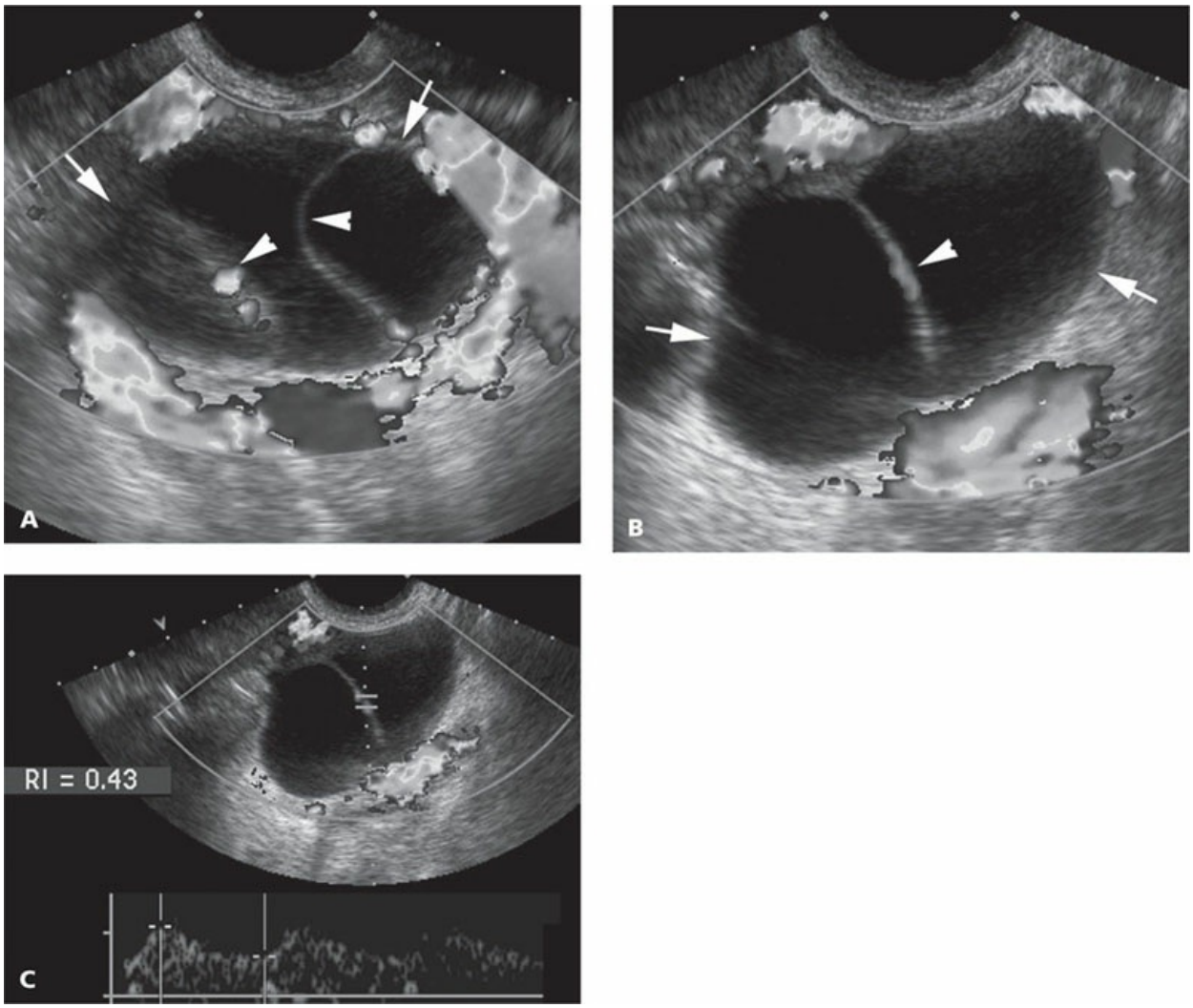


Figure 18-14 Ovarian serous cystadenoma. (**A** and **B**) Transvaginal color Doppler images of cystic ovarian lesion *(arrows)* with anechoic fluid and a few thin septations *(arrowheads)*. **C.** Spectral Doppler showing blood flow within the septations. (Color images provided online.)

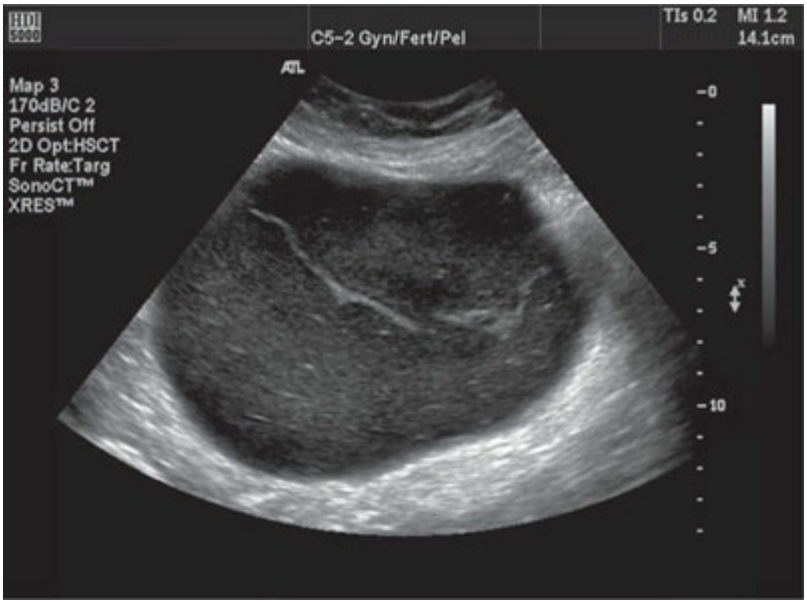


Figure 18-15 Ovarian mucinous cystadenoma. A transabdominal image demonstrating characteristics of a mucinous cystadenoma, which includes the presence of echogenic material within the mass.

SOUND OFF

Mucinous cystadenomas are often larger than serous cystadenomas, and they tend to contain echogenic material within their cystic components.

CLINICAL FINDINGS OF A SEROUS CYSTADENOMA

1. Patients are often asymptomatic

SONOGRAPHIC APPEARANCE OF A SEROUS CYSTADENOMA

1. Predominately anechoic lesion that contains septations and/or papillary projections

CLINICAL FINDINGS OF A MUCINOUS CYSTADENOMA

1. Pelvic pressure and swelling

SONOGRAPHIC APPEARANCE OF A MUCINOUS CYSTADENOMA

1. Large, predominately anechoic lesion that contains septations and/or papillary projections
2. May contain some recognizable internal, echogenic, layering debris

Malignant Ovarian Disease

Cystadenocarcinoma (Serous and Mucinous)

Serous cystadenocarcinoma is the most common malignancy of the ovary. It is, like its benign counterpart the serous cystadenoma, frequently bilateral. In addition, a serous cystadenocarcinoma sonographically resembles a serous cystadenoma, with the exception that often with malignancy, there appears to be more prominent papillary projections and thicker septations (Fig. 18-16). Patients often complain of weight loss, pelvic pressure and swelling, abnormal vaginal bleeding, and gastrointestinal problems. Although not always specific, they may also have an elevated cancer antigen 125 (CA 125), a protein that may be increased in the blood of women with ovarian cancer and other abnormalities.

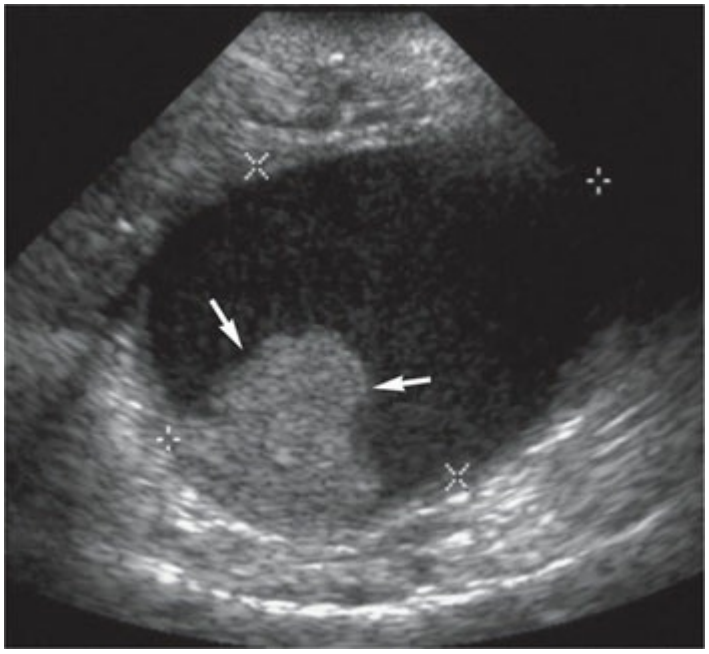


Figure 18-16 Ovarian (papillary) cystadenocarcinoma. Image of an ovarian mass (*calipers*) with an internal solid nodule *(arrows)* projecting from its wall. This was confirmed to be ovarian cystadenocarcinoma.

SOUND OFF

Patients with ovarian cancer may complain of weight loss, pelvic pressure and swelling, abnormal vaginal bleeding, and gastrointestinal problems. Although not always specific, they may also have an elevated CA 125.

Mucinous cystadenocarcinomas are malignant as well, and are less often bilateral than serous cystadenocarcinomas. The mucinous cystadenocarcinoma is associated with a condition known as pseudomyxoma peritonei, which describes the intraperitoneal extension of mucin-secreting cells that result from the rupture of this mucinous tumor. Often, the fluid escaping from the mass resembles ascites (Fig. 18-17).

Clinical Findings of Serous and Mucinous Cystadenocarcinomas

1. Weight loss
2. Pelvic pressure and swelling
3. Abnormal vaginal bleeding
4. Gastrointestinal symptoms
5. Acute abdominal pain associated with torsion or rupture
6. Elevated CA 125

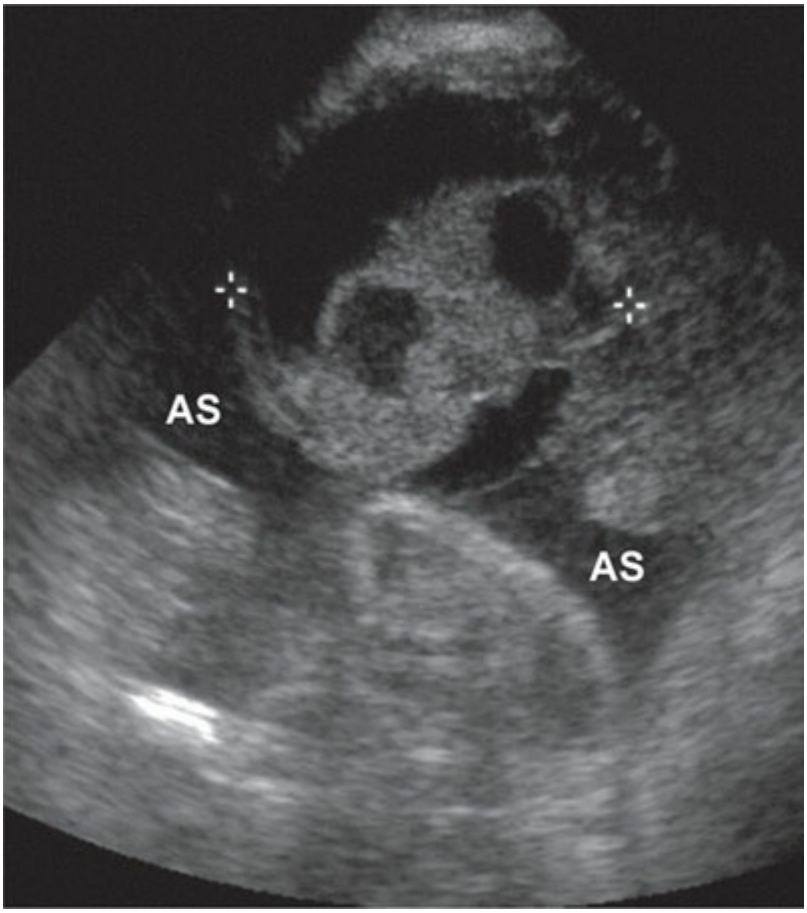


Figure 18-17 Ovarian mucinous cystadenocarcinoma. Transvaginal images of a large ovarian mass (*between calipers*) surrounded by ascites (*AS*).

Sonographic Appearance of Serous Cystadenocarcinoma

1. Large, multilocular cystic masses
2. Papillary projections and septations are often noted within the mass
3. Ascites

Sonographic Appearance of Mucinous Cystadenocarcinoma

1. Large, multilocular cystic mass
2. Papillary projections and septations are often noted within the mass
3. Echogenic material within the cystic components of the mass
4. Pseudomyxoma peritonei (complex ascites)

Krukenberg Tumor

A Krukenberg tumor is a malignant ovarian tumor that has most likely metastasized from the gastrointestinal tract. The most frequent origin is the stomach (gastric cancer), although it may begin in the colon. In addition, some authors claim that Krukenberg tumors can originate from primary breast, lung, contralateral ovary, pancreas, or biliary tract cancers. The key to histologic diagnosis is the presence of "signet-ring" cells.



SOUND OFF

Krukenberg tumors are metastatic tumors to the ovary, most often from gastrointestinal cancers, like stomach cancer.

Krukenberg tumors appear sonographically as smooth-walled, hypoechoic, or hyperechoic tumors that are often bilateral and may be accompanied by ascites. The Krukenberg tumor may also be described as having a "moth-eaten" appearance in that it can be a solid mass containing scattered cystic spaces. Patients may be asymptomatic at the time of detection or may complain of weight loss and pelvic pain. They may also present with a history of gastric or colon cancer.

CLINICAL FINDINGS OF A KRUKENBERG TUMOR

1. Asymptomatic
2. History of gastric or colon cancer
3. Possible weight loss
4. Pelvic pain

SONOGRAPHIC FINDINGS OF A KRUKENBERG TUMOR

1. Bilateral, smooth-walled, hypoechoic or hyperechoic ovarian masses
2. "Moth-eaten" appearance (solid mass containing cystic spaces)
3. May have ascites



SOUND OFF

Krukenberg tumors tend to have a "moth-eaten" sonographic appearance.

Sertoli–Leydig Cell Tumors (Androblastoma)

A Sertoli–Leydig cell tumor, or androblastoma, is a sex cord-stromal ovarian neoplasm that is associated with virilization; thus, patients may present with abnormal menstruation and hirsutism because of androgen production. Sertoli–Leydig tumors are found more often in women younger than 30 years of age but may be seen in older patients and may be malignant. Sonographically, a Sertoli–Leydig cell tumor may appear as a solid, hypoechoic ovarian mass or a complex, partially cystic mass.

CLINICAL FINDINGS OF SERTOLI–LEYDIG CELL TUMORS

1. Virilization
2. Abnormal menstruation
3. Hirsutism

SONOGRAPHIC FINDINGS OF SERTOLI–LEYDIG CELL TUMORS

1. Solid, hypoechoic ovarian mass
2. Complex or partially cystic mass

Dysgerminoma

A dysgerminoma is the most common malignant germ cell tumor of the ovary. Dysgerminomas arise more often in patients younger than 30 years of age and may be found in pregnancy. The dysgerminoma is the most frequent ovarian malignancy found in childhood. Children with ovarian dysgerminomas present with pseudoprecocious puberty and may have an elevation in serum hCG levels, although the tumor marker used for dysgerminoma is an elevation in serum lactate dehydrogenase. The testicular equivalent of an ovarian dysgerminoma is the seminoma.

CLINICAL FINDINGS OF DYSGERMINOMA

1. Children–pseudoprecocious puberty
2. Elevated serum lactate dehydrogenase
3. Possible elevated serum hCG

SONOGRAPHIC FINDINGS OF DYSGERMINOMA

1. Ovoid, solid echogenic mass on the ovary
2. May contain some cystic components



SOUND OFF

The dysgerminoma is the most common malignant germ cell tumor of

the ovary. It is the ovarian equivalent of the testicular seminoma.

Yolk Sac Tumor (Endodermal Sinus Tumor)

A yolk sac tumor, which may also be referred to as an endodermal sinus tumor, is the second-most common malignant germ cell tumor. It is characterized by rapid growth. A yolk sac tumor occurs in females younger than 20 years of age, is highly malignant, and carries a poor prognosis. Clinically, patients present with an elevation in serum alpha-fetoprotein (AFP). Sonographically, they have varying appearances.

CLINICAL FINDINGS OF YOLK SAC TUMOR

1. Elevation in serum AFP

SONOGRAPHIC FINDINGS OF YOLK SAC TUMOR

1. Homogeneous echogenic mass or complex mass
2. Varying sonographic appearances



SOUND OFF

The tumor marker for the yolk sac tumor is AFP.

Endometrioid Tumor (Endometrioid Carcinoma)

The endometrioid tumor (endometrioid carcinoma) is an ovarian tumor that has a high incidence of being malignant. It is most often seen in women in their fifth and sixth decade of life and is often associated with a history of endometrial cancer, endometriosis, or endometrial hyperplasia. It is the most common cancer to originate within an endometrioma. Sonographically, an endometrioid tumor appears as a complex mass with solid components or a cystic mass with papillary projections.

CLINICAL FINDINGS OF ENDOMETRIOID TUMOR

1. History of endometrial cancer or endometriosis

SONOGRAPHIC FINDINGS OF ENDOMETRIOID TUMOR

1. Complex mass with solid components
2. Cystic mass with papillary projections

Common Sonographic Findings and Doppler Findings of Ovarian

Carcinoma

There are several grayscale indicators that are worrisome for ovarian carcinoma (Table 18-2). Doppler analysis of malignant ovarian masses often reveals higher diastolic flow velocities because of the abnormal vessels that are created with malignancy. These new vessels often lack smooth muscle within their walls and, thus, produce a less resistive waveform pattern (Fig. 18-18). Specifically, malignant tumors tend to have resistive indices <0.4 and pulsatility indices <1.0. However, color-flow and spectral Doppler characteristic within a mass is not a specific finding and, therefore, is not typically used to determine the presence of malignancy.

Staging of Ovarian Carcinoma

The International Federation of Gynecology and Obstetrics (FIGO) recommends the proper staging of ovarian carcinoma. Table 18-3 is a summary of the FIGO staging of ovarian cancer.

Ovarian Torsion

Ovarian torsion, also referred to as adnexal torsion because it can involve the fallopian tube as well, results from the adnexal structures twisting on their mesenteric connection, consequently cutting off its blood supply. Ovarian torsion occurs most often on the right side, with the most common cause being an ovarian cyst or mass, such as the benign cystic teratoma or paraovarian cyst. Because of the cystic enlargement of the ovaries produced by ovarian hyperstimulation syndrome, this condition has also been recognized as a predisposing circumstance that can result in ovarian torsion. Torsion of the ovary has also been detected in the fetus and may even occur in normal ovaries. Patients most often present with slight leukocytosis, nausea, vomiting, and acute unilateral pelvic or abdominal pain. The sonographic appearance of the torsed ovary is that of an enlarged ovary, with or without multifollicular development (Fig. 18-19). In one study, the torsed ovary most often measured >5cm, with a mean of 9.5 cm. There may also be peripherally displaced small follicles secondary to edema. The “whirlpool sign” may be present as well. The “whirlpool sign” is an indicator of the torsed ovarian pedicle adjacent to the ovary, appearing as a round mass with concentric hypoechoic and hyperechoic rings that demonstrates a swirling color Doppler signature. An abnormal amount of free fluid in the pelvis is often seen as well.

TABLE 18-2 Sonographic findings that are worrisome for ovarian carcinoma

Worrisome Sonographic Findings for Ovarian Carcinoma[a]

- Complex ovarian mass
- Solid wall nodules within a cystic mass (the larger the solid component, the more likely for malignancy)
- Thick septations (>3 mm)
- Wall thickening
- Irregular wall or poorly defined margins
- Blood flow within the septations, wall, or nodules
- Ascites

[a]These findings may also be observed with benign tumors.



Figure 18-18 Low-resistance flow in ovarian cancer. Spectral Doppler of a vessel within this ovarian papillary cystadenocarcinoma demonstrating low-resistance flow with a low pulsatility index (*PI*).

SOUND OFF
The sonographic appearance of the torsed ovary is that of an enlarged ovary, with or without multifollicular development.

Some debate exists over the effectiveness of color Doppler and flow analysis of the torsed ovary. As stated earlier, the ovary receives its blood

supply from both the ovarian artery and a branch of the uterine artery. If one of these vessels has been occluded, thereby revealing a lack of arterial blood flow on spectral analysis, the other vessel may still be patent. That means, a lack of detectable arterial flow within an ovarian or uterine artery does not mean that there is occlusion of the entire blood supply. As a result, a combination of clinical presentation and imaging findings is essential for the precise diagnosis of this urgent condition.

CLINICAL FINDINGS OF OVARIAN TORSION

1. Acute unilateral abdominal or pelvic pain
2. Nausea and vomiting
3. Slight leukocytosis

SONOGRAPHIC FINDINGS OF OVARIAN TORSION

1. Enlarged ovary
2. Enlarged ovary in the presence of multifollicular development
3. Small peripherally located follicles on the enlarged ovary as a result of edema
4. Lack of or diminished flow patterns compared with the nonaffected ovary
5. “Whirlpool” sign
6. Excessive free fluid

TABLE 18-3 Staging of ovarian carcinoma

Stage of Ovarian Carcinoma	Condition
Stage I	Tumor is confined to the ovary.
Stage II	Tumor involves one or both of the ovaries with pelvic extension.
Stage III	Tumor involves one or both ovaries with confirmed peritoneal metastasis outside the pelvis and/or regional lymph node involvement.
Stage IV	Distant metastasis beyond the peritoneal cavity.

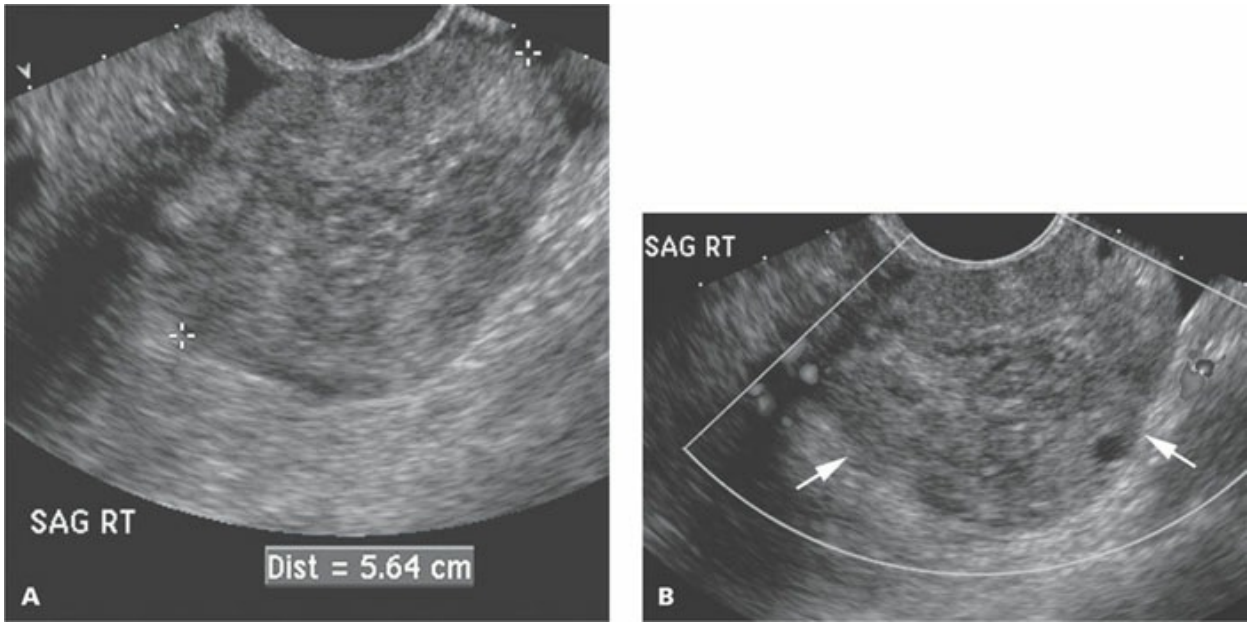


Figure 18-19 Ovarian torsion. **A.** Sagittal image of right ovary (*between calipers*) showing enlargement (>5 cm), globular shape, and edema, all as a result of torsion. **B.** Sagittal view with color Doppler showing no flow in the torsed ovary *(arrows)*. (Color images provided online.)

SOUND OFF
Ovarian torsion typically occurs on the right side.

ANATOMY AND PHYSIOLOGY OF THE FALLOPIAN TUBES

The fallopian tubes may be referred to as oviducts, uterine tubes, or salpinges. The primary purpose of the fallopian tube is to provide an area for fertilization (conception) to occur and to offer a means of transportation for the products of conception to reach the uterine cavity. The fallopian tubes consist of three layers: the outer serosa, middle muscular layer, and inner mucosal layer. Because the tube experiences peristalsis, within its lumen, small, hairlike structures referred to as cilia shift, thereby offering a mechanism for the transportation of the fertilized ovum.

The 7- to 12-cm paired fallopian tubes extend from the cornu of the uterus, travel within the broad ligaments, and are composed of five parts (Fig. 18-20). It is important to note that the proximal segment of the fallopian tube is located closest to the uterus, whereas the most distal part is within the adnexa or closer toward the ovary. Within the cornu of the uterus lies the intramural extension of the fallopian tube known as the interstitial segment. The isthmus, which literally means bridge, is a short and narrow segment of the tube connecting the interstitial area to the ampulla. The ampulla is the

longest and most tortuous segment of the tube. It is a significant portion of the tube because it is the location of fertilization and the area where ectopic pregnancies often embed. The distal portion of the tube is termed the infundibulum, which provides an opening to the peritoneal cavity within the pelvis. The fingerlike projections that extend from the infundibulum are the fimbria. The primary role of the fimbria is to draw the unfertilized egg into the tube.

SOUND OFF

The ampulla is the longest and most tortuous segment of the tube. It is a significant portion of the tube because it is the location of fertilization and the area where ectopic pregnancies often embed.

SONOGRAPHIC APPEARANCE OF THE FALLOPIAN TUBES

The fallopian tubes are not customarily identified on a transabdominal sonographic examination; however, some segments can be seen with today's high-resolution endovaginal transducers. Certainly in cases in which the tube has been involved with an inflammatory process or is obstructed, the tubes, when distended with fluid, can be visualized with sonography. The inner cavity of the fallopian tubes can be visualized and evaluated for patency using sonohysterography or hysterosalpingography.

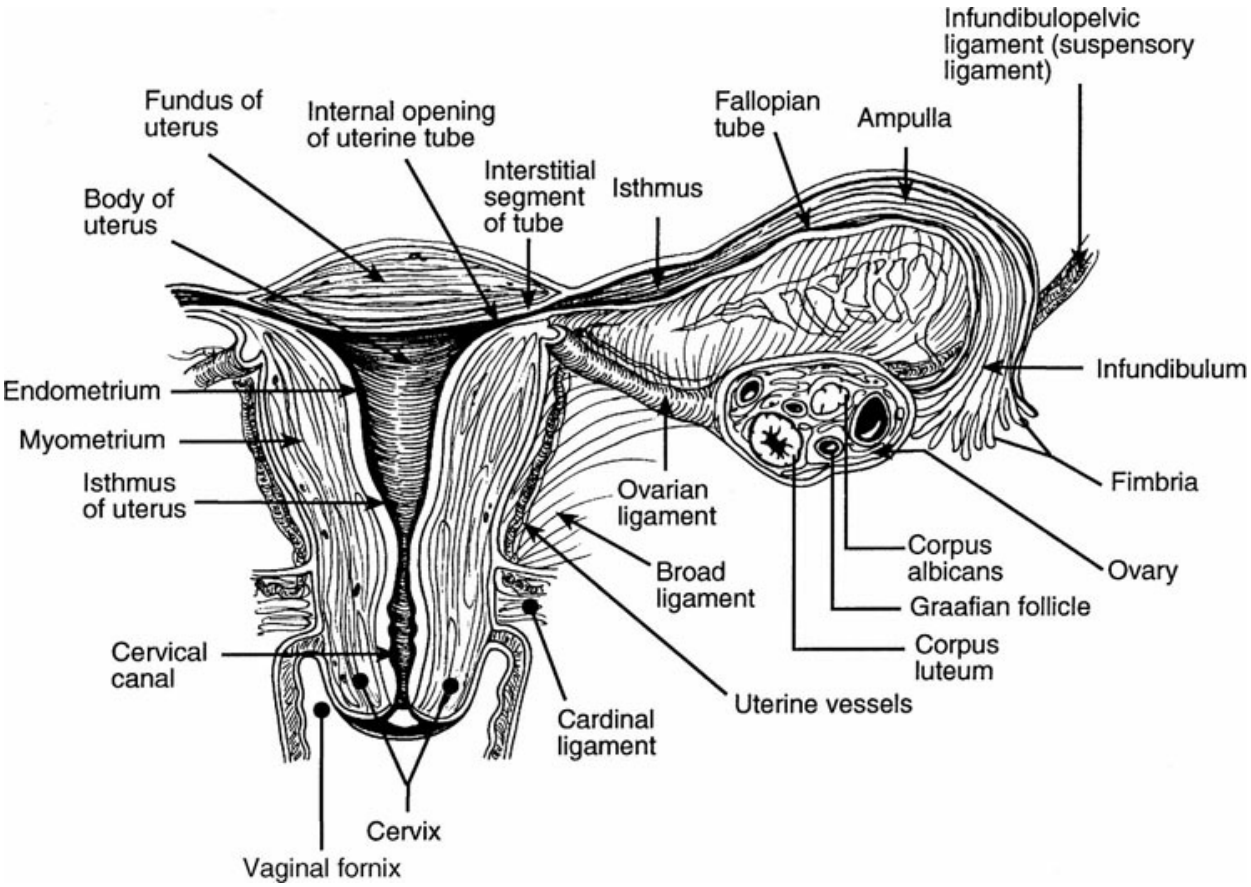


Figure 18-20 Fallopian tube anatomy.

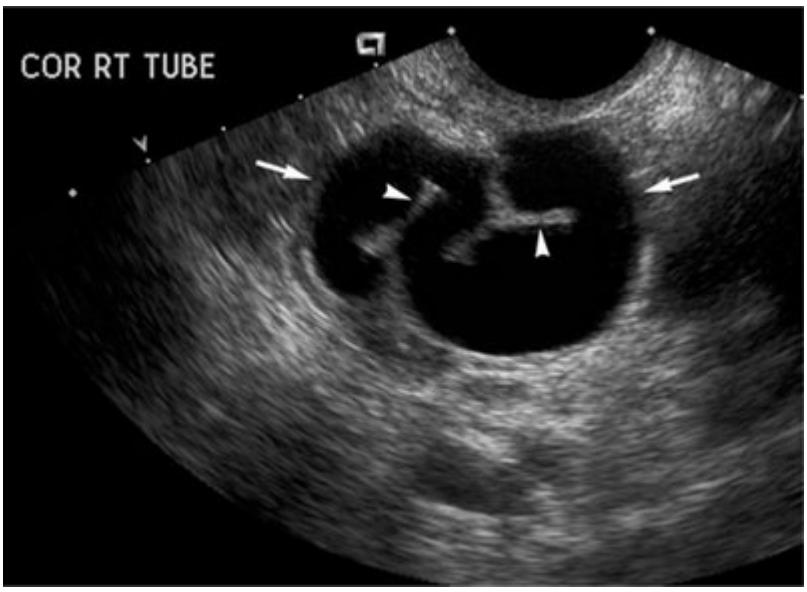


Figure 18-21 Hydrosalpinx. Coronal image of a dilated right fallopian tube (*between arrows*) filled with anechoic fluid. Note the folds *(arrowheads)* of the tortuous tube.

Abnormal Fallopian Tubes

Cancer of the fallopian tubes is rare and is typically in the form of adenocarcinoma. The sonographic appearance of fallopian tube carcinoma is that of a solid mass within the adnexa. The fallopian tubes may become

distended secondary to obstruction or infection. The fluid contained within the distended tubes could be simple serous fluid, blood, or pus. Simple serous fluid within the tube is termed hydrosalpinx (Fig. 18-21). Hydrosalpinx appears anechoic, whereas pus (pyosalpinx) and blood (hematosalpinx) have internal components and may appear echogenic or have a fluid–fluid level (Fig. 18-22). The fallopian tubes may also become inflamed due to infection, which is termed salpingitis, a common issue caused by pelvic inflammatory disease. Fallopian tube pathology is further discussed in Chapter 21 of this text.



Figure 18-22 Pyosalpinx. Echogenic debris or pus is noted within this dilated and inflamed fallopian tube.

REVIEW QUESTIONS

1. An edometrioma most likely appears as a:
   a. Simple, anechoic mass with through transmission
   b. Complex mass with internal shadowing components
   c. Mostly cystic mass with low-level echoes
   d. Solid, hyperechoic shadowing mass

2. With what ovarian tumor is Meigs syndrome most likely associated?
   a. Dysgerminoma
   b. Cystic teratoma
   c. Fibroma
   d. Yolk sac tumor

3. Sonographically, which of the following would most likely be confused for a pedunculated fibroid tumor because of its solid appearing structure?
   a. Serous cystadenoma

b. Mucinous cystadenoma
c. Fibroma
d. Theca lutein cyst

4. During a pelvic sonogram, you visualize a small cyst located adjacent to the ovary. What is the most likely etiology of this cyst?
a. Dermoid cyst
b. Ovarian cystadenoma
c. Endometrioma
d. Parovarian cyst

5. The most common benign ovarian tumor is the:
a. Cystic teratoma
b. Mucinous cystadenoma
c. Fibroma
d. Sertoli–Leydig cell tumor

6. The ovarian mass that contains fat, sebum, and teeth is the:
a. Dermoid
b. Fibroma
c. Mucinous cystadenoma
d. Yolk sac tumor

7. The ovarian cysts that are most often bilateral and are associated with markedly elevated levels of hCG are the:
a. Corpus luteum cysts
b. Parovarian cysts
c. Granulosa cell cysts
d. Theca lutein cysts

8. The cystic mass commonly noted with a pregnancy is the:
a. Corpus luteum
b. Dermoid cyst
c. Dysgerminoma
d. Serous cystadenoma

9. The sonographic appearance of an ovarian dermoid tumor in which only the anterior elements of the mass can be seen, while the greater part of the mass is obscured by shadowing is consistent with:
a. Whirlpool sign
b. Tip of the iceberg sign
c. Dermoid mesh sign
d. Dermoid plug sign

10. The dominant follicle prior to ovulation is termed the:
    a. Graafian follicle
    b. Corpus albicans
    c. Corpus luteum
    d. Medulla

11. After the Graafian follicle ruptures, the remaining structure is termed the:
    a. Graafian remnant
    b. Corpus albicans
    c. Corpus luteum
    d. Theca lutein cyst

12. Which of the following is the correct formula for calculating ovarian volume?
    a. Length × width × height × 0.6243
    b. Length × width × height × 0.3899
    c. Length × width × height × 0.5233
    d. Ovarian volume cannot be calculated

13. Which of the following sonographic findings would not increase the likelihood of an ovarian malignancy?
    a. Septation measuring >3 mm in thickness
    b. Irregular borders
    c. Solid wall nodule
    d. Anechoic components with acoustic enhancement

14. Normal ovarian flow is said to be:
    a. Low resistant during menstruation and high resistant during the proliferative phase
    b. High resistant during menstruation and low resistant at the time of ovulation
    c. Low resistant
    d. High resistant

15. What would be a predisposing condition that would increase the risk for suffering from ovarian torsion?
    a. Hirsutism
    b. Excessive exercise
    c. Ovarian mass
    d. Sonohysterography

16. The malignant ovarian tumor with gastrointestinal origin is the:

a. Brenner tumor
b. Krukenberg tumor
c. Yolk sac tumor
d. Granulosa cell tumor

17. The malignant ovarian mass that is associated with pseudomyxoma peritonei is the:
a. Dysgerminoma
b. Sertoli–Leydig cell tumor
c. Serous cystadenocarcinoma
d. Mucinous cystadenocarcinoma

18. All of the following adnexal masses may appear sonographically similar to a uterine leiomyoma except:
a. Thecoma
b. Parovarian cyst
c. Fibroma
d. Granulosa cell tumor

19. Which of the following is also referred to as a chocolate cyst?
a. Endometrioma
b. Endometroid
c. Cystic teratoma
d. Androblastoma

20. The ovarian tumor associated with an elevated serum lactate dehydrogenase is the:
a. Dysgerminoma
b. Sertoli–Leydig cell tumor
c. Androblastoma
d. Mucinous cystadenocarcinoma

21. Which of the following is a tumor of ectopic endometrial tissue?
a. Brenner tumor
b. Cystic teratoma
c. Yolk sac tumor
d. Endometrioma

22. What ovarian mass is associated with virilization?
a. Krukenberg tumor
b. Cystic teratoma
c. Serous cystadenoma
d. Sertoli–Leydig cell tumor

23. A 24-year-old female patient presents to the emergency department with severe right lower quadrant pain, nausea, and vomiting. The sonographic examination reveals an enlarged ovary with no detectable Doppler signal. What is the most likely diagnosis?
    a. Ovarian cystadenocarcinoma
    b. Cystic teratoma
    c. Ovarian torsion
    d. Endometriosis

24. Which of the following is an estrogen-producing ovarian tumor?
    a. Cystic teratoma
    b. Fibroma
    c. Thecoma
    d. Endometrioma

25. What ovarian tumor will most likely have a moth-eaten appearance on sonography?
    a. Cystic teratoma
    b. Serous cystadenocarcinoma
    c. Krukenberg tumor
    d. Sertoli–Leydig cell tumor

26. A 55-year-old patient presents to the sonography department with a history of pelvic pressure, abdominal swelling, and abnormal uterine bleeding. A pelvic sonogram reveals a large, multiloculated cystic mass with papillary projections. What is the most likely diagnosis?
    a. Serous cystadenocarcinoma
    b. Cystic teratoma
    c. Androblastoma
    d. Dysgerminoma

27. A patient with an ovarian mass presents with an elevated serum AFP. Which of the following would be the most likely?
    a. Ovarian fibroma
    b. Ovarian thecoma
    c. Cystic teratoma
    d. Yolk sac tumor

28. The ovarian cyst associated with gestational trophoblastic disease is the:
    a. Corpus luteum cyst
    b. Theca lutein cyst
    c. Dermoid cyst

d. Parovarian cyst

29. Pus within the fallopian tube is termed:
    a. Hematosalpinx
    b. Pyosalpinx
    c. Hydrosalpinx
    d. Hemosalpinx

30. Which of the following is the most common malignancy of the ovary?
    a. Cystic teratoma
    b. Serous cystadenocarcinoma
    c. Krukenberg tumor
    d. Sertoli–Leydig cell tumor

31. The short and narrow segment of the fallopian tube distal to the interstitial segment is the:
    a. Ampulla
    b. Fimbria
    c. Infundibulum
    d. Isthmus

32. The fingerlike extensions of the fallopian tube are called:
    a. Fimbria
    b. Infundibulum
    c. Cilia
    d. Ampulla

33. The longest and most tortuous segment of the fallopian tube is the:
    a. Fimbria
    b. Ampulla
    c. Isthmus
    d. Interstitial

34. Blood within the fallopian tube is termed:
    a. Hydrosalpinx
    b. Hematosalpinx
    c. Pyosalpinx
    d. Hemosalpinx

35. Hairlike projections within the fallopian tube are called:
    a. Interstitia
    b. Fimbria
    c. Cilia

d. Peristalsis

36. The inner layer of the wall of the fallopian tube is the:
    a. Muscular layer
    b. Mucosal layer
    c. Myometrial layer
    d. Serosal layer

37. The most distal part of the fallopian tube is the:
    a. Cornu
    b. Ampulla
    c. Interstitial
    d. Infundibulum

38. The segment of the fallopian tube where fertilization typically occurs is the:
    a. Cornu
    b. Fimbria
    c. Interstitial
    d. Ampulla

39. What substance does hysterosalpingography utilize for the visualization of the uterine cavity and fallopian tubes?
    a. Saline
    b. Radiographic contrast
    c. Water
    d. Betadine

40. Which of the following is associated with the “whirlpool sign”?
    a. Ovarian torsion
    b. Hydrosalpinx
    c. Ovarian hyperstimulation syndrome
    d. Ovarian carcinoma

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19

The Menstrual Cycle

Introduction

This chapter provides the reader with an overview of the menstrual cycle and the hormones that influence it. The variable sonographic appearance of the endometrium and the ovary as they progress through the menstrual cycle are also presented. Lastly, the interruption of the cycle by pregnancy and causes of abnormal uterine bleeding are discussed.

Key Terms

abnormal uterine bleeding—a change in menstrual bleeding patterns caused by either endocrine abnormalities or lesions within the uterus

adenomyosis—the benign invasion of endometrial tissue into the myometrium of the uterus

anovulatory—absence of ovulation

anterior pituitary gland—the anterior segment of the pituitary gland, which is responsible for releasing follicle-stimulating hormone and luteinizing hormone during the menstrual cycle

atresia (ovarian follicle)—degeneration of a follicle

blastocyst—the stage at which the conceptus implants within the decidualized endometrium

corpus albicans—the remaining structure of the corpus luteum after its deterioration

corpus luteum—the temporary endocrine gland that results from the rupture of the Graafian follicle after ovulation

corpus luteum of pregnancy—the corpus luteum that is maintained during early pregnancy for the purpose of producing estrogen and primarily progesterone

cumulus oophorus—the structure that contains the developing oocyte

dysfunctional uterine bleeding—a change in menstrual bleeding patterns related to hormonal imbalances, resulting in endometrial changes and subsequent abnormal bleeding

endometrial atrophy—the degeneration of the endometrium with advancing age; most often seen in postmenopausal women

endometrial carcinoma—cancer of the endometrium

endometrial hyperplasia—an increase in the number of endometrial cells

endometrial polyps—small nodules of hyperplastic endometrial tissue

estrogen—the hormone released by the ovary during the proliferative phase that initiates the proliferation and thickening of the endometrium

fimbria—the fingerlike extension of the fallopian tube located on the infundibulum

follicle—small, round groups of cells

follicle-stimulating hormone—the hormone of the anterior pituitary gland that causes the development of multiple follicles on the ovaries

follicular phase—the first phase of the ovarian cycle

gonadotropin-releasing hormone—the hormone released by the hypothalamus that stimulates the pituitary gland to release the hormones that regulate the female menstrual cycle

Graafian follicle—the name for the dominant follicle prior to ovulation

human chorionic gonadotropin—the hormone produced by the trophoblastic cells of the early placenta; may also be used as a tumor marker in nongravid patients and males

hypothalamus—the area within the brain that is located just beneath the thalamus and controls the release of hormones by the anterior pituitary gland

hypothalamic-pituitary-gonadal axis—the complex interactions that take place between the hypothalamus, pituitary gland, and ovaries as part of the female reproductive cycle

imperforate hymen—a vaginal anomaly in which the hymen has no opening, resulting in an obstruction of the vagina

luteal phase—the second phase of the ovarian cycle

luteinizing hormone—the hormone of the anterior pituitary gland that

surges around day 14 of the menstrual cycle, resulting in ovulation

menarche—the first menstrual cycle

menses—menstrual bleeding

mittelschmerz—pain at the time of ovulation

ovulation—the release of the mature egg from the ovary

periovulatory phase—another name for the late proliferative phase of the endometrial cycle, which occurs around the time of ovulation

primary amenorrhea—failure to experiencing menarche before age 16

progesterone—a hormone that prepares the uterus for pregnancy, maintains pregnancy, and promotes development of the mammary glands; primarily produced by the ovary and placenta

proliferation—the multiplication of similar forms

proliferative phase—the first phase of the endometrial cycle

secondary amenorrhea— the cessation of menstruation characteristically diagnosed in the postmenarchal woman who has had 3 to 6 months without a menstrual cycle

secretory phase—the second phase of the endometrial cycle

spiral arteries—coiled arteries that supply blood to the functional layer of the endometrium

syncytiotrophoblastic cells—the trophoblastic cells surrounding the blastocyst that are responsible for producing human chorionic gonadotropin

theca internal cells—cells of the follicle that produce estrogen

three-line sign—the periovulatory endometrial sonographic appearance in which the outer echogenic basal layer surrounds the more hypoechoic functional layer, with the functional layer separated by the echogenic endometrial stripe

THE MENSTRUAL CYCLE: DURATION AND DEFINITIONS

The last menstrual period relates to the onset of menses; therefore, the first day of the menstrual cycle is said to occur on the first day of bleeding. The average menstrual cycle lasts 28 days, with ovulation typically occurring around day 14. However, some menstrual cycles may last only 25 days, whereas others may last up to 45 days. Days 1 through 5 of the menstrual cycle correlate with menses, at which time the endometrium is shed.

SOUND OFF

The average menstrual cycle lasts 28 days, with ovulation occurring on day 14.

The first menstrual cycle is termed menarche. Menarche occurs at different ages and may be influenced by environment and diet. However, if an individual does not experience menarche before age 16, she is said to have primary amenorrhea. Primary amenorrhea may be caused by congenital abnormalities or congenital obstructions, such as an imperforate hymen. Secondary amenorrhea may be associated with endocrinologic abnormalities or pregnancy. Secondary amenorrhea that is not associated with pregnancy is characteristically diagnosed in the postmenarchal woman who has had 3 to 6 months without a menstrual cycle.

THE ROLE OF THE HYPOTHALAMUS

The hypothalamic-pituitary-gonadal axis is the complex interactions that take place between the hypothalamus, pituitary gland, and ovaries as part of the female reproductive cycle. The hypothalamus is an area within the brain that is located just beneath the thalamus. The primary responsibility of the hypothalamus, as it relates to the menstrual cycle, is to regulate the release of hormones by the anterior pituitary gland. The hypothalamus achieves this function by releasing its own hormone, gonadotropin-releasing hormone (GnRH), which in turn stimulates the release of hormones by the anterior pituitary gland.

HORMONES OF THE ANTERIOR PITUITARY GLAND

The pituitary gland, often referred to as the “master gland,” is an endocrine gland located within the brain that consists of an anterior and a posterior lobe. The anterior lobe of the pituitary gland is responsible for the release of two chief hormones that influence the menstrual cycle: follicle-stimulating hormone (FSH) and luteinizing hormone (LH) (Fig. 19-1). Both of these hormones act upon the ovaries. FSH causes the development of multiple follicles on the ovaries, whereas LH surges around day 14 of the menstrual cycle, resulting in ovulation.

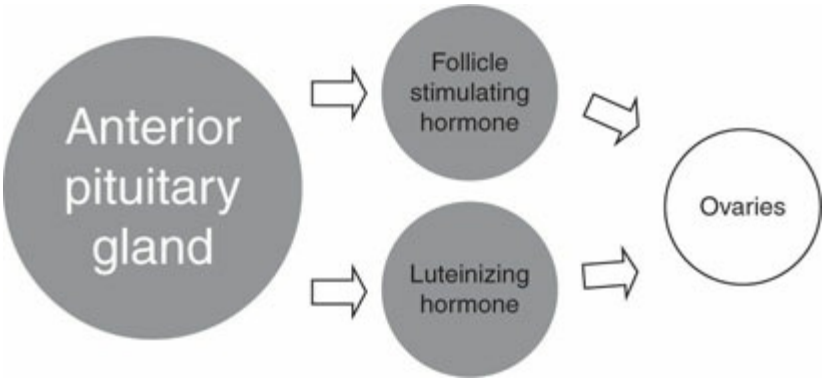


Figure 19-1 Hormones of the anterior pituitary gland influence the ovaries.

SOUND OFF
The hormones produced by the anterior pituitary gland (FSH and LH) both contain the word "hormone."

HORMONES OF THE OVARY

The ovary produces two hormones during the menstrual cycle, estrogen and progesterone (Fig. 19-2). Estrogen is produced throughout the menstrual cycle. It is initially produced by the theca internal cells of the secondary follicles during the first part of the menstrual cycle. During this phase, estrogen initiates the proliferation and thickening of the endometrium by encouraging the growth and expansion of the spiral arteries and glands within the functional layer of the endometrium. Estrogen has many other important functions, such as the regeneration of the endometrium after menses and the induction of salt and water retention. It also stimulates contractile motions within the uterine myometrium and the fallopian tubes. During the second half of the menstrual cycle, following ovulation, progesterone is produced by the corpus luteum of the ovary. Progesterone is responsible for maintaining the thickness of the endometrium and inducing its secretory activity as the endometrium prepares for the possible implantation of a pregnancy.

SOUND OFF
The hypothalamus releases GnRH, which influences the anterior pituitary gland. The anterior pituitary gland produces FSH and LH, which influence the ovary. The ovary produces estrogen and progesterone, which influence the endometrium.

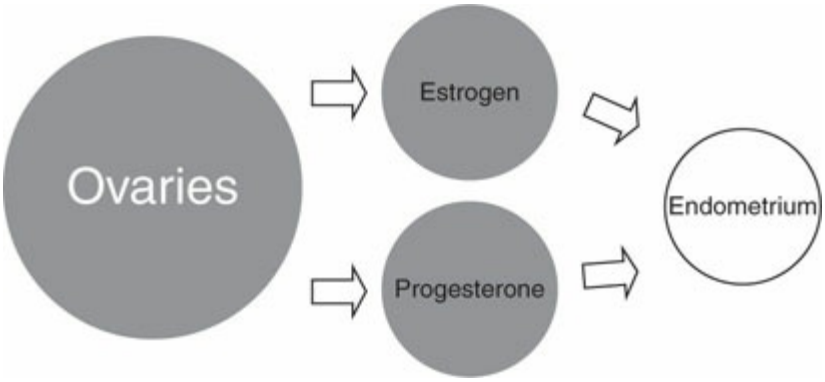


Figure 19-2 Hormones of the ovary influence the endometrium.

THE PHYSIOLOGY OF THE OVARIAN CYCLE

The ovarian cycle consists of two phases: the follicular phase and the luteal phase. The follicular phase of the ovarian cycle is considered to begin on day 1 and lasts until day 14, thus, in effect, ending with ovulation. During the follicular phase, the anterior pituitary gland secretes FSH, which initiates the follicular development of the ovary. Many follicles are produced on the ovary. Whereas numerous follicles manifest, only one follicle will be maintained and become the Graafian follicle or dominant follicle prior to ovulation. This Graafian follicle, which can grow as large as 2.7 cm, contains the developing oocyte (egg) within a region called the cumulus oophorus.

Around day 14, LH, produced by the anterior pituitary gland, stimulates ovulation, at which time the Graafian follicle, which has grown to a size of 15 to 27 mm, ruptures and expels a small amount of fluid and the ovum into the peritoneum. At the time of ovulation, the individual may feel a twinge of pain, and this is termed mittelschmerz. The ovum that was expelled by the ovary is picked up by the fimbria of the fallopian tube and is propelled through the tube, either to be fertilized, resorbed by the body, or passed with menstruation. The fluid from the ruptured follicle mostly collects in the posterior cul-de-sac. Thus, a minimal amount of fluid within the pelvis may be detected with sonography.

The second phase of the ovarian cycle, days 15 to 28, is termed the luteal phase. After the Graafian follicle ruptures, it is temporarily turned into an endocrine gland in the form of the corpus luteum. The corpus luteum, while producing estrogen in small amounts, primarily produces progesterone to maintain the thickness of the endometrium and prepares the endometrium for the (conceivably) fertilized ovum. All the other follicles undergo atresia.

While the corpus luteum depends on LH to be maintained, progesterone negatively inhibits the production of LH by the anterior pituitary gland, resulting in the regression of the corpus luteum. The remaining structure of the corpus luteum is now termed the corpus albicans, which can often be

seen sonographically as a small echogenic scar on the ovary.

THE PHYSIOLOGY OF THE ENDOMETRIAL CYCLE

The endometrium has two basic layers. The innermost portion, the functional layer, is the layer that is stimulated by the hormones of the ovary to undergo changes throughout the menstrual cycle. Thus, the functional layer provides an appropriate location for the implantation of the products of conception. The outermost portion, the basal layer, is only slightly altered during the menstrual cycle. It consists of dense, cellular stroma.

The endometrial cycle consists of two phases: the proliferative phase and the secretory phase. The proliferative phase occurs after menstruation and lasts until ovulation. Recall that the endometrium is influenced by estrogen and progesterone, which are produced by the ovary. During the first half of the menstrual cycle, the endometrium undergoes thickening as a result of estrogen stimulation. Thus, proliferation of the endometrium, which is described as the multiplication of similar forms, occurs during the proliferative phase of the endometrial cycle because the functional layer increases in thickness. The proliferative phase may be divided into two phases, early and late, with the late proliferative phase often being referred to as the periovulatory phase.



SOUND OFF

The proliferative phase may be divided into two phases, early and late, with the late proliferative phase often being referred to as the **periovulatory phase**.

The secretory phase of the endometrial cycle occurs after ovulation and is stimulated by progesterone. Progesterone maintains the thickness of the endometrium in preparation for implantation. Should fertilization not take place, menses begin on day 1 of the cycle, resulting from a lack of estrogen and progesterone. Conversely, if fertilization does occur, the endometrial thickness is maintained by the continual production of progesterone by the corpus luteum of pregnancy (see “Disruption of the Menstrual Cycle by Pregnancy” section).

CORRELATING THE PHASES OF THE MENSTRUAL CYCLE

It is significant for sonographers to have an understanding of what is

concurrently taking place in the ovary and the endometrium throughout the menstrual cycle (Table 19-1). As stated earlier, days 1 through 5 of the menstrual cycle correlate with menses, at which time the endometrium is shed. Following menses, the ovary is in the follicular phase, whereas the endometrium is in the proliferative phase. Following ovulation, the ovary begins the luteal phase, whereas the endometrium enters the secretory phase (Fig. 19-3).



SOUND OFF

Remember this mnemonic to recall the correlation of the menstrual cycle phases:

"Ovaries Freely Let Every Period Start"

Ovaries	**O**vary
Freely	**F**ollicular
Let	**L**uteal
Every	**E**ndometrium
Period	**P**roliferative
Start	**S**ecretory

SONOGRAPHIC APPEARANCES OF THE ENDOMETRIUM

Because the hormones produced by the ovary act upon the endometrium, the thickness of the endometrium varies (Fig. 19-4). Consequently, the sonographic appearance of the endometrium changes (Table 19-2). During menses, the endometrium typically appears as a thin, echogenic line that can measure up to 4 mm (Fig. 19-5). During the early proliferative phase, the functional layer gradually increases in size and becomes more hypoechoic. It can measure between 4 and 8 mm. During the late proliferative phase or periovulatory phase, which is between days 5 and 14, the endometrial layers display a stark contrast and can measure between 6 and 10 mm. While in the periovulatory phase, the outer echogenic basal layer of the endometrium will be seen surrounding the more hypoechoic functional layer, while the functional layer is separated by the echogenic uterine cavity (Fig. 19-6). This finding is referred to as the three-line sign. Following ovulation, the secretory endometrium is maintained by the production of progesterone because the endometrium becomes thickened and echogenic in appearance and measures between 7 and 14 mm (Fig. 19-7). The thickness measurement

of the endometrium obtained with sonography should not include the adjacent hypoechoic myometrium and is considered accurate when the double-layer thickness measurement is performed. The double-layer thickness includes only the distance from basal layer to basal layer.

TABLE 19-1 Correlation between the ovarian and endometrial phases

Structure	Days 1–14	Days 15–28
Ovary	Follicular phase	Luteal phase
Endometrium	Proliferative phase	Secretory Phase

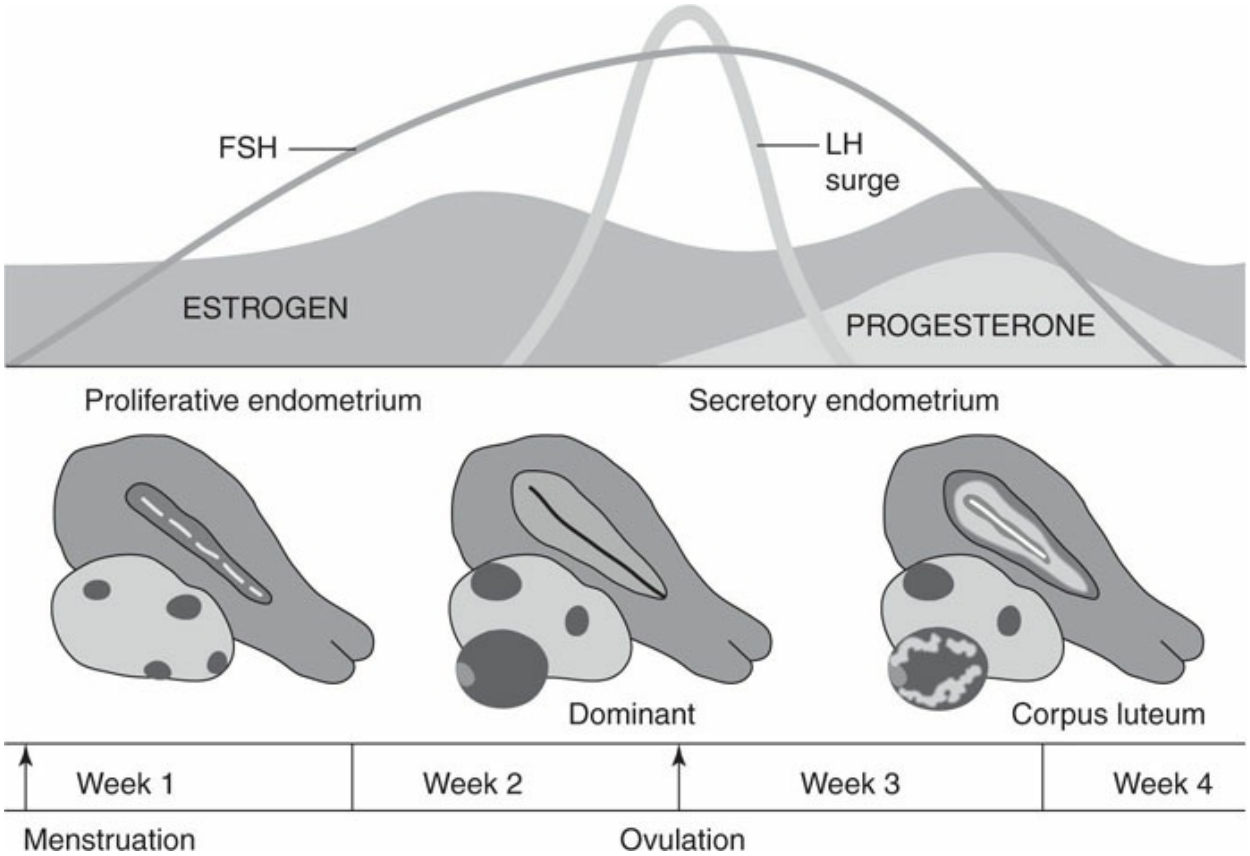


Figure 19-3 Sequence of events during the menstrual cycle. FSH, follicle-stimulating hormone; LH, luteinizing hormone.

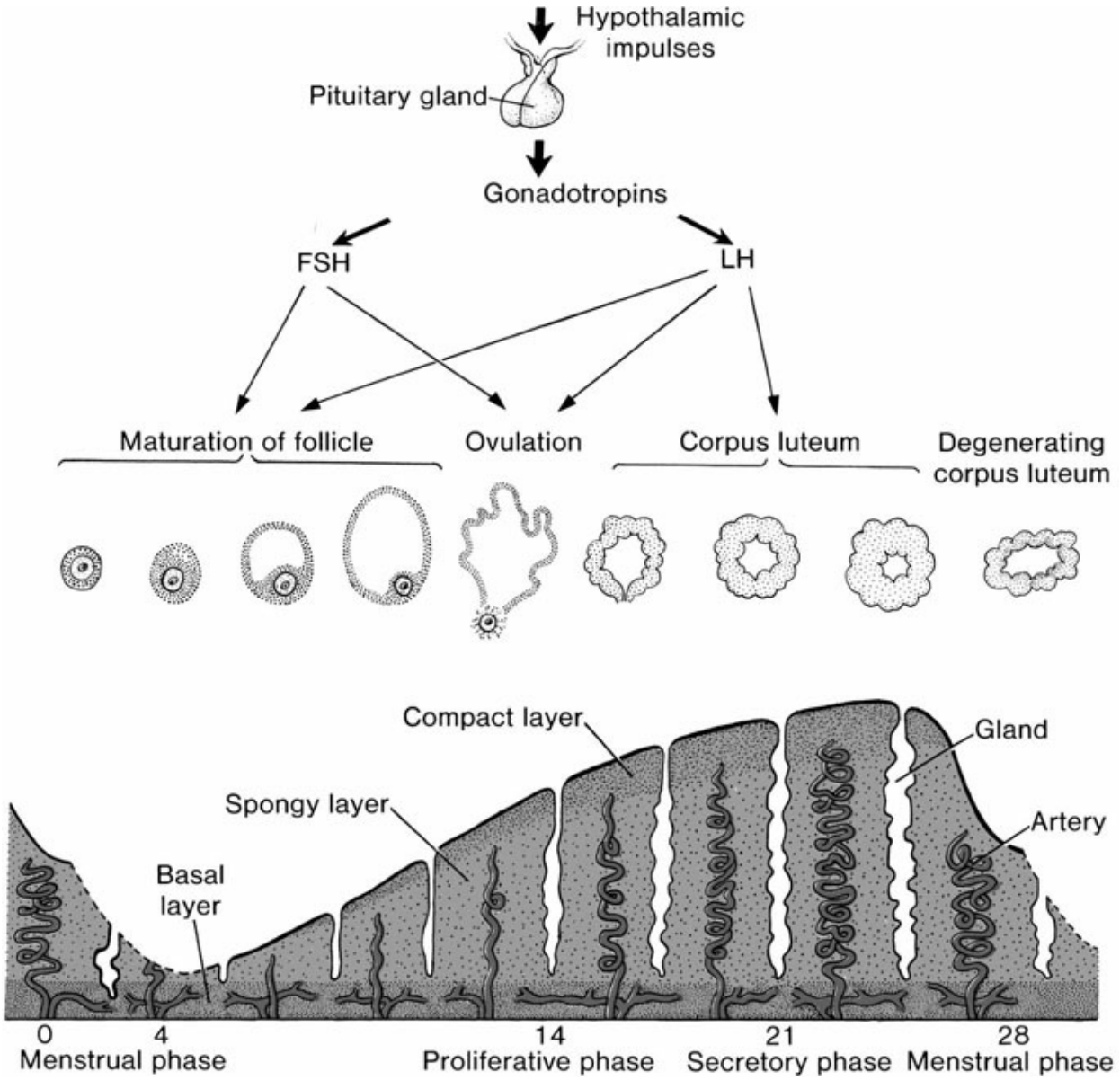


Figure 19-4 Changes in the uterine mucosa (endometrium) and corresponding changes in the ovary during a normal menstrual cycle without fertilization. FSH, follicle-stimulating hormone; LH, luteinizing hormone.

TABLE 19-2 Review of endometrial thickness measurements and sonographic appearance

Phase of the Endometrial Cycle	Endometrial Thickness (mm)	Sonographic Appearance
During menses	Up to 4	Thin and echogenic
Early proliferative phase	4–8	Thickening hypoechoic functional layer
Periovulatory (late proliferative) phase	6–10	Distinct three-line sign
Secretory phase	7–14	Thick and echogenic

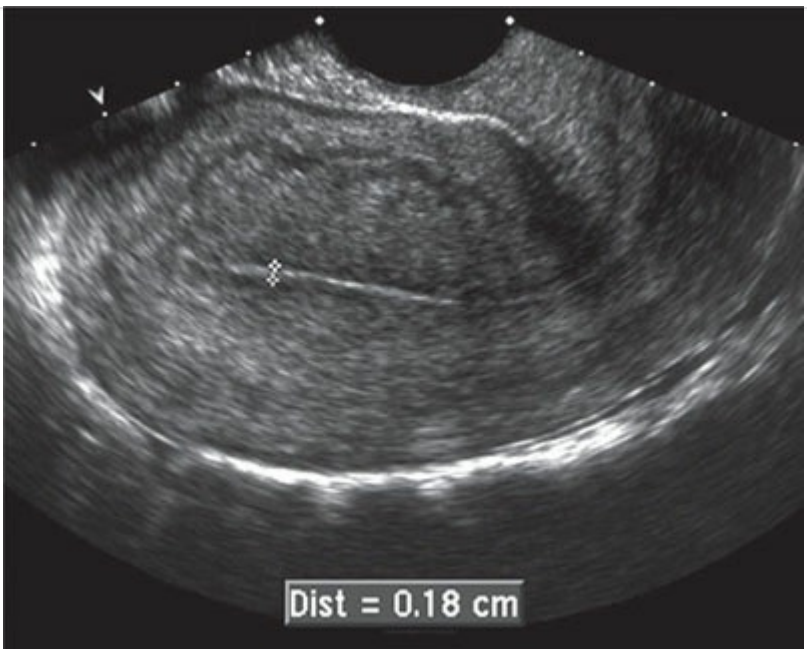


Figure 19-5 Sonographic appearance of the endometrium (**between calipers**) shortly after menses. Note how thin the endometrium appears in this image.

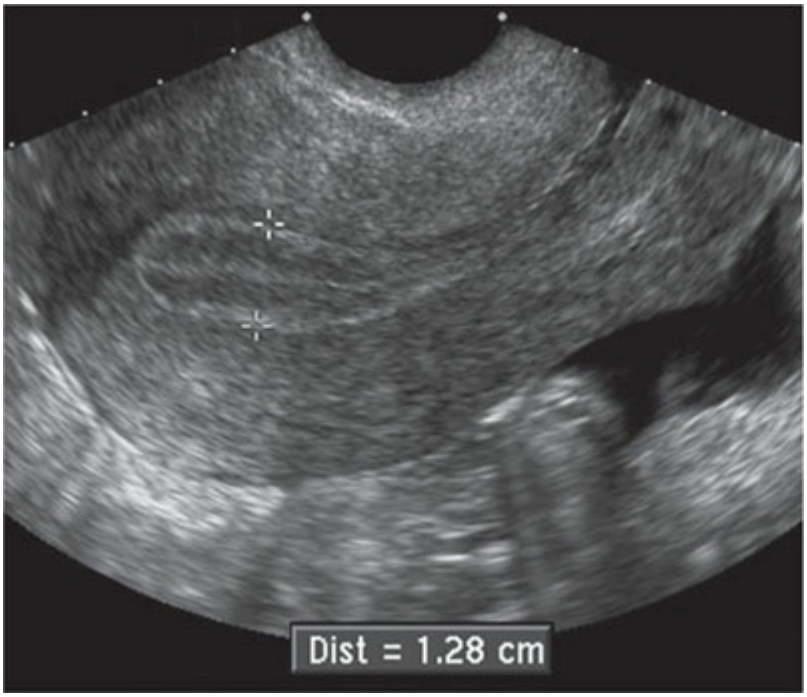


Figure 19-6 Sonographic appearance of the endometrium (**between calipers**) during the late proliferative (periovulatory) phase, also referred to as the “three-line” sign. The outer echogenic basal layer surrounds the more hypoechoic functional layer, whereas the functional layer is separated by the echogenic endometrial stripe.

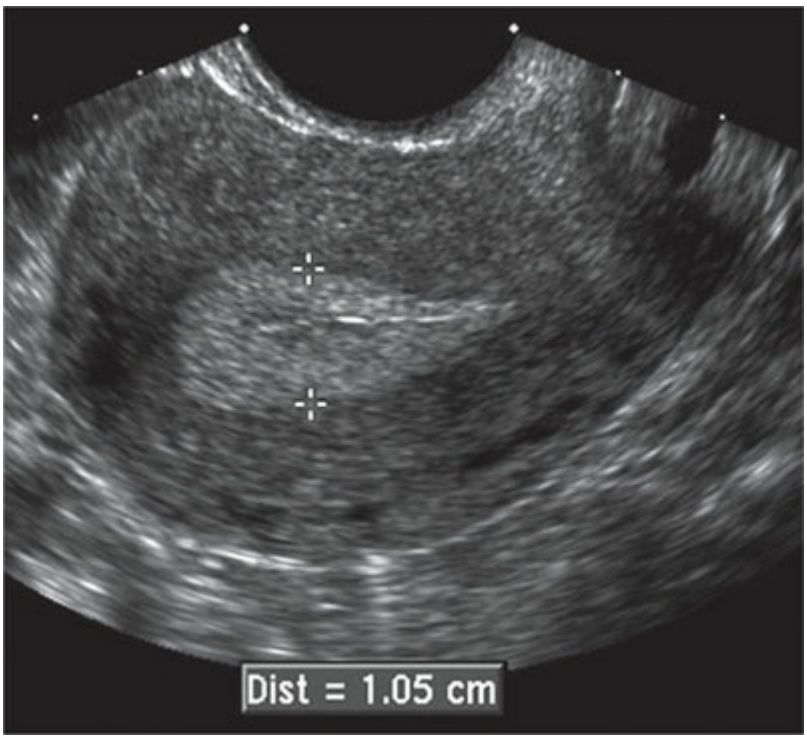


Figure 19-7 Sonographic appearance of the endometrium (between calipers) during the secretory phase. During this phase, the endometrium appears thick and echogenic.

Disruption of the Menstrual Cycle by Pregnancy

Fertilization, or conception, typically occurs on day 15, with the union of the egg and sperm in the fallopian tube. The cells that surround the blastocyst, the syncytiotrophoblastic cells (trophoblastic cells), then begin to produce human chorionic gonadotropin (hCG). The production of hCG maintains the corpus luteum. Thus, hCG allows the corpus luteum to continue to produce progesterone, which in turn maintains the thickness of the endometrium so that implantation can take place and the pregnancy can continue to progress normally.

Dysfunctional Uterine Bleeding and Abnormal Uterine Bleeding

Dysfunctional uterine bleeding (DUB) may be idiopathic, although it is usually related to hormonal imbalances resulting in endometrial changes with subsequent irregular bleeding. For example, polycystic ovary syndrome, which produces an anovulatory cycle, is said to be a common cause of DUB. DUB is usually diagnosed when all other causes of irregular bleeding are ruled out.

Abnormal uterine bleeding (AUB) may be caused by a number of complications and is defined as a change in menstrual bleeding patterns caused by either endocrine abnormalities or lesions within the uterus (Table 19-3). The indication for patients who present with abnormal or absent uterine bleeding is variable, depending on duration, amount, and frequency

of menstruation (Table 19-4). One of the more common suspicious pathologies that results in AUB is the presence of fibroid tumors or leiomyomas within or abutting the uterine cavity. Adenomyosis, which is ectopic endometrial tissue within the myometrium of the uterus, is another etiology of AUB and painful menstruation. Other origins of AUB, including endometrial hyperplasia, endometrial polyps, and endometrial carcinoma, are primarily diagnosed in the perimenopausal or postmenopausal population but may be found in younger age groups. Endometrial atrophy is also a common occurrence in the postmenopausal patient who presents with vaginal bleeding. Postmenopausal sonography is further discussed in Chapter 20 of this text.

TABLE 19-3 Causes of abnormal uterine bleeding

Causes of Abnormal Uterine Bleeding
Uterine fibroids
Adenomyosis
Cervical polyps
Endometrial polyps
Endometrial hyperplasia
Endometrial cancer
Hypothyroidism
Anovulation

TABLE 19-4 Common terms related to abnormal uterine bleeding

Abnormal Uterine Bleeding Term	Definition
Amenorrhea	Absence of menstruation
Cryptomenorrhea	Monthly symptoms of menstruation without bleeding
Dysmenorrhea	Painful or difficult menstruation
Menorrhagia (hypermenorrhea)	Abnormally heavy and prolonged menstruation
Metrorrhagia (intermenstrual bleeding)	Irregular menstrual bleeding between periods
Menometrorrhagia	Excessive or prolonged bleeding at irregular intervals
Oligomenorrhea	Irregular cycles greater than 35 days apart
Polymenorrhea	Frequent regular cycles but less than 21

	days apart
Hypomenorrhea	Regularly timed menses but light flow

REVIEW QUESTIONS

1. What hormone maintains the thickness of the endometrium after ovulation?
   a. LH
   b. Estrogen
   c. Progesterone
   d. FSH

2. Ovulation typically occurs on day — of the menstrual cycle.
   a. 12
   b. 14
   c. 16
   d. 1

3. What structure may be noted on the ovary just prior to ovulation?
   a. Corpus albicans
   b. Corpus luteum
   c. Graafian follicle
   d. Blastocyst

4. FSH is produced by the:
   a. Ovary
   b. Endometrium
   c. Hypothalamus
   d. Anterior pituitary gland

5. When the ovary is in the luteal phase, the endometrium is in the:
   a. Early proliferative
   b. Periovulatory
   c. Late proliferative
   d. Secretory

6. A change in menstrual bleeding associated with lesions within the uterus relates to:
   a. DUB
   b. AUB
   c. Pelvic inflammatory disease

d. Fibroids

7. Painful and difficult menstruation is termed:
   a. Menorrhagia
   b. Dysmenorrhea
   c. Metrorrhagia
   d. Amenorrhea

8. The temporary endocrine gland that results from the rupture of the Graafian follicle is the:
   a. Corpus albicans
   b. Corpus luteum
   c. Cumulus oophorus
   d. Trophoblastic cells

9. Which hormone maintains the corpus luteum during pregnancy?
   a. FSH
   b. LH
   c. Progesterone
   d. hCG

10. What is the typical sonographic appearance of the endometrium during the secretory phase?
    a. Anechoic and thin
    b. Hyperchoic and thick
    c. Hypoechoic and thin
    d. Echogenic basil layer and hypoechoic functional layer

11. An increase in the number of endometrial cells is termed:
    a. Endometrial hyperplasia
    b. Endometrial atrophy
    c. Endometrial carcinoma
    d. Polyps

12. Which of the following is said to be a common cause of DUB?
    a. Hursutism
    b. Polycystic ovary syndrome
    c. Fibroids
    d. Pelvic inflammatory disease

13. When the sonographic three-line sign is present, the functional layer of the endometrium typically appears:
    a. Anechioc

b. Echogenic
c. Hypoechoic
d. Complex

14. The structure noted within the Graafian follicle containing the developing ovum is the:
    a. Corpus luteum
    b. Corpus albicans
    c. Cumulus oophorus
    d. Theca internal cells

15. Which of the following would not be a cause of AUB?
    a. Endometrial hyperplasia
    b. Hypothyroidism
    c. Adenomyosis
    d. Ovarian torsion

16. Which structure remains after the corpus luteum has regressed?
    a. Theca luteal cyst
    b. Corpus luteum of pregnancy
    c. Corpus albicans
    d. Cumulus oophorus

17. The hormone of the pituitary gland that stimulates follicular development of the ovary is:
    a. LH
    b. Estrogen
    c. FSH
    d. GnRH

18. What structure produces hormones that directly act upon the endometrium to produce varying thicknesses and sonographic appearances?
    a. Hypothalamus
    b. Adrenal gland
    c. Ovary
    d. Uterus

19. The first phase of the ovarian cycle is the:
    a. Luteal phase
    b. Secretory phase
    c. Proliferative phase
    d. Follicular phase

20. The hormone produced by the hypothalamus that controls the release of the hormones for menstruation by the anterior pituitary gland is:
    a. FSH
    b. Estrogen
    c. GnRH
    d. LH

21. The dominant follicle prior to ovulation is termed the:
    a. Graafian follicle
    b. Ovarian hyper follicle
    c. Corpus luteum
    d. Corpus albicans

22. The hormone produced by the trophoblastic cells of the early placenta is:
    a. Estrogen
    b. FSH
    c. LH
    d. hCG

23. The hormone that surges at ovulation is:
    a. GnRH
    b. LH
    c. Aldosterone
    d. Progesterone

24. The first phase of the endometrial cycle is the:
    a. Secretory phase
    b. Follicular phase
    c. Luteal phase
    d. Proliferative phase

25. What is defined as frequent regular cycles but less than 21 days apart?
    a. Hypomenorrhea
    b. Polymenorrhea
    c. Menorrhagia
    d. Cryptomenorrhea

26. Which hormone released by the ovary during the proliferative phase stimulates endometrial thickening?
    a. FSH
    b. LH
    c. Estrogen

d. Progesterone

27. The periovulatory phase may also be referred to as the:
    a. Early secretory phase
    b. Late proliferative phase
    c. Late secretory phase
    d. Early proliferative phase

28. The corpus luteum primarily releases:
    a. Estrogen
    b. Progesterone
    c. LH
    d. FSH

29. Which of the following could also be described as intermenstrual bleeding?
    a. Metrorrhagia
    b. Polymenorrhea
    c. Menometrorrrhagia
    d. Menorrhagia

30. Ectopic endometrial tissue within the uterus that leads to AUB is termed:
    a. Endometriosis
    b. Adenomyosis
    c. Fibroids
    d. Endometrial hyperplasia

31. The arteries within the functional layer of the endometrium that are altered by the hormones of the ovary and are shed with menstruation are the:
    a. Arcuate arteries
    b. Radial arteries
    c. Straight arteries
    d. Spiral arteries

32. During which phase of the endometrial cycle would the endometrium yield the three-line sign?
    a. Late proliferative
    b. Early proliferative
    c. Early secretory
    d. Late secretory

33. The second phase of the endometrial cycle is the:

a. Secretory phase
b. Follicular phase
c. Luteal phase
d. Proliferative phase

34. Which of the following hormones is released by the ovary during the second half of the menstrual cycle?
a. LH
b. FSH
c. hCG
d. Progesterone

35. LH is produced by the:
a. Ovary
b. Endometrium
c. Hypothalamus
d. Anterior pituitary gland

36. The average menstrual cycle lasts:
a. 45 days
b. 24 days
c. 26 days
d. 28 days

37. The first menstrual cycle is termed:
a. Amenorrhea
b. Metrorrhagia
c. Mittelschmerz
d. Menarche

38. The measurement of the endometrium during the early proliferative phase ranges from:
a. 6 to 10 mm
b. 8 to 12 mm
c. 4 to 8 mm
d. 1 to 2 mm

39. The second phase of the ovarian cycle is called the:
a. Follicular phase
b. Luteal phase
c. Secretory phase
d. Proliferative phase

40. The two hormones produced by the anterior pituitary gland that impact the menstrual cycle are:
    a. LH and FSH
    b. LH and estrogen
    c. Progesterone and estrogen
    d. FSH and progesterone

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20

Postmenopausal Sonography and Sonohysterography

Introduction

This chapter discusses the various causes of postmenopausal bleeding. Given that sonohysterography has begun to play an important role in the diagnosis and treatment of patients who present with abnormal uterine bleeding, a discussion on this essential diagnostic instrument is also provided in this chapter.

Key Terms

adenocarcinoma—cancer that originates in glandular tissue

adhesions—irregular bands of tissue

amenorrhea—absence of menstruation

anovulation—lack of ovulation

Asherman syndrome—a syndrome characterized by endometrial adhesions that typically occur as a result of scar formation after some types of uterine surgery

atrophy—wasting away of a part of the body

bilateral salpingo-oophorectomy—the surgical removal of both ovaries and both fallopian tubes

CA-125—a tumor marker in the blood that can indicate certain types of cancer, such as cancer of the ovary, endometrium, breast, gastrointestinal tract, and lungs; stands for cancer antigen-125

climacteric—another name for menopause

coronary heart disease—the buildup of plaque within the arteries that supply the myocardium of the heart

dilation and curettage—a procedure in which the cervix is dilated and the uterine cavity is scraped with a curette

double-layer thickness—measurement of the endometrium from basal layer to basal layer excluding both the adjacent hypoechoic myometrium and the intracavitary fluid (if present)

endometrial atrophy—the degeneration of the endometrium with advanced age; most often seen in postmenopausal women

endometrial carcinoma—cancer of the endometrium

endometrial hyperplasia—an increase in the number of endometrial cells

endometrial polyps—small nodules of hyperplastic endometrial tissue

estrogen—the hormone released by the ovary that initiates the proliferation and thickening of the endometrium

estrogen replacement therapy—hormone replacement therapy that involves the administration of synthetic estrogen

hematometra—blood accumulation within the uterine cavity

hormone replacement therapy—the medical treatment used to accommodate the reduction of estrogen and progesterone that occurs during menopause

hyperplasia—an increase in the number of cells of a tissue or an organ

hypertension—high blood pressure

hypomenorrhea—decreased or scant menstrual flow

hysteroscopy—endoscopy of the uterine cavity

intermenstrual bleeding—bleeding between periods

leiomyoma (uterine)—a benign, smooth muscle tumor of the uterus; may also be referred to as a fibroid or uterine myoma

menometrorrhagia—excessive and prolonged menstrual bleeding at irregular intervals

menopause—cessation of menstruation with advanced age

metastasis—the spread of cancer from a distant site

nulliparity—having birthed no children

osteopenia—a bone density that is lower than normal

osteoporosis—bone loss that predisposes the individual to fractures

pedunculated—something that grows off a stalk

pelvic inflammatory disease—infection of the female genital tract that may

involve the ovaries, uterus, and/or the fallopian tubes

perimenopausal—the time prior to menopause

polycystic ovary syndrome—a syndrome characterized by anovulatory cycles, infertility, hirsutism, amenorrhea, and obesity; may also be referred to as Stein–Leventhal syndrome

polypectomy—the surgical removal of a polyp

polypoid—shaped like a polyp

postmenopausal vaginal bleeding—vaginal bleeding after the onset of menopause

postmenopause—the time after menopause

postpartum—the time directly after giving birth and extending to about 6 weeks

progesterone—a hormone that prepares the uterus for pregnancy, maintains pregnancy, and promotes development of the mammary glands; primarily produced by the ovary and placenta

progestogen therapy—a hormone replacement therapy that involves administering synthetic progesterone

pyometra—the presence of pus within the uterus

saline infusion sonography—see key term saline infusion sonohysterography

saline infusion sonohysterography—a sonographic procedure that uses saline instillation into the endometrial cavity and fallopian tubes to evaluate for internal abnormalities

Stein–Leventhal syndrome—see key term polycystic ovary syndrome

synechiae—adhesions

tamoxifen—a breast cancer drug that inhibits the effects of estrogen on the breast

thecoma—benign ovarian sex cord-stromal tumor that produces estrogen in older women

thromboembolism—the formation of a clot within a blood vessel with the potential to travel to a distant site and cause an occlusion

total abdominal hysterectomy—the removal of the uterus and cervix

MENOPAUSE

Menopause, or climacteric, is the cessation of menstruation with advanced age. The average age at which menopause occurs is 51, with a range in normal women between the ages of 42 and 58. As menopause approaches,

the follicles that normally develop in the ovary are less responsive to the hormones produced by the anterior pituitary gland. During menopause, the follicles cease to mature, resulting in a considerable reduction in the amounts of estrogen and progesterone.

REPERCUSSIONS OF MENOPAUSE

As discussed in Chapter 19, estrogen and progesterone are the hormones released by the ovary that facilitate menses. Without estrogen and progesterone, menstruation ceases, and the uterus and ovaries undergo atrophy or decrease in size. Although smaller, the uterus will maintain its adult shape. The ovaries also become more echogenic, during postmenopause, and lack follicles, thus making them more difficult to image with sonography.

The decrease production of estrogen by the ovaries has other physiologic consequences. Along with the decrease in uterine size, the mucosal layer of the uterus—the endometrium—begins to become atrophic as menstruation come to an end. The vagina also becomes smaller and decreases in caliber. The breasts tend to accumulate more adipose or fat tissue within them. Patients undergoing menopause may also suffer from night sweats or hot flashes, mood changes, depression, dyspareunia, dysuria, and a decrease in libido. There are several long-term consequences of menopause that are a main concern. Because of the lack of circulating estrogen during and after menopause, there is a notable increase risk for coronary heart disease and an increase threat for developing osteopenia and osteoporosis.

HORMONE REPLACEMENT THERAPY

Hormone replacement therapy (HRT) is often used to combat the reduction of estrogen circulating in the female body after menopause and to prevent menopausal symptoms such as hot flashes and vaginal atrophy. Estrogen replacement therapy (ERT) has been shown to significantly reduce the risk of developing osteoporosis and coronary heart disease, with possible associated reduction in risk for developing colon cancer and Alzheimer disease. However, unopposed ERT (not combined with progestogen therapy) has been shown to increase the risk for developing endometrial hyperplasia and endometrial carcinoma. There may also be an increase risk of developing breast cancer, thromboembolism, hypertension, and possibly diabetes in patients who are on ERT. For this reason, many physicians attempt to thwart the risks of unopposed ERT with progestogen therapy (progestin therapy). These hormones, when used in conjunction, act upon the endometrium and in

effect induce a menstrual cycle. Combined estrogen and progestogen therapy, when used consistently, can reduce the risk of developing endometrial carcinoma but cannot eliminate it entirely. The sonographic appearance and thickness of the endometrium is variable and comparable with the endometrium in the premenopausal female. Thus, prior to performing a postmenopausal pelvic sonogram, it is vital for the sonographer to inquire if the patient is undergoing HRT, because HRT will influence the sonographic appearance of the endometrium.



SOUND OFF

Unopposed estrogen exposure on the endometrium increases the risk for endometrial hyperplasia and endometrial carcinoma.

POSTMENOPAUSAL VAGINAL BLEEDING AND ENDOMETRIAL THICKENING

A common indication for postmenopausal sonography is postmenopausal vaginal bleeding (PMB). There are several complications that may lead to PMB. Endometrial atrophy, uncontrolled HRT, endometrial hyperplasia, endometrial polyps, submucosal or intracavitary leiomyoma, endometrial carcinoma, and some ovarian tumors are among the differential abnormalities that can be linked to vaginal bleeding in the postmenopausal population.



SOUND OFF

Prior to performing a postmenopausal pelvic sonogram, it is vital for the sonographer to inquire if the patient is undergoing HRT, because HRT will influence the sonographic appearance of the endometrium.

Accurate sonographic endometrial thickness measurements are vitally important and are used in correlation with clinical findings in patients who present with PMB. Endometrial thickness cutoff measurements vary depending on the patient's clinical presentation (Table 20-1). The thickness measurement of the endometrium should not include the adjacent hypoechoic myometrium and is considered accurate only when the double-layer thickness measurement is performed without the inclusion of endometrial fluid in the measurement (Fig. 20-1). Transvaginal sonography has been reported to be highly effective, with a sensitivity of up to 95% for detecting endometrial carcinoma when an endometrial thickness threshold of 4 to 5 mm is used for the patient with PMB. If the endometrium measures less than 5 mm, the bleeding is typically caused by endometrial atrophy. If the

endometrium exceeds 5 mm, endometrial biopsy is warranted. The asymptomatic patient, or those with no vaginal bleeding, can have an endometrial thickness of up to 8 mm and, in some cases, 11 mm based on clinical presentation. It is significant to note that carcinoma has been found in patients with measurements below these thresholds too. Conversely, benign endometrial pathologies have been seen in patients with measurements above these thresholds. It may be that focal irregularity and myometrial distortion may be more specific findings than just endometrial thickness.

TABLE 20-1 Normal endometrial thickness measurements for the asymptomatic and symptomatic postmenopausal patient

Clinical Presentation	Normal Endometrial Thickness (mm)
Negative postmenopausal vaginal bleeding	≤8
Positive postmenopausal vaginal bleeding	≤5

Any measurement over these thresholds would warrant further investigation.

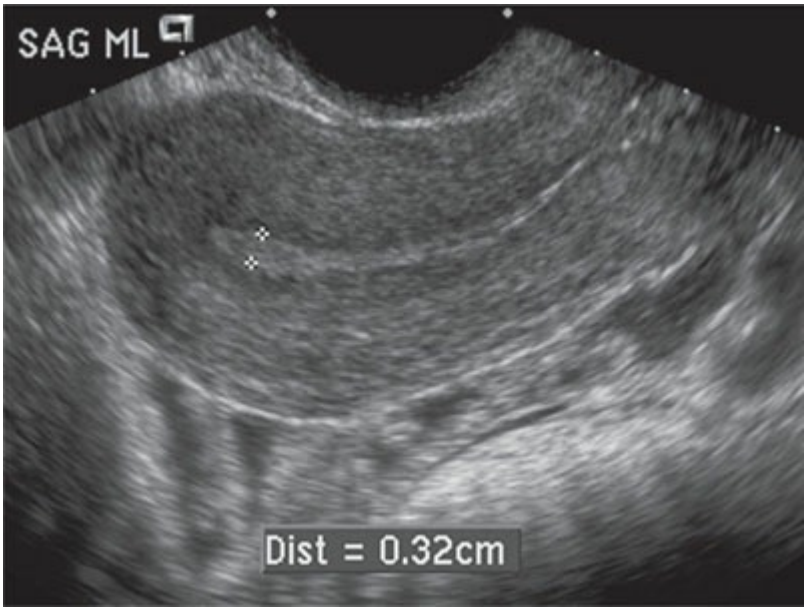


Figure 20-1 Normal postmenopausal endometrium. This endometrium (*between calipers*) appears thin and echogenic.

Endometrial Atrophy

In the postmenopausal patient, the endometrium often bleeds spontaneously secondary to atrophy. As a result, the most common cause of PMB is

endometrial atrophy. The endometrium will appear thin and should not exceed 5 mm, although with atrophy the endometrium typically measures 4 mm or thinner (Fig. 20-2). The endometrium may also contain some intracavitary fluid. A thin endometrial stripe in the postmenopausal patient usually does not warrant endometrial biopsy, although the patient's clinical history should be closely analyzed.

Endometrial Hyperplasia

Endometrial hyperplasia is a common cause of abnormal vaginal bleeding, not only in the postmenopausal female but also in the reproductive years. Endometrial hyperplasia results from the unopposed stimulation of estrogen on the endometrium. Secondary to continual estrogen stimulation, sonographically, the endometrium may contain small cystic spaces or appear diffusely echogenic (Fig. 20-3). Endometrial hyperplasia may also be caused by polycystic ovary syndrome, obesity, tamoxifen therapy for breast cancer, or estrogen-producing ovarian tumors, such as the ovarian thecoma or granulosa cell tumor. There seems to be an increased risk for one form of endometrial hyperplasia (atypical adenomatous hyperplasia) progressing into endometrial carcinoma more often in the postmenopausal woman. For this reason, an endometrial biopsy is typically warranted to rule out endometrial carcinoma.

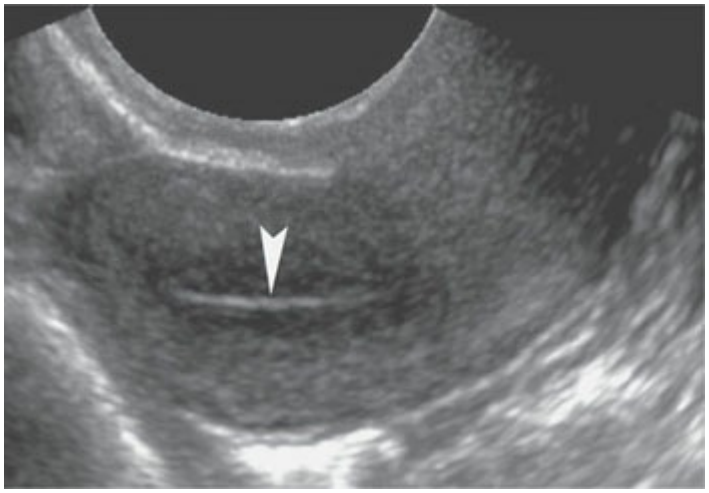


Figure 20-2 Endometrial atrophy. Longitudinal transvaginal sonogram revealing a thin endometrium (*arrowhead*) measuring only 2 mm in a postmenopausal woman with vaginal bleeding, which is indicative for endometrial atrophy.



Figure 20-3 A thickened endometrium (*between arrows*) is demonstrated in this patient with endometrial hyperplasia.

CLINICAL FINDINGS OF ENDOMETRIAL HYPERPLASIA

1. Abnormal uterine bleeding (any age)
2. Polycystic ovary syndrome
3. Obesity
4. Tamoxifen therapy

SONOGRAPHIC FINDINGS OF ENDOMETRIAL HYPERPLASIA

1. Thickened echogenic endometrium
2. Small cystic spaces within the endometrium

SOUND OFF

Endometrial hyperplasia may also be caused by polycystic ovary syndrome, obesity, tamoxifen therapy for breast cancer, or estrogen-producing ovarian tumors, such as the ovarian thecoma or granulosa cell tumor.

Endometrial Carcinoma

Endometrial carcinoma is the most common female genital tract malignancy, with PMB being the most common clinical presentation. Endometrial carcinoma is most often in the form of adenocarcinoma, and it has been linked with unopposed estrogen therapy, nulliparity, obesity, chronic anovulation, Stein–Leventhal syndrome, estrogen-producing ovarian tumors, and the use of tamoxifen. Peak incidence at the time of diagnosis is between

50 and 65 years of age. Tumors with penetration into the surrounding myometrium have a poorer prognosis than those confined to the endometrium.

The sonographic appearance of endometrial carcinoma is that of a thickened endometrium with variable echogenicity (Fig. 20-4). Sonographically, fluid and a polypoid mass may also be noted within the endometrium. Color Doppler should be applied to assess for vascularity within the thickened endometrium. Pulsed Doppler of the uterine cavity may indicate low-impedance flow in the presence of endometrial carcinoma. Suspicion of endometrial carcinoma typically leads to an endometrial biopsy, endocervical curettage, cancer antigen-125 (CA-125) testing, and in most confirmed cases the performance of a total abdominal hysterectomy with a bilateral salpingo-oophorectomy. Staging of the disease is performed surgically to determine the involvement of lymph nodes and the presence of extrauterine metastasis. These tumors may obstruct the cervical canal, thus leading to an accumulation of blood or pus within the uterus termed hematometra or pyometra, respectively.

CLINICAL FINDINGS OF ENDOMETRIAL CARCINOMA

1. Postmenopausal bleeding
2. Intermenstrual bleeding
3. Enlarged uterus
4. Elevation of CA-125

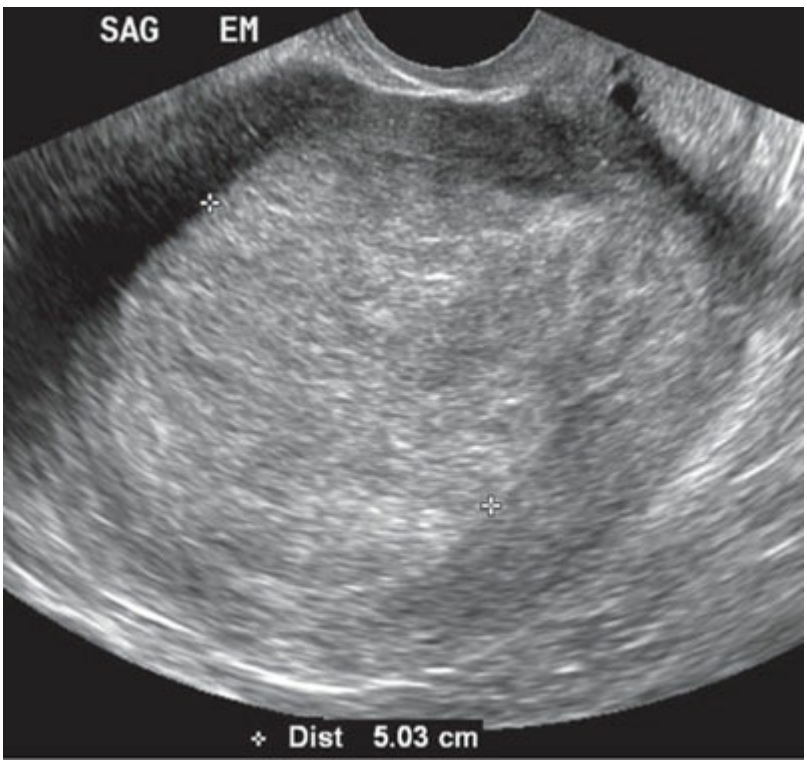


Figure 20-4 Endometrial carcinoma. Longitudinal transvaginal image of the uterus in

a postmenopausal patient revealing a markedly thickened and heterogeneous endometrium (*between calipers*) measuring over 5 cm. A biopsy revealed endometrial carcinoma.

SONOGRAPHIC FINDINGS OF ENDOMETRIAL CARCINOMA

1. Thickened endometrium
2. Heterogeneous uterus
3. Enlarged uterus with lobular contour
4. Endometrial fluid
5. Polypoid mass within the endometrium

SOUND OFF
Pulsed Doppler of the uterine cavity may indicate low-impedance flow in the presence of endometrial carcinoma.

Endometrial Polyps

Endometrial polyps are small nodules of hyperplastic endometrial tissue that may cause abnormal vaginal bleeding in both postmenopausal or perimenopausal woman. They have been linked with infertility during the reproductive period. Clinically, patients may present with menometrorrhagia and/or intermenstrual bleeding, or may even be asymptomatic. Endometrial polyps can have many different shapes, including a broad base, or can be pedunculated and, if large, may prolapse through the cervix. The sonographic appearance of an endometrial polyp varies and can appear as a focal echogenic area of thickening within the endometrium if solitary or a diffuse thickening of the endometrium in the presence of multiple or large polyps. An endometrial polyp will most often contain a small vessel and have cystic areas within it. Polyps are better visualized with the use of saline infusion sonohysterography (SIS) (Fig. 20-5). Three-dimensional sonography can be used to better demonstrate polyps as well (Fig. 20-6). Treatment for endometrial polyps is typically a polypectomy with the use of hysteroscopy.

SOUND OFF
A key clinical feature of patient with an endometrial polyp is intermenstrual bleeding.

CLINICAL FINDINGS OF ENDOMETRIAL POLYPS

1. Can be asymptomatic
2. Menometrorrhagia

3. Intermenstrual bleeding
4. Has been linked with infertility in reproductive-aged group

SONOGRAPHIC FINDINGS OF ENDOMETRIAL POLYPS

1. Focal thickening of the endometrium
2. Diffuse thickening of the endometrium

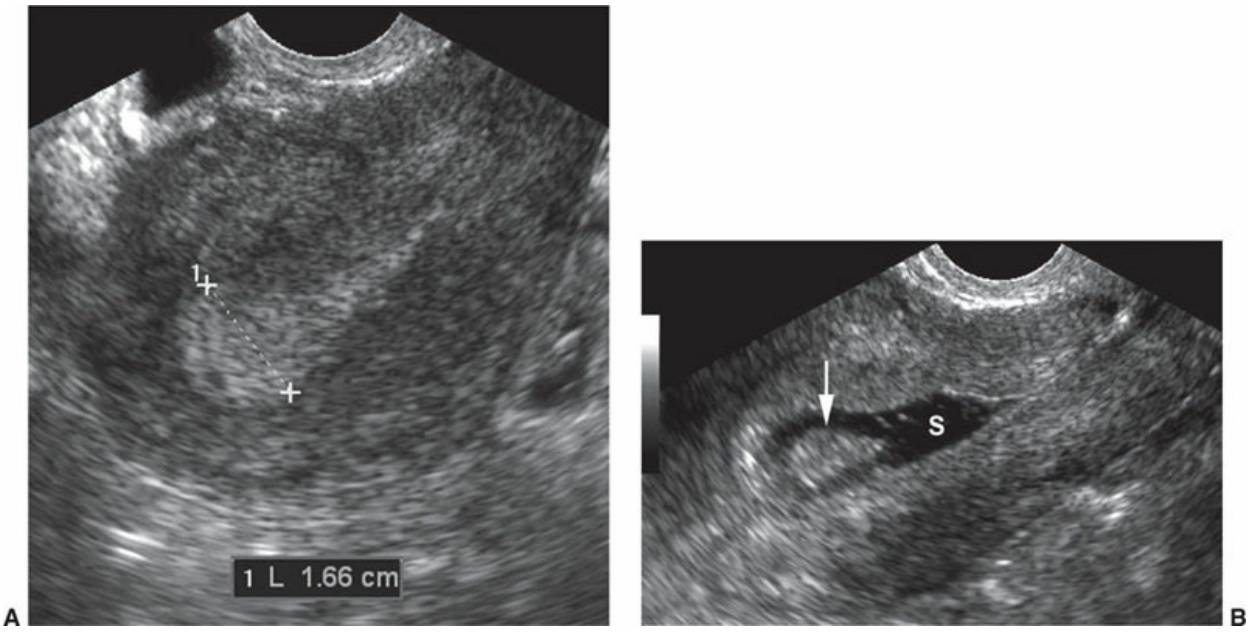


Figure 20-5 Endometrial polyp and saline infusion sonohysterography. **A.** A polyp is suspected in a patient with focal thickening of the endometrium (*between calipers*)**. B.** Saline (*S*) infusion sonohysterography better depicts the evidence of an endometrial polyp (*arrow*).

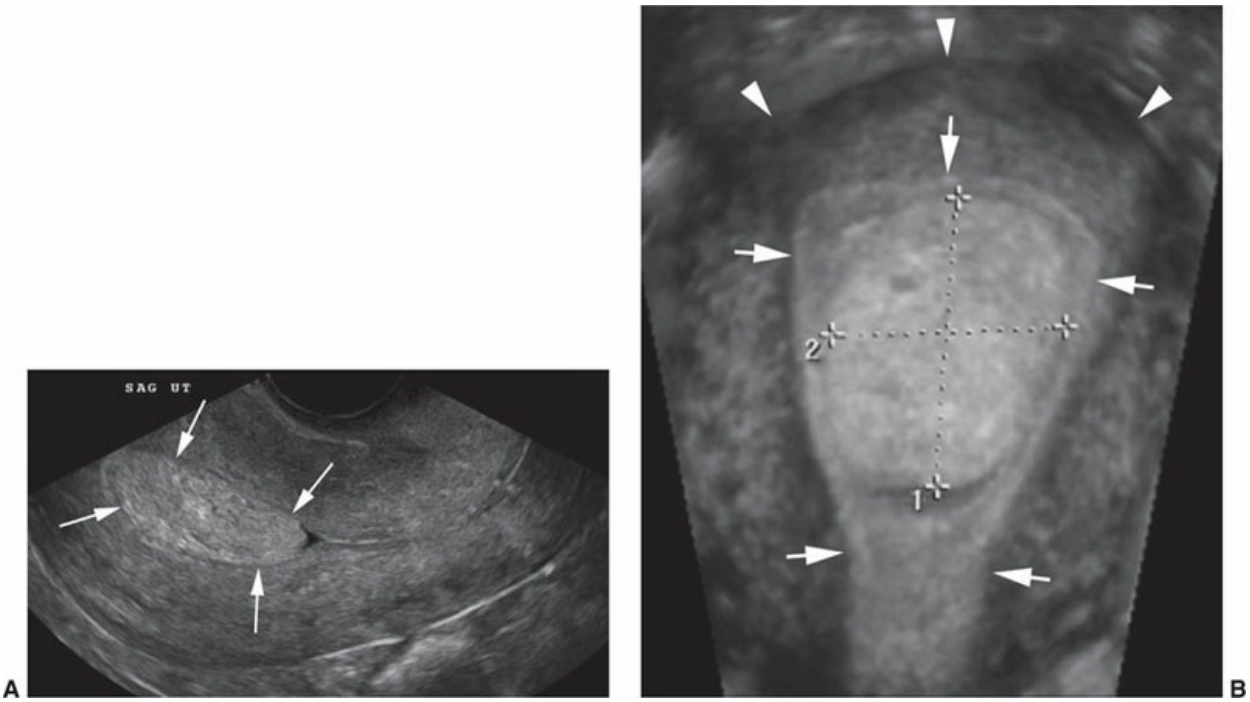


Figure 20-6 Three-dimensional endometrial polyp. **A.** Longitudinal image of a rounded mass (*between arrows*) within the endometrial cavity suggesting a polyp. **B.** Coronal reconstruction of the uterus (*arrowheads*) revealing the presence of a polyp (*between calipers*) within the endometrial cavity (*arrows*).

Ovarian Tumors and Postmenopausal Bleeding

Some functioning ovarian tumors and malignant ovarian neoplasms may in fact cause postmenopausal bleeding. For instance, estrogen-producing tumors such as the thecoma, which is mostly benign, have been shown to cause abnormal thickening of the endometrium with subsequent vaginal bleeding. In addition, the malignant serous and mucinous cystadenocarcinomas have been associated with vaginal bleeding.

CA-125

Serum levels of CA-125 are often elevated in women who have some forms of cancer. Elevation of this tumor marker has been linked with cancers of the ovary, endometrium, breast, gastrointestinal tract, and lungs. However, CA-125 may also be elevated in some benign conditions such as endometriosis, pelvic inflammatory disease, fibroids, and even pregnancy. Therefore, it is not typically used as a screening tool but more as an adjunct to clinical examination and diagnostic imaging tests.

Tamoxifen

Tamoxifen is a breast cancer drug that inhibits the effects of estrogen on the breast, thus slowing the growth of malignant breast cells. Tamoxifen can also be used in the treatment of female infertility as well. Unfortunately, tamoxifen use has been linked with the development of endometrial hyperplasia, endometrial polyps, and endometrial carcinoma. Sonographically, tamoxifen will cause cystic changes to occur within the endometrium, and it produces a more heterogeneous and thickened endometrial appearance (Fig. 20-7).

SONOHYSTEROGRAPHY

SIS, or saline infusion sonography or sonohysterography, is a procedure in which sterile saline is instilled into the uterine cavity with a catheter under sonographic guidance. Patients who present with abnormal uterine bleeding or have indications such as infertility, abnormally thickened endometrium, or a suspected intracavitary masses may be further evaluated with SIS. This procedure can help determine whether the cause of the vaginal bleeding is intracavitary in origin, such as in the case of an endometrial polyp (Fig. 20-

8). It is also helpful in differentiating an endometrial polyp from a submucosal fibroid. Endometrial polyps will be outlined by the saline and seen projecting into the uterine cavity from the endometrium, whereas the submucosal fibroid will have a layer of endometrium overlying the mass and originate in the myometrium.



Figure 20-7 Tamoxifen effects on the endometrium. A 62-year-old woman with postmenopausal bleeding undergoing tamoxifen therapy. The sagittal view of the uterus revealing a thickened endometrial lining (*between calipers*) with cystic changes. A polyp was confirmed.



Figure 20-8 SIS and multiple endometrial polyps. After instillation of saline, multiple polyps (*arrows*) are seen within the uterine cavity and are clearly outlined by the

saline. SIS, saline infusion sonohysterography.

Asherman Syndrome

Asherman syndrome is the presence of intrauterine adhesions or synechiae within the uterine cavity that typically occur as a result of scar formation after uterine surgery, especially after a dilation and curettage (D&C). The adhesions may cause hypomenorrhea or amenorrhea, pregnancy loss, and/or infertility (for more about the infertility link with Asherman syndrome, see Chapter 21). Sonographic detection is difficult without the use of sonohysterography. Sonohysterography findings include bright bands of tissue traversing the uterine cavity.

CLINICAL FINDINGS OF ASHERMAN SYNDROME

1. History of D&C, trauma, and uterine surgery
2. Recurrent pregnancy loss
3. Amenorrhea or hypomenorrhea

SONOGRAPHIC FINDINGS OF ASHERMAN SYNDROME

1. Bright areas within the endometrium
2. Sonohysterography findings include bright bands of tissue traversing the uterine cavity

REVIEW QUESTIONS

1. What is the most likely pulsed Doppler characteristic of endometrial cancer?
   a. Low-impedance flow
   b. High-impedance flow
   c. Absent systolic flow
   d. Converse diastolic flow

2. The absence of menstrual bleeding is termed:
   a. Amenorrhea
   b. Dysmenorrhea
   c. Oligomenorrhea
   d. Polymenorrhea

3. Asherman syndrome is associated with:
   a. Uterine leiomyoma

b. Endometrial polyps
c. Endometrial adhesions
d. Ovarian fibroma

4. What would increase a patient's likelihood of suffering from thromboembolism?
   a. Polycystic ovary disease
   b. ERT
   c. Endometrial carcinoma
   d. Endometrial atrophy

5. What is used as a tumor marker for endometrial carcinoma?
   a. CR-124
   b. CE-125
   c. CA-125
   d. CA-45

6. The removal of tissue from the endometrium by scraping is termed:
   a. Dilatation
   b. Curettage
   c. Sonohysterography
   d. Hysteroscopy

7. What is the most common form of endometrial carcinoma?
   a. Cystadenocarcinoma
   b. Krukenberg tumor
   c. Adenocarcinoma
   d. Squamous cell carcinoma

8. Measurement of the endometrium should include:
   a. The uterine cavity only
   b. The deep myometrial echoes and both basal layers
   c. The distance from the basal layer to the functional layer
   d. The measurement from the basal layer to the basal layer

9. The most common cause of postmenopausal bleeding is:
   a. Endometrial carcinoma
   b. Endometrial atrophy
   c. Endometrial leiomyoma
   d. Cervical carcinoma

10. Which of the following is not associated with endometrial hyperplasia?
    a. Tamoxifen therapy

b. Polycystic ovary syndrome
c. Ovarian thecoma
d. Asherman syndrome

11. The best description for endometrial polyps is:
a. Malignant nodules that cause bleeding
b. Benign lesions associated with cervical stenosis
c. Malignant nodules that are associated with endometrial atrophy
d. Benign nodules of hyperplastic endometrial tissue

12. Blood accumulation within the uterus is termed:
a. Hematometra
b. Hydrometra
c. Asherman syndrome
d. Endometrial carcinoma

13. Which of the following would increase the risk of a patient developing endometrial cancer?
a. Unopposed ERT
b. Multiparity
c. Osteoporosis
d. Endometrial atrophy

14. What is a gynecologic procedure to remove an endometrial polyp?
a. Hysterectomy with myomectomy
b. Histogram with myomectomy
c. Hysteroscopy with polypectomy
d. Hysteroscopy with polyp myomectomy

15. Cessation of menstruation with advanced age is termed:
a. Asherman disease
b. Premenopausal syndrome
c. Perimenopausal syndrome
d. Menopause

16. Stein–Leventhal syndrome is related to all of the following except:
a. Infertility
b. Anovulatory cycles
c. Hirsutism
d. Ovarian hyperstimulation syndrome

17. What hormone plays a major role in the symptoms associated with menopause?

a. hCG
b. LH
c. Estrogen
d. CA-120

18. The breast cancer treatment drug that may alter the sonographic appearance of the endometrium is:
    a. Progestogen
    b. Estrogenate
    c. Tamoxifen
    d. CA-125

19. Possible benefits of ERT include all of the following except:
    a. Reduction in osteoporosis risk
    b. Reduction in colon cancer risk
    c. Reduction in heart disease risk
    d. Reduction in endometrial cancer risk

20. Which of the following does not occur as a result of menopause?
    a. Uterine atrophy
    b. Decreased sexual libido
    c. Accumulation of fat in the breasts
    d. Cystic enlargement of the ovaries

21. Unopposed estrogen therapy has been shown to increase the risk for developing:
    a. Alzheimer disease
    b. Colon cancer
    c. Coronary heart disease
    d. Endometrial carcinoma

22. The sonographic appearance of a 59-year-old woman on HRT is:
    a. Hypoechoic and thickened
    b. Hyperechoic and thickened
    c. Cystic areas within a thickened endometrium
    d. Variable depending upon the menstrual cycle

23. Tamoxifen has been linked with all of the following except:
    a. Endometrial polyps
    b. Endometrial hyperplasia
    c. Endometrial leiomyoma
    d. Endometrial carcinoma

24. Which of the following ovarian tumors would be most likely to cause postmenopausal bleeding?
    a. Cystic teratoma
    b. Endometrioma
    c. Thecoma
    d. Fibroma

25. Tamoxifen effects on the endometrium will sonographically appear as:
    a. Cystic changes within a thickened endometrium
    b. Cystic areas within a thin endometrium
    c. Thin endometrium
    d. No apparent effect on endometrial thickness or appearance

26. Which of the following would most likely lead to the development of endometrial adhesions?
    a. Endometrial carcinoma
    b. D&C
    c. Pregnancy
    d. Adenomyomatosis

27. Causes of postmenopausal bleeding include all of the following except:
    a. Asherman syndrome
    b. Endometrial atrophy
    c. Endometrial hyperplasia
    d. Intracavitary fibroids

28. An asymptomatic 65-year-old patient presents to the sonography department with pelvic pain but no vaginal bleeding. Her endometrial thickness should not exceed:
    a. 6 mm
    b. 8 mm
    c. 5 mm
    d. 3 mm

29. An 84-year-old patient presents to the sonography department with sudden onset of vaginal bleeding. Her endometrium should not exceed:
    a. 6 mm
    b. 8 mm
    c. 5 mm
    d. 3 mm

30. With endometrial atrophy, the endometrial thickness should not exceed:
    a. 6 mm

b. 3 mm
c. 8 mm
d. 5 mm

31. A 68-year-old patient presents to the sonography department complaining of vaginal bleeding. The most likely cause of her bleeding is:
a. Endometrial carcinoma
b. Endometrial polyps
c. Endometrial atrophy
d. Endometrial fibroids

32. A 60-year-old patient presents to the emergency department with sudden onset of vaginal bleeding. The sonographic examination reveals an endometrium that measures 4 mm. There are no other significant sonographic findings. What is the most likely diagnosis?
a. Endometrial atrophy
b. Endometrial carcinoma
c. Endometrial polyp
d. Cervical stenosis

33. A 67-year-old patient on HRT presents to the sonography department with abnormal uterine bleeding. Sonographically, the endometrium is diffusely thickened, contains small cystic areas, and measures 9 mm in thickness. The most likely cause of her bleeding is:
a. Endometrial atrophy
b. Asherman syndrome
c. Endometrial thecoma
d. Endometrial hyperplasia

34. Endometrial hyperplasia may be caused by all of the following except:
a. HRT
b. ERT
c. Endometrial atrophy
d. Tamoxifen

35. All of the following are clinical findings with endometrial hyperplasia except:
a. Obesity
b. Polycystic ovary syndrome
c. Abnormal uterine bleeding
d. Thickened endometrium

36. The sonographic findings of an endometrial polyp may include:

a. Diffuse thickening of the endometrium
b. Menometrorrhagia
c. Intermenstrual bleeding
d. Infertility

37. Endometrial polyps are associated with all of the following except:
a. Intermenstrual bleeding
b. Tamoxifen therapy
c. Prolapse through the cervix
d. Coronary heart disease

38. A 34-year-old patient presents to the sonography department for an endovaginal sonogram complaining of intermenstrual bleeding. The sonographic findings include a focal irregularity and enlargement of one area of the endometrium. The most likely diagnosis is:
a. Endometrial polyps
b. Endometrial carcinoma
c. Endometrial atrophy
d. Intramural leiomyoma

39. The most common female genital tract malignancy is:
a. Ovarian carcinoma
b. Cervical carcinoma
c. Endometrial carcinoma
d. Pelvic inflammatory disease

40. A 31-year-old patient presents to the sonography department for a saline infusion sonohysterogram complaining of intermenstrual bleeding and infertility. Sonographically, a mass is demonstrated emanating from the myometrium and distorting the endometrial cavity. What is the most likely diagnosis?
a. Endometrial polyp
b. Endometrial carcinoma
c. Endometrial hyperplasia
d. Submucosal leiomyoma

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21

Pelvic Inflammatory Disease and Infertility

Introduction

This chapter discusses the clinical manifestation and sonographic appearance of pelvic inflammatory disease and associated pathology. Given that there is a notable relationship between pelvic infections and infertility, this chapter also provides an overview of the causes and treatment of female infertility. A discussion on assisted reproductive technology and contraceptive use is also provided.

Key Terms

acute respiratory distress syndrome—the buildup of fluid within the air sacs or alveoli within the lungs

adhesions—irregular bands of tissue

amenorrhea—absence of menstruation

androgen—a hormone, such as testosterone, that is responsible for male characteristics

anovulation—lack of ovulation

Asherman syndrome—syndrome characterized by endometrial adhesions that typically occur as a result of scar formation after some types of uterine surgery

bicornuate uterus—a common uterine anomaly in which the endometrium divides into two horns; also referred to as bicornis unicollis

cervicitis—inflammation of the cervix

chlamydia—a sexually transmitted disease that can lead to an infection of the genital tract in both sexes

cholecystitis—inflammation of the gallbladder

Clomid or clomiphene citrate—fertility drug used to treat anovulation

dysmenorrhea—difficult or painful menstruation

dyspareunia—painful sexual intercourse

dysuria—painful or difficult urination

ectopic pregnancy—a pregnancy located outside the endometrial cavity of the uterus

endometriosis—functional ectopic endometrial tissue located outside the uterus

endometritis—inflammation of the endometrium

Essure device—a permanent form of birth control that uses small coils placed into the proximal isthmic segment of the fallopian tubes

Fitz-Hugh–Curtis syndrome—a perihepatic infection that results in liver capsule inflammation from pelvic infections such as gonorrhea and chlamydia

follicular aspiration—technique used for in vitro fertilization in which follicles are drained for oocyte retrieval

gamete intrafallopian tube transfer—infertility treatment in which oocytes and sperm are placed in the fallopian tube by means of laparoscopy

gonorrhea—a sexually transmitted disease that can lead to pelvic inflammatory disease

hepatorenal space—peritoneal space located between the liver and right kidney; also referred to as Morison pouch

heterotopic pregnancy—coexisting ectopic and intrauterine pregnancies

hirsutism—excessive hair growth in women in areas where hair growth is normally negligible

hydrosalpinx—the abnormal accumulation of fluid within the fallopian tube

hyperandrogenism—excessive serum androgen levels; produces male characteristics in females

hyperemic—an increase in blood flow

hypomenorrhea—decreased or scant menstrual flow

hysterosalpingography—a radiographic procedure that uses a dye instilled into the endometrial cavity and fallopian tubes to evaluate for internal abnormalities

in vitro fertilization—fertility treatment that requires that a mature ovum be extracted from the ovary, with fertilization taking place outside of the body

infertility—the inability to conceive a child after 1 year of unprotected intercourse

intracavitary (fibroid)—a leiomyoma located within the uterine cavity

intrauterine device—a common form of birth control in which a small device is placed within the endometrium to prevent pregnancy; also referred to as an intrauterine contraceptive device

leukocytosis—an elevated white blood cell count

luteal phase deficiency—when the endometrium does not develop appropriately in the luteal phase of the endometrial cycle as a result of reduced progesterone production

Mirena—a small plastic T-shaped intrauterine device

obesity—overweight to the point of causing significant health problems and increased mortality

oligomenorrhea—infrequent or light menstrual periods

oliguria—scant or decreased urine output

oocyte retrieval—the removal of oocytes from ovarian follicles by aspiration

ovarian hyperstimulation syndrome—a syndrome resulting from hyperstimulation of the ovaries by fertility drugs; results in the development of multiple, enlarged follicular ovarian cysts

ovarian torsion—an abnormality that results from the ovary twisting on its mesenteric connection, consequently cutting off the blood supply to the ovary

ovulation induction—the stimulation of the ovaries by hormonal therapy in order to treat infertility

ParaGard—intrauterine contraceptive device that utilizes copper in its composition to inhibit sperm transport, or to prevent fertilization or transplantation

pelvic inflammatory disease—infection of the female genital tract that may involve the ovaries, uterus, and/or the fallopian tubes

Pergonal—infertility medicine used to stimulate the follicular development of the ovaries

polycystic ovary syndrome—syndrome characterized by anovulatory cycles, infertility, hirsutism, amenorrhea, and obesity; may also be referred to as Stein–Leventhal syndrome

postpartum—time directly after giving birth and extending to about 6 weeks

progestin—synthetic progesterone secreted by some intrauterine devices to regulate menstrual flow

purulent—an inflammatory reaction that leads to the formation of pus

pyometra—the presence of pus within the uterus

pyosalpinx—the presence of pus within the fallopian tube

ring-down artifact—artifact seen posterior to air or gas bubbles

salpingitis—inflammation of the fallopian tube

selective reduction—a method of reducing the number of pregnancies in a multiple gestation, whereby certain embryos/fetuses are terminated

septate uterus—congenital malformation of the uterus that results in a single septum that separates two endometrial cavities

sequela—an illness resulting from another disease, trauma, or injury

sonohysterography—a sonographic procedure that uses saline instillation into the endometrial cavity and fallopian tubes to evaluate for internal abnormalities; also referred to as a sonohysterogram

Stein–Leventhal syndrome—see key term polycystic ovary syndrome

"string of pearls" sign—sonographic finding that is described as the presence of 10 or more small cysts measuring 2 to 18 mm along the periphery of the ovary

submucosal (fibroid)—a leiomyoma that distorts the shape of the endometrium

synechiae—adhesion

theca lutein cysts—functional ovarian cysts that are found in the presence of elevated levels of human chorionic gonadotropin; also referred to as a theca luteal cyst

thromboembolism—the formation of clot within a blood vessel with the potential to travel to a distant site and cause an occlusion

tubal ligation—a permanent form of female sterilization in which the fallopian tubes are severed

tubal sterilization—see key term tubal ligation

tubo-ovarian abscess—a pelvic abscess involving the fallopian tubes and ovaries that is often caused by pelvic inflammatory disease

tubo-ovarian complex—when adhesions develop within the pelvis that leads to the fusion of the ovaries and the dilated tubes as a result of pelvic inflammatory disease

upper genital tract—the uterus, ovaries, and fallopian tubes

uterine leiomyoma—a benign, smooth muscle tumor of the uterus; may also be referred to as a fibroid or uterine myoma

vaginitis—inflammation of the vagina

zygote intrafallopian transfer—infertility treatment where the zygote is

placed into the fallopian tube

PELVIC INFLAMMATORY DISEASE

Pelvic inflammatory disease (PID) is an infection of the upper genital tract. The origin of the majority of upper genital tract infections is ascension of an infection from the lower genital tract. Infections can travel into normally sterile areas such as the endometrium and fallopian tubes.

Previous history of PID, the utilization of an intrauterine contraceptive device (IUD), postabortion, post childbirth, douching, multiple sexual partners, and early sexual contact have all been established as risk factors for developing PID. PID may manifest after pelvis surgery, accompany tuberculosis, or occur in association with an abscessed appendix or ruptured colonic diverticulum. A common cause of PID is sexually transmitted diseases like chlamydia and gonorrhea. However, about half of PID cases have non–sexually transmitted disease causes, such as vaginal flora, anaerobic gram-negative rods, and Mycoplasma bacteria. PID is characteristically a bilateral condition affecting not only the uterus but also both fallopian tubes, and possibly the ovaries. The sequela of PID range from a negligible infection that is relatively easy to treat, to the development of a tubo-ovarian abscess. In some cases, PID may also lead to death. Potent antibiotic treatment is typically warranted.



SOUND OFF

A common cause of PID is sexually transmitted diseases like chlamydia and gonorrhea.

Clinically, patients with PID tend to have complaints such as fever, chills, pelvic pain, cervical motion tenderness, purulent vaginal discharge with foul odor, vaginal itchiness, vaginal bleeding, and dyspareunia. Leukocytosis is also present. The sonographic findings of acute and chronic PID vary. The uterus involved with an acute infection may show signs of a thickened, irregular endometrium, which is often indicative of endometritis. The uterus can have ill-defined borders, and the fallopian tubes may contain fluid (Fig. 21-1). Echogenic material within the tubes can be evidence of pyosalpinx, whereas simple-appearing fluid may be referred to as hydrosalpinx. The sonographer should look for further signs of a tubo-ovarian abscess (see “Tubo-ovarian Complex and Tubo-ovarian Abscess” section). The possible evolution of PID will be discussed in detail in the subsequent sections, but Table 21-1 provides a brief summary.



Figure 21-1 Pelvic inflammatory disease. Transverse transabdominal image of the female pelvis revealing bilateral complex adnexal masses (*arrows*) in the setting of an extensive pelvic infection.

TABLE 21-1 Evolution of PID

Vaginitis → Cervicitis → Endometritis → Salpingitis → Tubo-ovarian complex → Tubo-ovarian abscess

Chronic PID can lead to continual pelvic or abdominal pain, infertility (resulting from adhesions and scaring of the fallopian tubes), possible palpable adnexal mass, and irregular menses (Fig. 21-2). Sonographically, the long-standing PID can reveal evidence of markedly distended fallopian tubes, the development of adhesion between the pelvic organs, and further findings consistent with tubo-ovarian complex and/or tubo-ovarian abscess.

CLINICAL FINDINGS OF ACUTE PELVIC INFLAMMATORY DISEASE

1. Possible history of a sexually transmitted disease (chlamydia or gonorrhea)
2. Fever
3. Chills
4. Pelvic pain and/or tenderness
5. Purulent vaginal discharge
6. Vaginal bleeding or itchiness
7. Dyspareunia
8. Leukocytosis

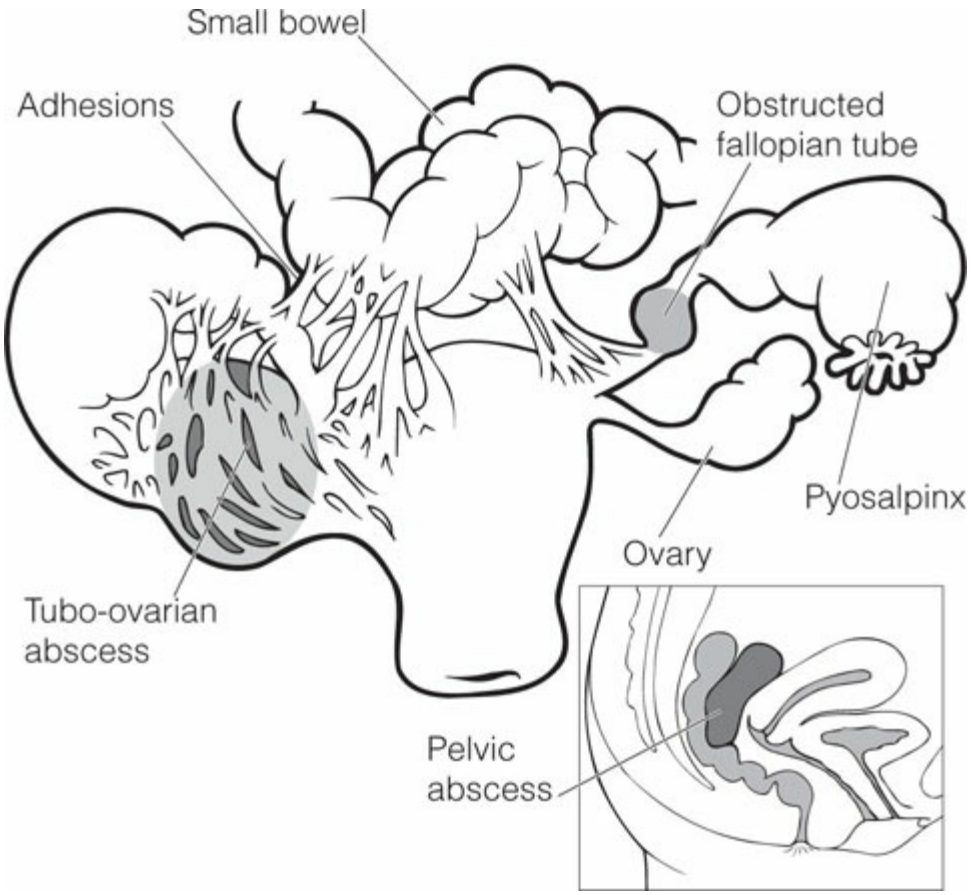


Figure 21-2 Results of chronic pelvic inflammatory disease.

SONOGRAPHIC FINDINGS OF ACUTE PELVIC INFLAMMATORY DISEASE

1. Thickened, irregular endometrium (endometritis)
2. Ill-defined uterine borders
3. Tubular structures representing dilated fallopian tubes containing echogenic material (pyosalpinx)
4. Tubular structures representing dilated fallopian tubes containing simple-appearing, anechoic fluid (hydrosalpinx)
5. Cul-de-sac fluid
6. Multicystic and solid complex adnexal mass(es) (see “Tubo-ovarian Complex and Tubo-ovarian Abscess” section)

CLINICAL FINDINGS OF CHRONIC PELVIC INFLAMMATORY DISEASE

1. Continual pelvic or abdominal pain
2. Infertility (resulting from adhesions and scaring of the fallopian tubes)
3. Possible palpable adnexal mass
4. Irregular menses
5. Purulent vaginal discharge

SONOGRAPHIC FINDINGS OF CHRONIC PELVIC INFLAMMATORY DISEASE

1. Dilated fallopian tubes containing simple-appearing, anechoic fluid (hydrosalpinx)
2. Scars may be noted within the dilated tube and appear as echogenic bands within the tube
3. Development of adhesions may obliterate distinct borders of organs because they become fixated to each other
4. Multicystic and solid complex adnexal mass(es) (see "Tubo-ovarian Complex and Tubo-ovarian Abscess" section)

Vaginitis and Cervicitis

Vaginitis is the most common initial clinical presentation in the early stages of PID. Vaginitis can lead to excessive vaginal discharge, and in cases of PID, patient may present with a purulent, foul-smelling discharge. The progression of the infection into the cervix is termed cervicitis. Although vaginitis and cervicitis may not be apparent with sonography, sonography may be utilized to determine whether the infection has spread to the upper genital tract in patients with positive cultures. Infections that do ascend into the endometrium may lead to inflammation of the endometrium—termed endometritis.

Endometritis

Endometritis is the inflammation of the endometrium. It may occur postpartum, after a dilation and curettage (D&C), in the presence of PID, after surgery, and may be seen with an intrauterine device (IUD). Patients complain of pelvic tenderness, fever, and will have evidence of leukocytosis. In some patients, pyometra, which is described as pus formation within the endometrium, may occur. Endometritis appears sonographically as a thickened echogenic or irregular-appearing endometrium that may contain some intraluminal fluid. Gas or air formation within the thickened endometrium may be seen and will produce a distinct ring-down artifact. Endometritis can be effectively treated with oral antibiotics and/or curettage.



SOUND OFF

Endometritis appears sonographically as a thickened or irregular-appearing endometrium that may contain some intraluminal fluid. Gas formation within the thickened endometrium may be seen and will produce a distinct ring-down artifact.

CLINICAL FINDINGS OF ENDOMETRITIS

1. History of recent abortion, postpartum, D&C, PID, surgery, or intrauterine device
2. Pelvic tenderness
3. Fever
4. Leukocytosis

SONOGRAPHIC FINDINGS OF ENDOMETRITIS

1. Thickened echogenic or irregular-appearing endometrium
2. Endometrial fluid
3. Ring-down artifact from gas or air within the endometrium

Pelvic Inflammatory Disease and the Fallopian Tubes

The fallopian tubes, often difficult to visualize with sonography, may be seen in the presence of PID. The spread of the infection beyond the endometrium can lead to inflammation of the fallopian tubes, commonly referred to as salpingitis. The tubes subsequently distend, thus allowing for visualization with sonography. Unfortunately, in cases where salpingitis is present and the tube is not distended, it may be difficult to determine whether salpingitis is present with sonography. In these instances, the sonographic evidence of salpingitis can be depicted by documenting hyperemic flow within or around the tube. This is best demonstrated with the use of color Doppler. In addition, there may be signs of nodular thickening in the wall of the affected tube.

Patients suffering from salpingitis from PID may present clinically with symptoms resembling cholecystitis. Pelvic infections, such as chlamydia or gonorrhea, can actually lead to a perihepatic infection and the subsequent development of adhesions located between the liver and the diaphragm. As a result, the liver capsule can become inflamed, thus leading to a clinical presentation much like gallbladder disease. This event is called Fitz-Hugh–Curtis syndrome. Thus, right upper quadrant pain, free fluid within the hepatorenal space (Morison pouch), and elevated liver function tests may be noted with this condition.



SOUND OFF

The liver capsule can become inflamed, thus leading to a clinical presentation much like gallbladder disease. This event is called Fitz-Hugh–Curtis syndrome.

Tubal infections often lead to fluid accumulation within the lumen of the tube. Pyosalpinx is the result of the tube becoming distended with purulent fluid (pus), sonographically represented by a dilated fallopian tube filled with

thick, echogenic material (Fig. 21-3). The accumulation of simple, anechoic, serous fluid within the dilated fallopian tube may also occur. This is referred to as hydrosalpinx.

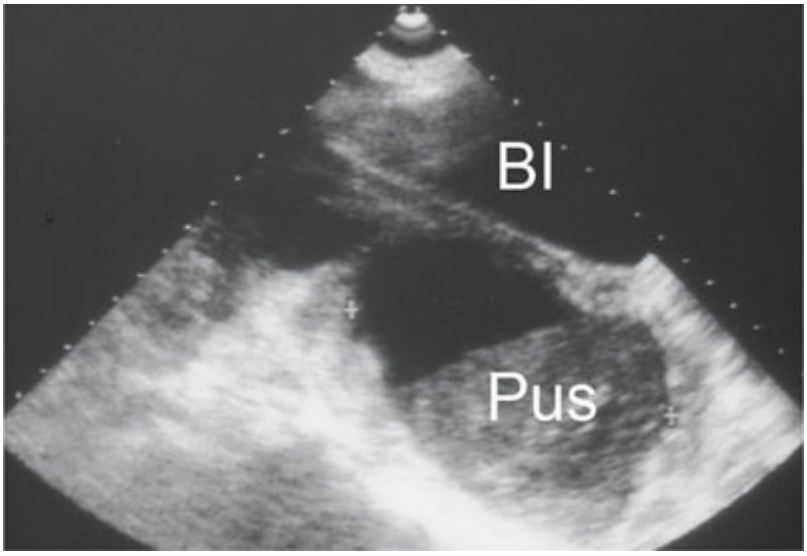


Figure 21-3 Pyosalpinx. This dilated tube (between calipers), seen posterior to the urinary bladder (*Bl*), contains pus and has a thickened wall.

PID has been linked with infertility and ectopic pregnancy. This is secondary to the formation of scarring within the formerly inflamed opening of the fallopian tube. Scar formation can disrupt the motility and function of the tube and/or inhibit the likelihood of conception. If conception does occur, the development of scar tissue within the fallopian tube increases the possibility of the pregnancy implanting in the tube, thus leading to an ectopic pregnancy.

SOUND OFF

PID has been linked with infertility and ectopic pregnancy. This is secondary to the formation of scarring within the formerly inflamed opening of the fallopian tube. Scar formation can disrupt the motility and function of the tube and/or inhibit the likelihood of conception.

CLINICAL FINDINGS OF SALPINGITIS

1. Findings consistent with PID
2. Pelvic tenderness
3. Fever
4. Leukocytosis

SONOGRAPHIC FINDINGS OF SALPINGITIS

1. Distended fallopian tube filled with echogenic material (pus) or anechoic fluid
2. Hyperemic flow within or around the affected fallopian tube depicted with color Doppler
3. Nodular, thickened wall of the fallopian tube

Tubo-ovarian Complex and Tubo-ovarian Abscess

As PID progresses and reaches beyond the fallopian tubes, the ovaries and peritoneum become involved. Consequently, adhesions develop within the pelvis that lead to the fusion of the ovaries and the dilated tubes, a condition known as tubo-ovarian complex (Fig. 21-4). Further progression of PID beyond this stage leads to a tubo-ovarian abscess. The sonographic findings of these two processes are similar in that upon sonographic examination the pelvic structures are often indistinguishable, with a loss of discrete borders of the adnexal structures occurring more often when an abscess has developed (Fig. 21-5). Treatments for these two conditions differ in that drainage is required only when an abscess has developed. Consequently, it is important to understand the sonographic appearance of both abnormalities.

Sonographically, the tubo-ovarian complex has signs of PID progression that includes a thickened, irregular endometrium, pyosalpinx or hydrosalpinx, cul-de-sac fluid, and often bilateral complex adnexal masses. The distinguishing feature is that the ovaries and tubes are more readily recognized as distinct structures, but the ovaries will not be able to be separated from the tube by pushing with the vaginal probe. Conversely, when an tubo-ovarian abscess is present within the pelvis, there will be a complete loss of borders of all adnexal structures, and the development of a conglomerated adnexal (possibly bilateral) mass.

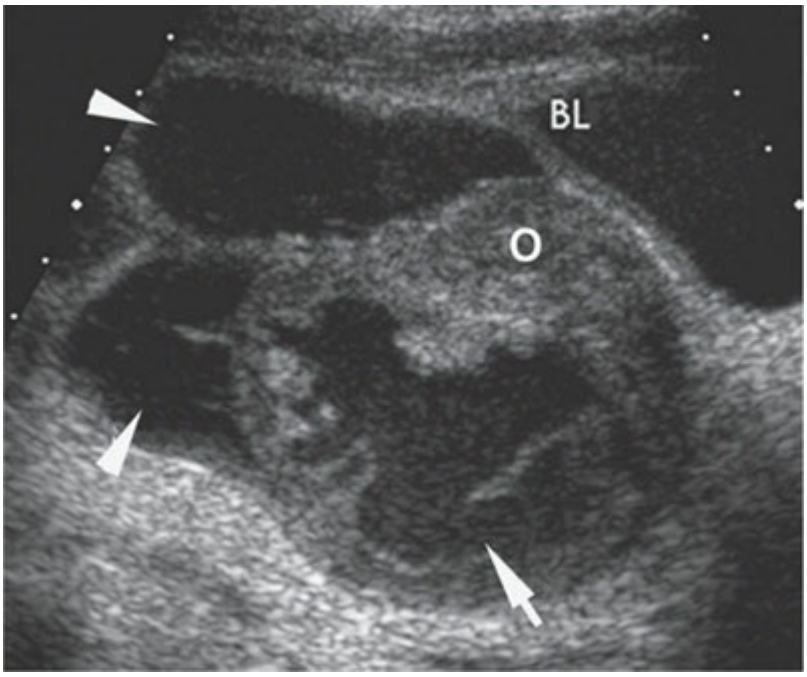


Figure 21-4 Tubo-ovarian complex. Longitudinal transabdominal image of the adnexa revealing a complex adnexal mass (*arrow*) composed of a dilated fallopian tube (*arrowheads*) and enlarged ovary (*O*) seen posterior to the bladder (*BL*).

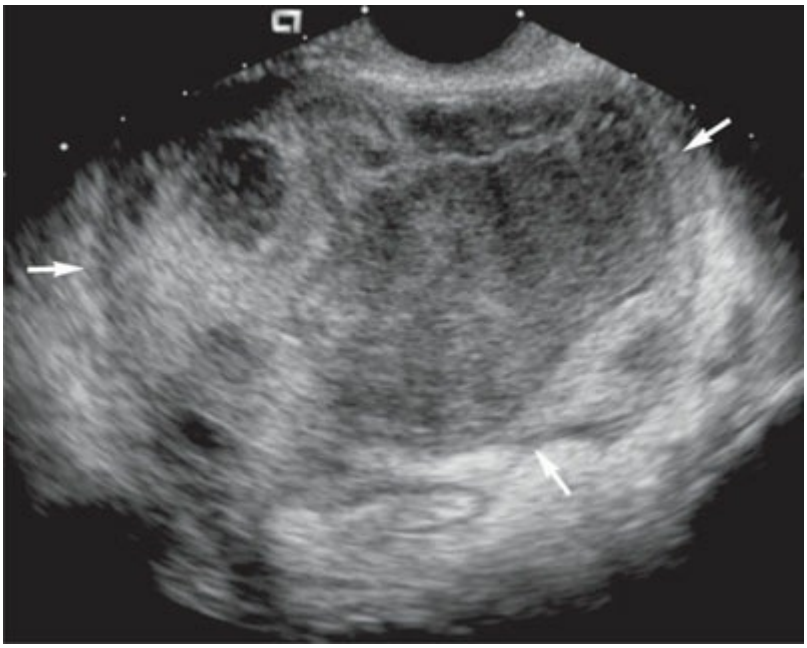


Figure 21-5 Tubo-ovarian abscess. Transvaginal image of a complex adnexal mass (*arrows*) with poorly defined borders and complex fluid.

SOUND OFF

With tubo-ovarian complex, the ovaries and tubes are more readily recognized as distinct structures, but the ovaries will not be able to be separated from the tube by pushing with the vaginal probe.

CLINICAL FINDINGS OF TUBO-OVARIAN COMPLEX AND TUBO-OVARIAN ABSCESS

1. Findings consistent with PID

SONOGRAPHIC FINDINGS OF TUBO-OVARIAN COMPLEX

1. Thickened, irregular endometrium
2. Pyosalpinx or hydrosalpinx
3. Cul-de-sac fluid
4. Multicystic and solid complex adnexal mass(es)
5. Ovaries and tubes recognized as distinct structures, but the ovaries will not be separated from the tube by pushing with the vaginal probe

SONOGRAPHIC FINDINGS OF TUBO-OVARIAN ABSCESS

1. Thickened, irregular endometrium
2. Pyosalpinx or hydrosalpinx
3. Cul-de-sac fluid
4. Multicystic and solid complex adnexal mass(es)
5. Complete loss of borders of all adnexal structures, and the development of a conglomerated adnexal (possibly bilateral) mass

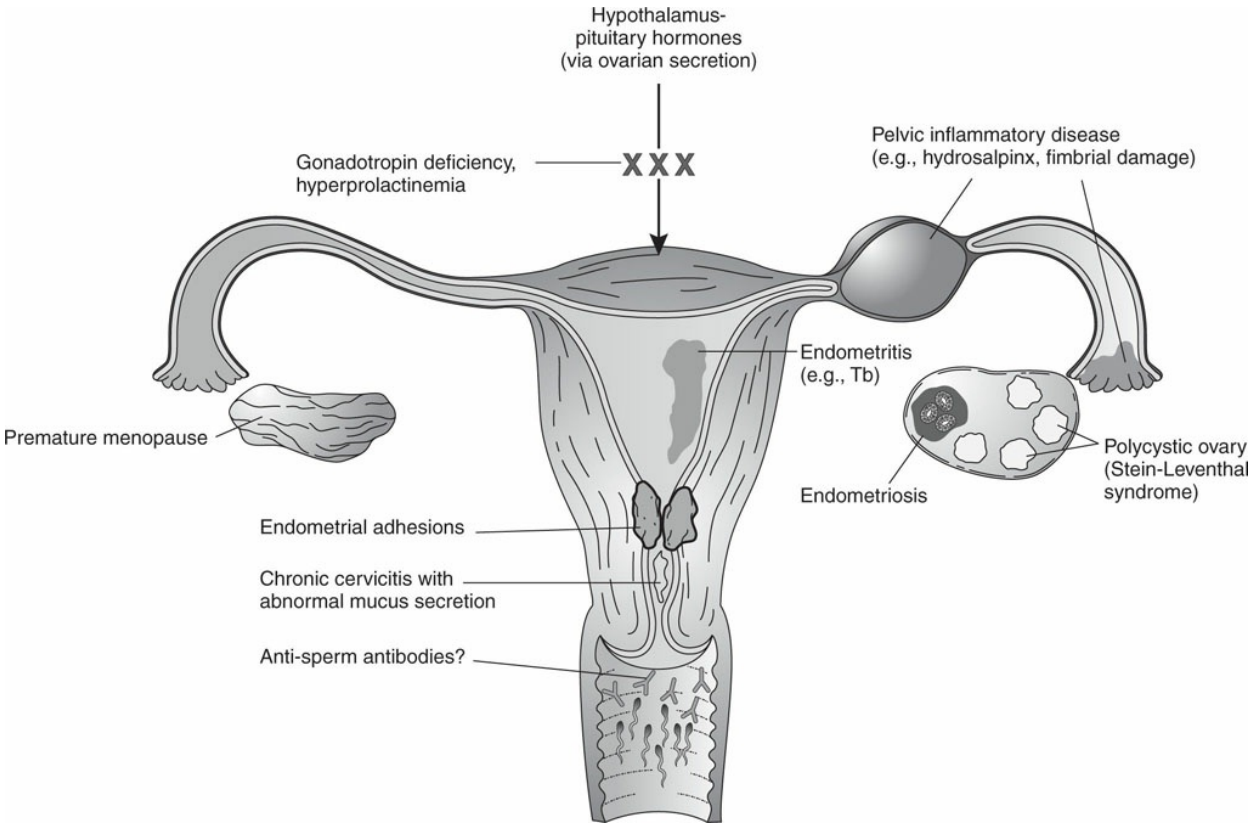


Figure 21-6 Acquired causes of female infertility.

CAUSES OF FEMALE INFERTILITY

Infertility is defined as the inability to conceive a child after 1 year of unprotected intercourse. For females, there can be several different causes of infertility (Fig. 21-6). As noted in the beginning of this chapter, PID is a common cause of infertility. Congenital uterine malformations (especially septate uterus), endometriosis, polycystic ovarian syndrome, tubal causes, Asherman syndrome, and uterine leiomyomas, and their impact on female infertility, are all topics of discussion in the following sections.

Congenital Uterine Malformations and Infertility

Congenital uterine malformations, also referred to as Müllerian anomalies, have been linked with female infertility. Rather than preventing pregnancy from occurring, uterine malformations often lead to repeated abortions as a

result of structural abnormalities within the uterus. The various types of uterine malformations are discussed in Chapter 17. Bicornuate uterus is a common structural defect of the uterus that could lead to fertility troubles. In addition, a septate uterus frequently requires surgical intervention to reduce the division of the uterine cavity. For patients with a septate uterus, sonography can also aid in the resection of the septum during a hysteroscopic uterine septoplasty. Specifically, transabdominal sonography can provide the proximity of the uterine repair to the subserosal surface to help prevent unnecessary bleeding.

Endometriosis

Endometriosis is defined as functional, ectopic endometrial tissue located outside the uterus (Fig. 21-7). Implantation of ectopic endometrial tissue may be the result of endometrial tissue being passed through the fallopian tubes during menstruation or may result from scarring from surgery, such as after a cesarean section. This ectopic tissue does undergo physiologic changes as a result of stimulation by the hormones of the menstrual cycle. Hemorrhage of this tissue often occurs, resulting in focal areas of bloody tumors known as endometriomas or chocolate cysts. Endometriosis can be located anywhere throughout the pelvis, with the most common location being the ovaries. It has even been found within cesarean section scars, the appendix, lungs, liver, and extremities. The age of the patients at the time of diagnosis is typically between 25 and 35 years, with the common clinical findings being pelvic pain, dyspareunia, and infertility. Patient may also have dysmenorrhea, menorrhagia, painful bowel movements, or may be completely asymptomatic.

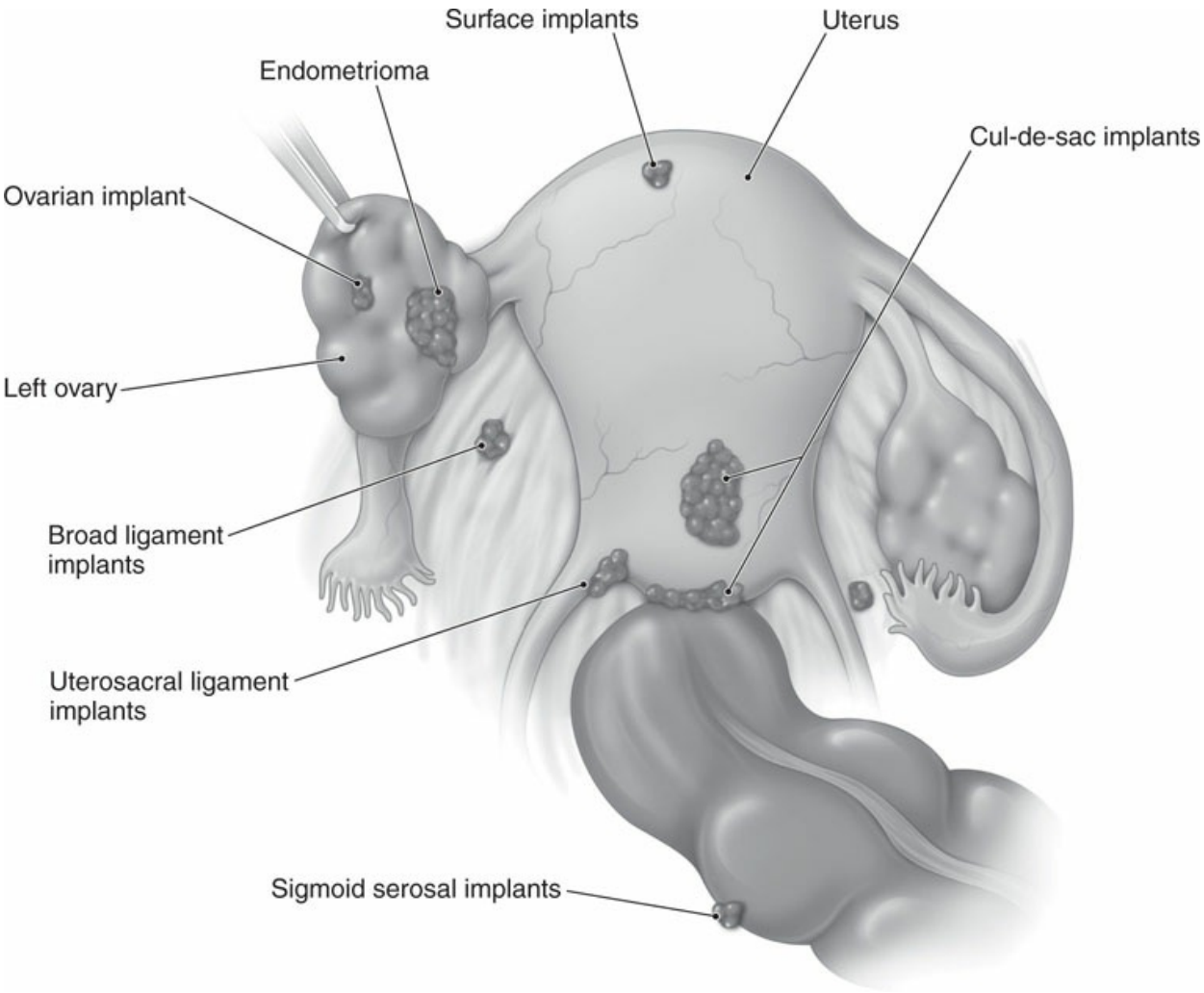


Figure 21-7 Various locations of endometriosis.

SOUND OFF
The most common location of endometriosis is the ovary.

The link between endometriosis and infertility is still being investigated. However, one valid argument states that infertility results from the development of pelvic adhesions that may alter normal anatomy, thus preventing ovum pickup or causing tubal obstruction. Sonography can be used to indicate the existence of endometriomas; however, smaller implants may be overlooked. Endometriomas are commonly cystic masses with low-level echoes that may or may not contain fluid–fluid levels (Fig. 21-8).

Polycystic Ovary Syndrome

Polycystic ovary syndrome (PCOS), also referred to as Stein–Leventhal syndrome, is an endocrinologic ovarian disorder linked with infertility. Patients suffer from chronic anovulation as a result of hormonal imbalances. The syndrome is characterized by amenorrhea, hirsutism, and obesity.

Patients may present with oligomenorrhea and acne as well. PCOS has been cited as the most common cause of androgen excess, which is termed hyperandrogenism, and hirsutism in women. The established clinical criteria for the diagnosis of PCOS include oligo or anovulation, blood work indicative of hyperandrogenism, and sonographic findings consistent with PCOS.

Clinical Findings of Endometriosis

1. Patient may be asymptomatic
2. Pelvic pain
3. Infertility
4. Dysmenorrhea
5. Menorrhagia
6. Dyspareunia
7. Painful bowel movements

Sonographic Findings of an Endometriosis

1. Predominantly cystic mass with low-level internal echoes (may resemble a hemorrhagic cyst)
2. Anechoic or complex mostly cystic mass with posterior enhancement and may contain a fluid–fluid level

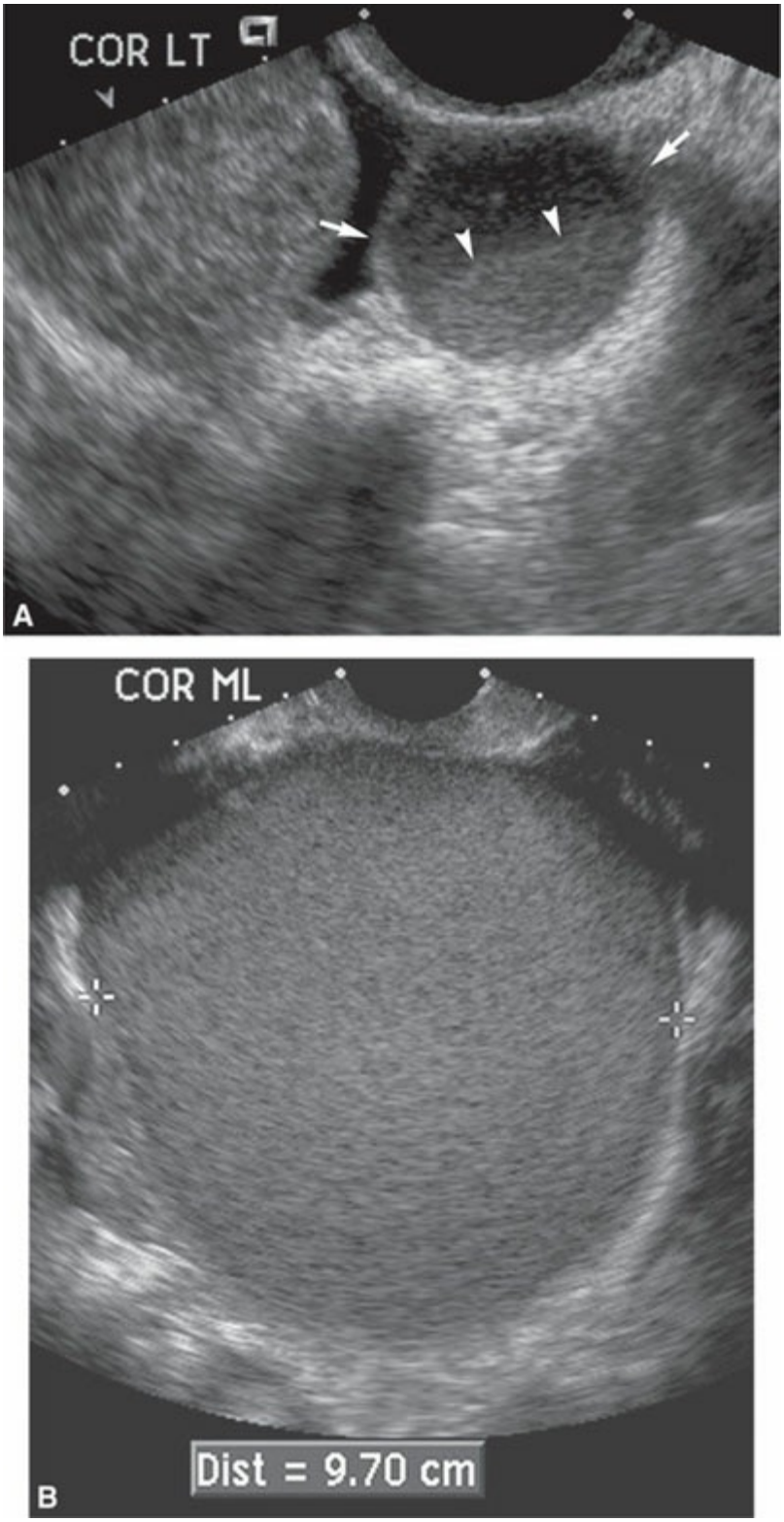


Figure 21-8 Endometrioma. **A.** Fluid–fluid level in an endometrioma. Coronal scan of the left ovary revealing a cystic adnexal mass (*arrows*) containing a fluid–fluid level (*arrowheads*). **B.** Transvaginal image of a homogeneous mass containing low-level echoes that was determined to be an endometrioma.

Sonographically, the ovaries are often enlarged and contain multiple, small follicles along the periphery or throughout the ovary, with prominent echogenic stromal elements. The sonographic "string of pearls" sign or

"necklace" sign denotes the presence of many small cysts along the periphery of the ovary, whereas another manifestation is many small cysts dispersed throughout the ovary (Fig. 21-9). Although clinical signs and symptoms are vital—for the imaging diagnosis of PCOS—it has been suggested that one or both ovaries should contain 12 or more follicles that measure between 2 and 9 mm in diameter, and the ovarian volume should exceed 10 mL. Another investigator suggested that a threshold of 25 small follicles should be used. Nonetheless, it is important to note that, although sonography can play an important confirmatory function, the diagnosis of PCOS is based more on clinical findings. Lastly, high levels of unopposed estrogen stimulation on the endometrium, as seen in patient suffering from PCOS, has also been linked to the subsequent development of endometrial and breast cancer.

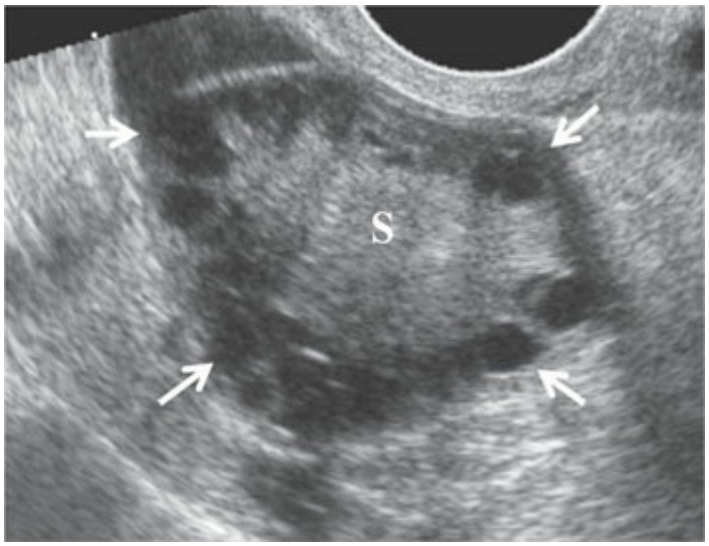


Figure 21-9 Polycystic ovary. Longitudinal sonogram demonstrating an enlarged round ovary (*between arrows*) with multiple small follicles less than or equal to 8 mm in diameter located around the periphery of the ovary (string of pearls sign). The stroma (*S*) of the ovary also appears to have increased echogenicity.

SOUND OFF

For the imaging diagnosis of PCOS, one or both ovaries should contain 12 or more follicles that measure between 2 and 9 mm in diameter, and the ovarian volume should exceed 10 mL. A threshold of 25 small follicles can also be used.

CLINICAL FINDINGS OF POLYCYSTIC OVARY SYNDROME

1. Stein–Leventhal syndrome (amenorrhea, hirsutism, and obesity)
2. Infertility
3. **Oligomenorrhea**

4. Hyperandrogenism

SONOGRAPHIC FINDINGS OF POLYCYSTIC OVARY SYNDROME

1. "String of pearls" sign or "necklace" sign describes the presence of many small cysts measuring along the periphery of the ovary
2. Many small cysts scattered throughout the ovary
3. Bilateral enlargement of the ovaries
4. Increased stroma and increased stromal echogenicity
5. One or both ovaries should contain 12 or more follicles that measure between 2 and 9 mm in diameter
6. Ovarian volume greater than 10 mL
7. Threshold of 25 small follicles can also be used

Tubal Causes of Infertility

As mentioned previously, hydrosalpinx is the accumulation of fluid within the fallopian tube. It is often the result of obstruction of the fimbriated end of the fallopian tube by adhesions. The presence of adhesions within the tube can prevent the normal peristaltic motion that typically occurs. Adhesion development can occur as a result of long-standing PID, endometriosis, and tubal surgery. Hysterosalpingography can be used to evaluate the patency of the fallopian tubes, as well as hysterosalpingosonography or hysterosalpingo-contrast-sonography (Fig. 21-10).

Endometrial Factors Contributing to Infertility

The endometrium may not develop appropriately in the luteal phase of the endometrial cycle as a result of reduced progesterone production by the ovary; this is termed "luteal phase deficiency." The sonographic appearance of the endometrium during the luteal phase can be analyzed. The endometrium becomes thickened and echogenic in appearance during the normal ovarian luteal phase (secretory phase of the endometrial cycle). However, this abnormality is typically diagnosed with endometrial biopsy.

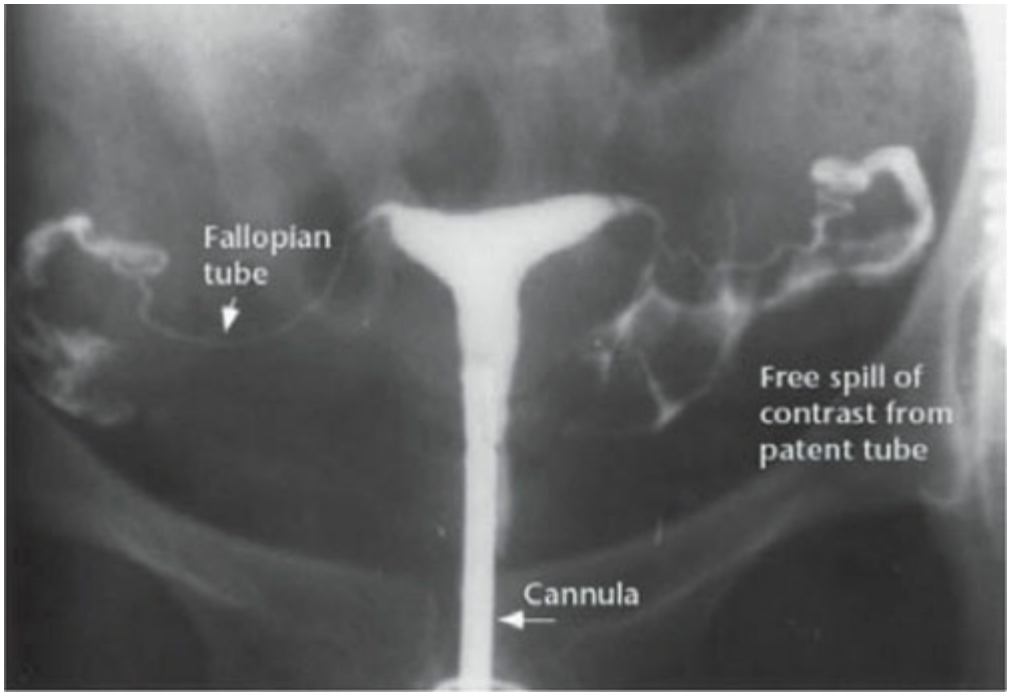


Figure 21-10 Hysterosalpingography. The hysterosalpingography procedure is a radiographic procedure used to evaluate the patency of the fallopian tubes with contrast.

Asherman Syndrome and Infertility

Asherman syndrome is the presence of intrauterine adhesions or synechiae within the uterine cavity that typically occur as a result of scar formation after uterine surgery, especially after a D&C. Adhesions within the uterine cavity often prevent implantation or lead to recurrent early pregnancy loss. Patients may suffer from amenorrhea or hypomenorrhea. Sonographic detection is difficult without the use of sonohysterography or saline infusion sonohysterography. Sonohysterography findings include bright bands of tissue traversing the uterine cavity (Fig. 21-11).

CLINICAL FINDINGS OF ASHERMAN SYNDROME

1. History of D&C, trauma, and uterine surgery
2. Recurrent pregnancy loss
3. Amenorrhea or hypomenorrhea

SONOGRAPHIC FINDINGS OF ASHERMAN SYNDROME

1. Bright areas within the endometrium
2. Sonohysterography findings include bright bands of tissue traversing the uterine cavity

SOUND OFF

Asherman syndrome is the presence of intrauterine adhesions or synechiae within the uterine cavity.

Uterine Leiomyomas and Infertility

A uterine leiomyoma is a benign, smooth muscular tumor of the uterus that may also be referred to as a fibroid or uterine myoma. Although women with fibroids can still become pregnant, fibroids that are intracavitary or submucosal in location may distort the endometrium, thus preventing implantation of the early products of conception. Fibroids may also impair tubal transport because of obstruction, and they may also enlarge during pregnancy. Uterine leiomyomas are also discussed in Chapter 17.

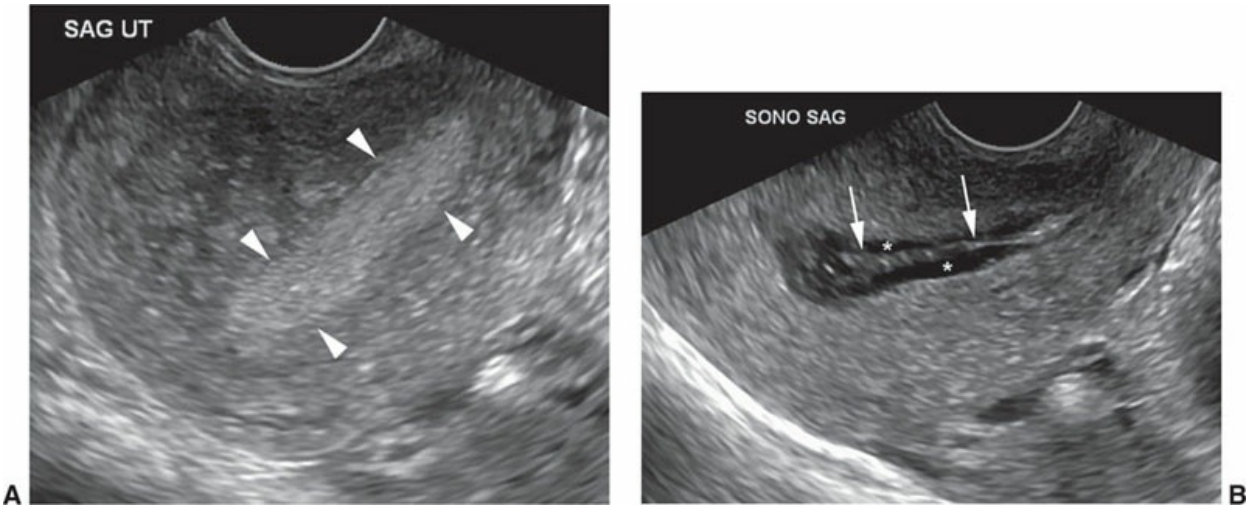


Figure 21-11 Endometrial adhesion. **A.** Normal-appearing endometrium (*between arrowheads*). **B.** With saline infusion (*) during a saline infusion sonohysterogram, an endometrial adhesion is noted (*arrows*).

Clinical Findings of a Uterine Leiomyoma

1. Pelvic pressure
2. Menorrhagia
3. Palpable abdominal mass
4. Enlarged, bulky uterus (if multiple)
5. Urinary frequency
6. **Dysuria**
7. Constipation
8. Infertility

Sonographic Findings of a Uterine Leiomyoma

1. Hypoechoic mass within the uterus
2. Posterior shadowing from mass

3. Degenerating fibroids may have calcifications or cystic components
4. Multiple fibroids appear as an enlarged, irregular shaped, diffusely heterogeneous uterus

ASSISTED REPRODUCTIVE TECHNOLOGY

Great advances in assisted reproductive technology (ART) have occurred since the 1970s. Sonography is often used to monitor ovulation and follicular growth, and to assist during reproductive therapies such as follicular aspiration and oocyte retrieval. Oocyte retrieval may be performed via the endovaginal or transabdominal approach (Fig. 21-12). With ART, ovarian stimulation is often used to increase follicular development, thus allowing the opportunity to extract multiple oocytes during one procedure. In vitro fertilization requires that a mature ovum be extracted from the ovary. Fertilization takes place outside the body, and four to eight developing embryos are placed into the uterus by means of a catheter (Fig. 21-13). This often results in multiple gestations. Selective reduction also referred to as multifetal pregnancy reduction, is the means by which twins, triplets, quadruplets, and quintuplet pregnancies are reduced.

Endovaginal sonography aids in both the initial follicular aspiration and providing guidance for catheter delivery into the uterus. An additional technique of ART, whereby fertilization takes place in the fallopian tube, is termed gamete intrafallopian tube transfer (GIFT). GIFT requires that oocytes and sperm be placed in the fallopian tube by means of laparoscopy. Zygote intrafallopian transfer is another method that requires the zygote to be inserted into the fallopian tube. Sonographers should be aware that patients who are being treated with assisted reproductive therapy are an increased risk for ectopic pregnancy, heterotopic pregnancy, multiple gestations, and ovarian hyperstimulation syndrome (OHS).

Ovulation Induction

Ovulation induction is the stimulation of the ovaries by hormonal therapy to treat infertility. Clomid, or clomiphene citrate, is a drug that is used to stimulate the pituitary gland to secrete increased amounts of follicle-stimulating hormone (FSH). The increased level of FSH encourages the development of multiple follicles on the ovaries. Pergonal is also a fertility drug. It is a hormone extracted from the urine of postmenopausal women that is often used when Clomid administration is not successful. Pergonal consists of a mixture of FSH and luteinizing hormone, and it is often given in conjunction with human chorionic gonadotropin. However, there are many types of fertility drugs. Ovulation induction dramatically increases the risk of

multiple gestations and OHS.

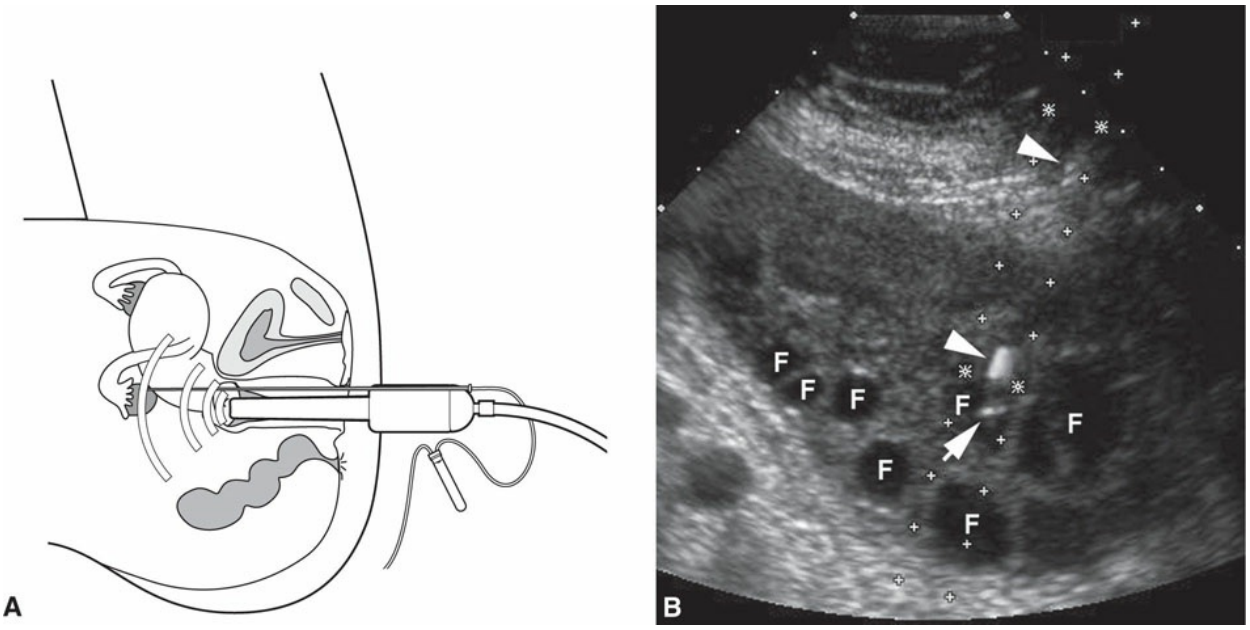


Figure 21-12 Sonography-guided oocyte retrieval. **A.** Endovaginal oocyte retrieval method. **B.** The transabdominal method may be used as well. This is a sagittal view (using a needle guide). The ovary is seen here containing multiple follicles (*F*) as a result of follicular-stimulating medication. A needle (*arrowheads*) has been inserted into the ovary, with its tip (*arrow*) in one of the follicles.

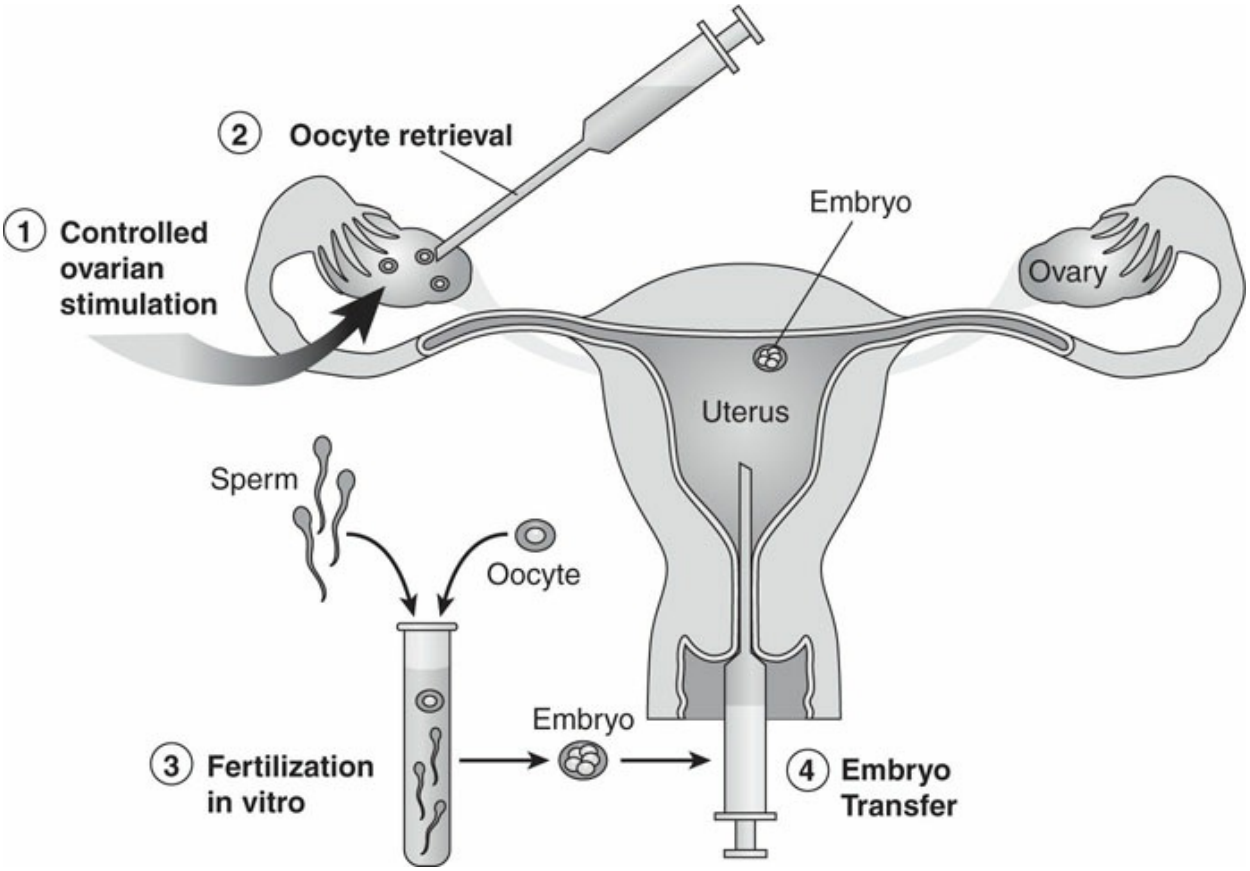


Figure 21-13 In vitro fertilization process.

SOUND OFF
Ovulation induction medications dramatically increase the risk of multiple gestations and OHS.

Ovarian Hyperstimulation Syndrome

Women who are undergoing ovulation induction by means of hormone administration are at an increased risk for developing OHS. The ovaries can enlarge, often measuring between 5 and 12 cm (Fig. 21-14). The ovary will also contain multiple large follicles known as theca lutein cysts. Remember that hCG is administered as part of ovulation induction, and theca lutein cysts occur as a result of high levels of hCG. As a result of these large cysts on the ovary, the patient could suffer from ovarian torsion, resulting in acute pelvic pain. In cases of severe OHS, patients have nausea, vomiting, and abdominal distension, ovarian enlargement, an electrolyte imbalance, and oliguria, with sonographic signs of ascites and pleural effusions. OHS can initiate renal failure, thromboembolism, and acute respiratory distress syndrome.

SOUND OFF
Remember that hCG is administered as part of ovulation induction, and theca lutein cysts occur as a result of high levels of hCG.

CLINICAL FINDINGS OF OVARIAN HYPERSTIMULATION SYNDROME

1. Fertility treatment, including ovulation induction
2. Electrolyte imbalance
3. Oliguria
4. Nausea
5. Vomiting
6. Abdominal distension
7. Ovarian enlargement



Figure 21-14 Ovarian hyperstimulation syndrome. Dramatically enlarged ovary secondary to ovulation induction medication. Color image provided online.

SONOGRAPHIC FINDINGS OF OVARIAN HYPERSTIMULATION SYNDROME

1. Cystic enlargement of the ovaries >5 cm
2. Ascites
3. Possible pleural effusion

SOUND OFF
OHS can initiate renal failure, thromboembolism, and acute respiratory distress syndrome.

FORMS OF CONTRACEPTION

An IUD or IUCD is a reversible form of contraception. An IUD is placed in the uterine cavity and prevents implantation of the fertilized ovum. There are several types of intrauterine devices (Table 21-2; Fig. 21-15). Some forms of intrauterine devices also have progestin-releasing capabilities. For instance, the Mirena, a small plastic T-shaped IUD, distorts the uterine cavity and also releases small amounts of progestin to impede implantation and produce lighter menstrual bleeding. The ParaGard is another T-shaped IUD, although it utilizes copper in its composition to inhibit sperm transport, or to prevent fertilization or transplantation.

Intrauterine devices create posterior shadowing and have been described as producing an “entrance and exit echo” on a sonogram (Fig. 21-16). A sonographic examination may be indicated when the string of an IUD cannot be found on physical examination. A sonographic description of these

devices must include the location of the IUD in relation to the endometrium. IUDs should be located within the fundal portion of the endometrium. If the IUD is not located within the endometrium, then the existence of myometrial perforation should be explored. Patients who have an IUD that has perforated into the uterine wall will often complain of irregular or heavy bleeding and cramping. The use of IUDs has been linked with PID, ectopic pregnancy, and spontaneous abortions (Fig. 21-17).

TABLE 21-2 Types of intrauterine devices and their sonographic findings

Intrauterine Contraceptive Device	Sonographic Findings
Copper 7	Shadowing number “7”-shaped device
Copper T	Shadowing letter “T”-shaped device
Lippes loop	Five equally spaced shadowing structures
Dalkon shield	Shadowing ovoid shape device
Mirena	Shadowing letter “T”-shaped device
ParaGard	Shadowing letter “T”-shaped device

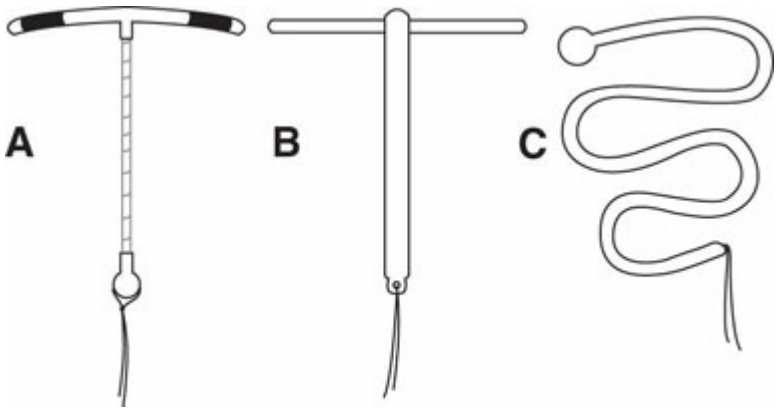


Figure 21-15 Intrauterine devices. **A.** The ParaGard is a copper-releasing IUD (approved life span, 10 years). **B.** The Mirena progestin-releasing IUD (approved life span, 5 years) are available in the United States. **C.** Although sonographers may encounter these devices, the flexible polyethylene Lippes loop is used throughout the world except in the United States. IUD, intrauterine contraceptive device.

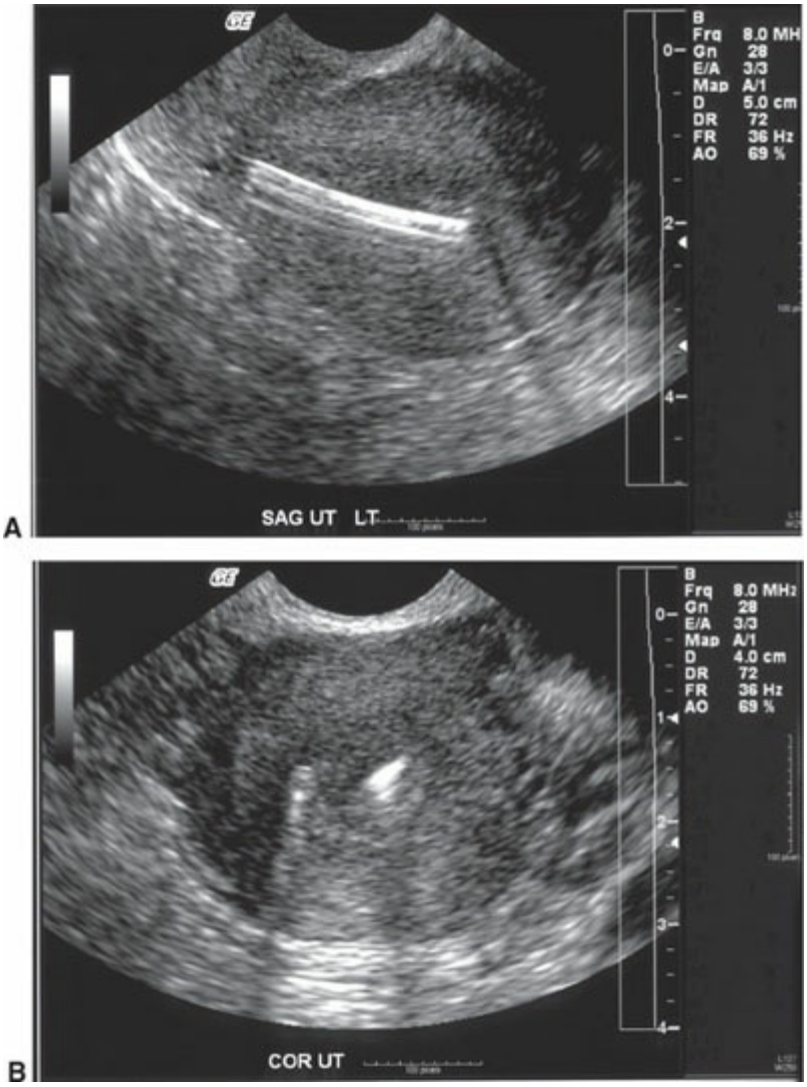


Figure 21-16 Intrauterine device. Transvaginal image of an intrauterine device in sagittal (**A**) and coronal (**B**).

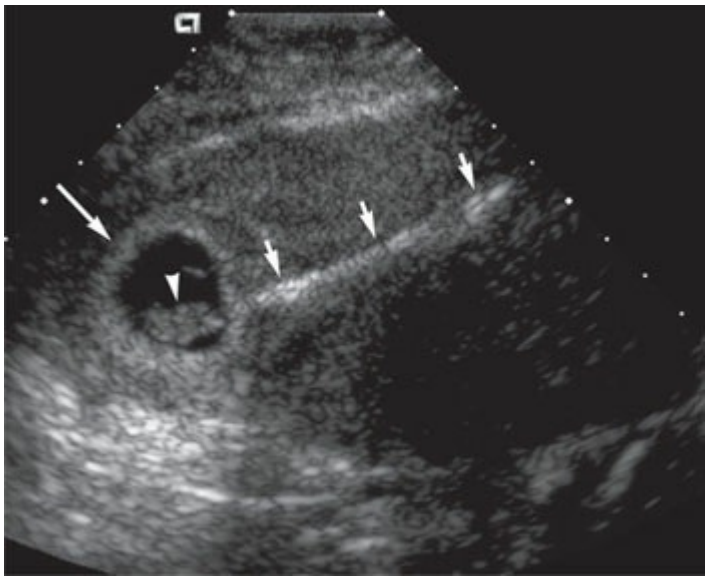


Figure 21-17 Intrauterine device and coexisting intrauterine pregnancy. Transabdominal image revealing an intrauterine device (*small arrows*) adjacent to an intrauterine gestational sac (*long arrow*) containing an embryo (*arrowhead*).

SOUND OFF
Intrauterine devices create posterior shadowing and have been described as producing an "entrance and exit echo" on a sonogram.

The pill is a popular form of birth control, and it is highly successful if the manufacturer guidelines are strictly followed. Birth control pills produce an anovulatory cycle. Other forms of contraception include the Essure device, and tubal sterilization. The Essure device is a permanent form of birth control that uses small coils placed into the proximal isthmic segment of the fallopian tubes. Over time, these tubal implants cause scar tissue to develop around the coils, eventually obstructing the fallopian tubes and preventing the migration of sperm into the tube toward the ovum. Sonography may play a role in the follow-up for the placement of these devices. Sonographically, the Essure devices appear as bilateral, echogenic linear structures within proximal isthmic segments of the fallopian tubes (near the cornua of the uterus), most likely seen best in a transverse plane to the uterus (Fig. 21-18). Female sterilization, in the form of tubal sterilization or tubal ligation, offers another permanent pregnancy prevention method. However, if a patient presents to the sonography department with a history of tubal ligation and a positive pregnancy test, an ectopic pregnancy should be highly suspected.

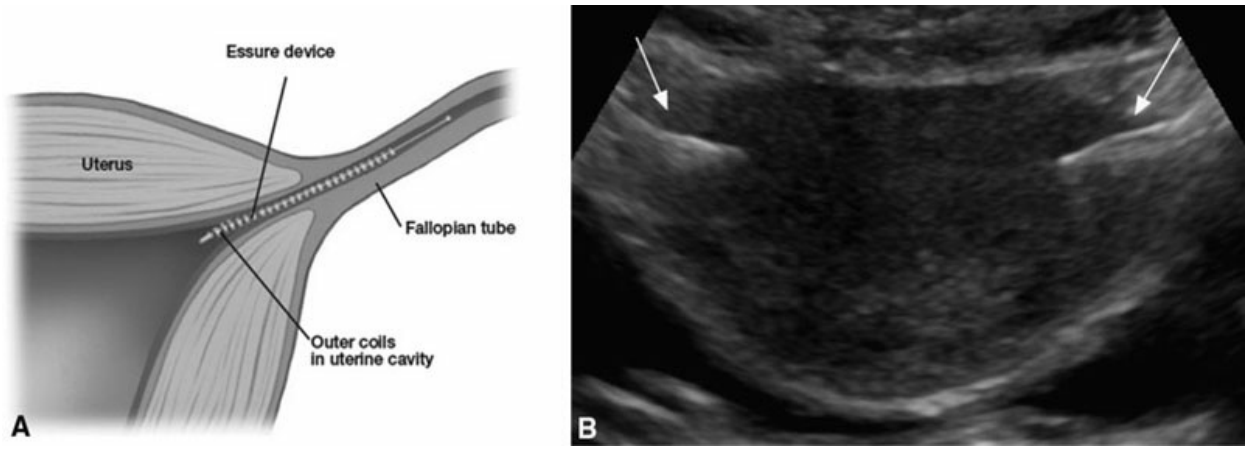


Figure 21-18 Essure. **A.** Essure device placement. **B.** Bilateral Essure devices are seen in the uterine horns (*arrows*) in this transverse transabdominal pelvic image.

REVIEW QUESTIONS

1. What is the radiographic procedure used to evaluate the patency of the fallopian tubes?
   a. Sonohysterography
   b. Hysterosalpingography

c. Hysteroscopy
d. Hysteroscopic fallopian septoplasty

2. The sonographic finding of a tubular, simple-appearing, anechoic structure within the adnexa is most consistent with:
   a. Dyspareunia
   b. Hematometra
   c. Hydrosalpinx
   d. Endometritis

3. All of the following are considered risk factors for PID except:
   a. IUD
   b. Multiple sexual partners
   c. Post childbirth
   d. Uterine leiomyoma

4. Which of the following would be the least likely clinical finding for a patient with endometriosis?
   a. Pelvic pain
   b. Dysmenorrhea
   c. Painful bowel movements
   d. Hyperandrogenism

5. Which of the following is not a potential cause of PID is?
   a. Intrauterine contraception use
   b. Postabortion
   c. Chlamydia
   d. Pyelonephritis

6. A patient presents to the sonography department with a fever, chills, and vaginal discharge. Sonographically, what findings would you most likely not encounter?
   a. Cul-de-sac fluid
   b. Uterine adhesions
   c. Dilated uterine tubes
   d. Ill-defined uterine border

7. A 26-year-old patient presents to the sonography department with a history of infertility and oligomenorrhea. Sonographically, you discover that the ovaries are enlarged and contain multiple, small follicles along their periphery, with prominent echogenic stromal elements. What is the most likely diagnosis?
   a. Ovarian torsion

b. OHS
c. PID
d. PCOS

8. The most common initial clinical presentation of PID is:
   a. Endometritis
   b. Tubo-ovarian abscess
   c. Vaginitis
   d. Pyosalpinx

9. Sonographic findings of the endometrium in a patient with a history of PID, fever, and elevated white blood cell count would include all of the following except:
   a. Ring-down artifact posterior to the endometrium
   b. Thin, hyperechoic endometrium
   c. Endometrial fluid
   d. Thickened, irregular endometrium

10. What is another name for an endometrioma?
    a. Dermoid
    b. Teratoma
    c. Chocolate cyst
    d. String of pearl

11. Fitz-Hugh–Curtis syndrome could be described as:
    a. Clinical findings of gallbladder disease as a result of PID
    b. The presence of uterine fibroids and adenomyosis in the gravid uterus
    c. Coexisting intrauterine and extrauterine pregnancies
    d. The presence of pyosalpinx, hydrosalpinx, and endometritis

12. All of the following statements concerning PID are true except:
    a. PID is typically a unilateral condition.
    b. PID can be caused by douching.
    c. PID can lead to a tubo-ovarian abscess.
    d. Dyspareunia is a clinical finding in acute PID.

13. A patient presents to the sonography department with complaints of infertility and painful menstrual cycles. Sonographically, you discover a cystic mass on the ovary consisting low-level echoes. Based on the clinical and sonographic findings, what is the most likely diagnosis?
    a. Cystic teratoma
    b. Endometrioma
    c. PID

d. OHS

14. The development of adhesions between the liver and the diaphragm as a result of PID is termed:
    a. Fitz-Hugh–Curtis syndrome
    b. Dandy–Walker syndrome
    c. Stein–Leventhal syndrome
    d. Asherman syndrome

15. Assisted reproductive therapy can result in all of the following except:
    a. Heterotopic pregnancy
    b. Multiple gestations
    c. OHS
    d. Asherman syndrome

16. Polycystic ovarian syndrome may also be referred to as:
    a. Fitz-Hugh–Curtis syndrome
    b. Plateau syndrome
    c. Stein–Leventhal syndrome
    d. Asherman syndrome

17. PID can lead to all of the following except:
    a. Infertility
    b. Polycystic ovarian disease
    c. Ectopic pregnancy
    d. Scar formation in the fallopian tubes

18. What term is used to describe painful intercourse?
    a. Dyspareunia
    b. Dysuria
    c. Dysmenorrhea
    d. Dysconception

19. The presence of functional, ectopic endometrial tissue outside the uterus is termed:
    a. Adenomyosis
    b. Asherman syndrome
    c. Fitz-Hugh–Curtis syndrome
    d. Endometriosis

20. All of the following are sonographic findings of a tubo-ovarian abscess except:
    a. The presence of 10 or more small cysts along the periphery of the

ovaries
b. Cul-de-sac fluid
c. Thickened, irregular endometrium
d. Fusion of the pelvic organs as a conglomerated mass

21. A patient presents to the sonography department with a history of Chlamydia and suspected PID. Which of the following would be indicative of the typical sonographic findings of PID?
a. Enlarged cervix, thin endometrium, and theca lutein cysts
b. Atrophic uterus, free fluid, and small ovaries
c. Bilateral, cystic enlargement of the ovaries with no detectable flow
d. Thickened irregular endometrium, cul-de-sac fluid, and complex adnexal masses

22. Causes of female infertility include all of the following except:
a. Previous intrauterine device use
b. Polycystic ovary syndrome
c. Asherman syndrome
d. Endometriosis

23. Infertility is defined as:
a. The inability to conceive a child after 2 years of unprotected intercourse
b. The inability to conceive a child after 5 years of unprotected intercourse
c. The inability to conceive a child after 1 year of unprotected intercourse
d. The inability to conceive a child after 3 months of unprotected intercourse

24. A 25-year-old patient presents to the sonography department complaining of pelvic pain, dyspareunia, and oligomenorrhea. An ovarian mass, thought to be a chocolate cyst, is noted during the examination. Which of the following is consistent with the sonographic appearance of a chocolate cyst?
a. Simple-appearing anechoic mass
b. Echogenic mass with posterior shadowing
c. Cystic mass with low-level echoes
d. Anechoic mass with posterior shadowing

25. Amenorrhea, hirsutism, and obesity describe the clinical features of:
a. Fitz-Hugh–Curtis syndrome
b. Stein–Leventhal syndrome

c. Asherman syndrome
d. Endometriosis

26. The sonographic evidence of a hyperemic fallopian tube is consistent with:
a. Pyosalpinx
b. Hydrosalpinx
c. Endometritis
d. Salpingitis

27. The sonographic “string of pearls” sign is indicative of:
a. Polycystic ovary syndrome
b. Tubo-ovarian disease
c. PID
d. OHS

28. Complex-appearing fluid within the fallopian tubes seen with PID is most likely:
a. Pyosalpinx
b. Pyometra
c. Hydrosalpinx
d. Hematometra

29. Sonographic findings of OHS include all of the following except:
a. Cystic enlargement of the ovaries
b. Ascites
c. Pleural effusions
d. Oliguria

30. The development of adhesions within the uterine cavity is termed:
a. Fitz-Hugh–Curtis syndrome
b. Dandy–Walker syndrome
c. Stein–Leventhal syndrome
d. Asherman syndrome

31. OHS can cause multiple large follicles to develop on the ovaries termed:
a. Theca lutein cysts
b. Chocolate cysts
c. Corpus luteum cysts
d. Dermoid cysts

32. What is another name for adhesions within the endometrial cavity?
a. Endometritis

b. Synechiae
c. Septation
d. Mural nodules

33. A female patient presents to the sonography department with a clinical history of Clomid treatment. She is complaining of nausea, vomiting, and abdominal distension. What circumstance is most likely causing her clinical symptoms?
a. Stein–Leventhal syndrome
b. Polycystic ovarian disease
c. Fitz-Hugh–Curtis syndrome
d. OHS

34. A 35-year-old patient presents to the sonography department with a history of tubal ligation and positive pregnancy test. What condition should be highly suspected?
a. Asherman syndrome
b. Polycystic ovarian disease
c. Endometriosis
d. Ectopic pregnancy

35. Patients with OHS are at increased risk for:
a. Ovarian torsion
b. Chlamydia
c. Gonorrhea
d. Vaginitis

36. Which of the following would be described as functional cysts that are found in the presence of elevated levels of human chorionic gonadotropin?
a. Theca lutein cysts
b. Chocolate cysts
c. Corpus luteum cysts
d. Endometrial cysts

37. The presence of pus within the uterus defines:
a. Pyosalpinx
b. Pyometra
c. Pyocolpos
d. Pyomyoma

38. The occurrence of having both an intrauterine and extrauterine pregnancy at the same time describes:

a. PID
b. Ectopic pregnancy
c. Heterotopic pregnancy
d. Molar pregnancy

39. Excessive hair growth in women in areas where hair growth is normally negligible would be seen with:
a. Ectopic pregnancy
b. Fitz-Hugh–Curtis syndrome
c. Asherman syndrome
d. Stein–Leventhal syndrome

40. What form of permanent birth control would be seen sonographically as echogenic, linear structures within the lumen of both isthmic portions of the fallopian tubes?
a. Essure devices
b. ParaGards
c. Lippes loops
d. Mirenas

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Section III Obstetric Sonography Review

22

Obstetric Sonography Overview

Introduction

A synopsis of obstetric sonography practice is provided in this chapter. A brief summary of the importance of obtaining and recognizing significant clinical findings, relevant laboratory results, frequently identified artifacts, fetal biometry, biophysical profile scoring, fetal presentation, and extrauterine abnormalities should provide the analytical groundwork for a thorough preparation for the obstetric component of the registry provided by the American Registry for Diagnostic Medical Sonography and the obstetric portion of the registry offered by the American Registry of Radiologic Technologist. The outlines for each examination can be found at www.ardms.org and www.arrt.org, respectively.

Key Terms

acute appendicitis—inflammation of the appendix

adnexa—the area located posterior to the broad ligaments and adjacent to the uterus, which contains the ovaries and fallopian tubes

alpha-Fetoprotein—a protein produced by the fetal yolk sac, fetal gastrointestinal tract, and the fetal liver; may also be produced by some malignant tumors

corpus luteum cyst—a physiologic cyst that develops after ovulation has occurred

estriol—an estrogenic hormone produced by the placenta

gravid—pregnant

gravidity—the number of times that a woman has been pregnant

human chorionic gonadotropin—a hormone produced by the trophoblastic cells of the early placenta; may also be used as a tumor marker in nongravid patients and males

hydronephrosis—the dilation of the renal collecting system resulting from the obstruction of the flow of urine from the kidney(s) to the bladder; also referred to as pelvocaliectasis or pelvicaliectasis

idiopathic—from an unknown origin

inhibin A—a peptide hormone secreted by the placenta during pregnancy

meningocele—the herniation of the cranial or spinal meninges caused by an open cranial or spinal defect

myelomeningocele—mass that results from spina bifida that contains the spinal cord and the meninges

nuchal translucency—the anechoic space along the posterior aspect of the fetal neck

ovarian torsion—an abnormality that results from the ovary twisting on its mesenteric connection, consequently cutting off the blood supply to the ovary

pallor—extreme paleness of the skin

parity—the number of pregnancies in which the patient has given birth to a fetus at or beyond 20 weeks gestational age or an infant weighing more than 500 g

placenta previa—when the placenta covers or nearly covers the internal os of the cervix

placental abruption—the premature separation of the placenta from the uterine wall before the birth of the fetus

pregnancy-associated plasma protein A—a protein that is produced by the placenta

quadruple screen—a maternal blood test that includes an analysis of human chorionic gonadotropin, alpha-fetoprotein, estriol, and inhibin A

supine hypotensive syndrome—a reduction in blood return to the maternal heart caused by the gravid uterus compressing the maternal inferior vena cava

triple screen—a maternal blood test that typically includes an analysis of human chorionic gonadotropin, alpha-fetoprotein, and estriol

UNDERSTANDING THE TRIMESTERS

A normal pregnancy lasts for 9 months, 40 weeks, or 280 days. However, it may last up to 42 weeks. As a result, typically the first trimester is defined as weeks 1 through 12, the second trimester is defined as weeks 13 through 26, and the third trimester is defined as weeks 27 through 42. Fetal age is determined by the last menstrual period, which may be referred to as menstrual age or gestational age.

CLINICAL INDICATIONS FOR AN OBSTETRIC SONOGRAM

An obstetric sonogram may be requested for various reasons. The American Institute of Ultrasound in Medicine publishes the practice guidelines for an obstetric sonogram on their website at www.aium.org (Tables 22-1 and 22-2).

PATIENT PREPARATION FOR AN OBSTETRIC SONOGRAM AND PATIENT CARE

Both transvaginal (TV) and transabdominal (TA) imaging may be utilized to evaluate the gravid uterus. Although both techniques have their limitations, they often work well in conjunction with each other. In the early first trimester, if TA imaging is used, the patient should have a distended urinary bladder to better visualize not only the uterus but also the adnexa. TV imaging is most often the technique used to imagine the early pregnancy because it offers superior resolution. An empty maternal bladder is needed for this examination. Second- and third-trimester sonographic examinations also require an empty maternal bladder.

First-trimester sonograms may require the use of a 5- to 10-MHz or higher TV transducer to better visualize intrauterine structures and the adnexa. Typically, a 3- to 5-MHz TA transducer will allow sufficient penetration in most pregnant patients, while providing sufficient resolution. These frequency ranges will vary among ultrasound equipment. Obese patients may require the use of lower frequency transducers for additional penetration.

All transducers and transducer cords should be cleaned after performing an obstetric sonogram to prevent the spread of disease. TV transducers should undergo high-level disinfection, and the manufacturer’s specified instructions should be followed. Because TV imaging requires that the transducer be placed into the vagina, a probe cover should be placed on the transducer and it should be inserted into the vagina using sterile jelly as a lubricant.

TABLE 22-1 AIUM practice guidelines for a first-trimester sonogram

Indications for a First-Trimester Sonogram
Confirmation of the presence of an intrauterine pregnancy
Evaluation of a suspected ectopic pregnancy
Defining the cause of vaginal bleeding
Evaluation of pelvic pain
Estimation of gestational (menstrual) age
Diagnosis or evaluation of multiple gestations
Confirmation of cardiac activity
Imaging as an adjunct to chorionic villus sampling, embryo transfer, and localization and removal of an intrauterine device
Assessing for certain fetal anomalies, such as anencephaly, in high-risk patients
Evaluation of maternal pelvic masses and/or uterine abnormalities
Measuring the nuchal translucency (NT) when part of a screening program for fetal aneuploidy
Evaluation of a suspected hydatidiform mole

AIUM, The American Institute of Ultrasound in Medicine.

TABLE 22-2 AIUM practice guidelines for a second- and third-trimester sonogram

AIUM Practice Guidelines for a Second- and Third-Trimester Sonogram
Screening for fetal anomalies
Evaluation of fetal anatomy
Estimation of gestational (menstrual) age
Evaluation of fetal growth
Evaluation of vaginal bleeding
Evaluation of abdominal or pelvic pain
Evaluation of cervical insufficiency
Determination of fetal presentation
Evaluation of suspected multiple gestation
Adjunct to amniocentesis or other procedure
Evaluation of a significant discrepancy between uterine size and clinical dates
Evaluation of a pelvic mass
Evaluation of a suspected hydatidiform mole
Adjunct to cervical cerclage placement
Suspected ectopic pregnancy
Suspected fetal death
Suspected uterine abnormalities
Evaluation of fetal well-being

Suspected amniotic fluid abnormalities
Suspected placental abruption
Adjunct to external cephalic version
Evaluation of premature rupture of membranes and/or premature labor
Evaluation of abnormal biochemical markers
Follow-up evaluation of a fetal anomaly
Follow-up evaluation of placental location for suspected placenta previa
History of previous congenital anomaly
Evaluation of the fetal condition in late registrants for prenatal care
Assessment for findings that may increase the risk for aneuploidy

AIUM, The American Institute of Ultrasound in Medicine.

SOUND OFF
TV transducers should undergo high-level disinfection, and the manufacturer's specified instructions should be followed.

While evaluating the gravid patient, the sonographer should be aware of a unique situation that may arise during the examination. Patients in their late second or third trimester may suffer from supine hypotensive syndrome, which is a reduction in blood return to the maternal heart caused by the gravid uterus compressing the maternal inferior vena cava. Patients can complain of tachycardia, sweating, nausea, and pallor. The sonographer can assist the patient into a right lateral or left lateral position to alleviate symptoms.

SOUND OFF
Patients in their late second or third trimester may suffer from supine hypotensive syndrome, which is a reduction in blood return to the maternal heart caused by the gravid uterus compressing the maternal inferior vena cava.

GATHERING A CLINICAL HISTORY

A review of prior examinations should be performed by the sonographer before any interaction with the patient. This review includes previous sonograms and other imaging studies when applicable. Gathering a clinical history includes a basic inquiry into the patients past obstetric history by documenting gravidity (G) and parity (P) (Table 22-3). Gravidity denotes the number of times a woman has been pregnant, whereas parity denotes the

number of pregnancies that led to the birth of a fetus at or beyond 20 weeks gestational age or of an infant who weighed at least 500 g. A more specific method can be further added using the TPAL (Term, Premature, Abortions, Live birth) description. These inquiries should include questions about previous pregnancies or fetal complications, diabetes, hypertension, infertility, and the general health of other children at the time of birth and currently. Moreover, sonographers must be capable of analyzing the clinical history and complaints of their patients. This practice will not only aid in clinical practice but will also assist in answering complex certification examination questions.



SOUND OFF

Gravidity denotes the number of times a woman has been pregnant, whereas parity denotes the number of pregnancies that led to the birth of a fetus at or beyond 20 weeks gestational age or of an infant who weighed at least 500 g.

By correlating clinical findings with sonographic findings, the sonographer can directly impact patient care by providing the most targeted examination possible. Furthermore, when faced with a complicated, in-depth registry question, the registrant will be able to eliminate information that is not relevant in order to answer the question appropriately. Although questions in the obstetric portion of these registries may have some clinical history, like laboratory findings, many are image-based questions that examine the reviewer's ability to discern sonographic anatomy and pathology. For this reason, crucial sonographic images and diagrams are provided throughout this section.

Determining the cause of vaginal bleeding is a common obstetrical dilemma. Although vaginal bleeding can be idiopathic, in the first trimester, the sonographer should be aware that there can be multiple reasons why a patient could present with vaginal bleeding, including ectopic pregnancy, gestational trophoblastic disease, miscarriage, blighted ovum, embryonic demise, and subchorionic hemorrhage. In the second trimester, painless vaginal bleeding is most often associated with placenta previa, whereas painful vaginal bleeding may occur as a result of placental abruption.

LABORATORY FINDINGS RELEVANT TO OBSTETRIC SONOGRAPHY

The Triple and Quadruple Screen

The triple screen is a maternal blood test performed between 15 and 20 gestational weeks. It includes human chorionic gonadotropin (hCG), maternal serum alpha-fetoprotein (MSAFP), and estriol. The quadruple screen adds an additional analysis of inhibin A. Atypical laboratory findings can be associated with abnormal pregnancies (Table 22-4).

Early First-Trimester Screening

Some medical institutions provide an earlier test than the customary triple screen offered during the second trimester. This test can be performed between 11 and 14 gestational weeks. It is an analysis of maternal blood levels of hCG and pregnancy-associated plasma protein A (PAPP-A), combined with fetal nuchal translucency (NT) measurements obtained with sonography. Guidelines for the NT measurement can be found in Chapter 23. One of the newer maternal blood test available is the MaterniT21Plus test (Sequenom Laboratories, San Diego, CA), which is a type of cell-free fetal DNA testing. This simple blood test can reveal gender and is also highly accurate in detecting chromosomal anomalies, including trisomies 21, 18, and 13 and sex chromosome abnormalities, as early as 9 weeks gestation.

TABLE 22-3 Common clinical pregnancy terminology

Common Clinical Pregnancy Terminology	
Gravida (G) or gravidity	the number of pregnancies
Multigravida	has been pregnant more than once
Multiparous	has given birth more than once
Nulliparous	not given birth
Para (P) or parity	the number of pregnancies in which the patient has given birth to a fetus at or beyond 20 wk gestational age or an infant weighing more than 500 g
Primigravida	first pregnancy
Primiparous	has given birth once

TABLE 22-4 Common abnormalities encountered during pregnancy and associated elevation (↑) or reduction (↓) in laboratory findings compared to a normal pregnancy

Abnormality	Triple Screen Findings	Additional Labs
Abortion (miscarriage)	↓ hCG	

Anembryonic pregnancy	↓ hCG	
Anencephaly	↑ MSAFP	
Cephalocele	↑ MSAFP	
Down syndrome (trisomy 21)	↑hCG	↑ Inhibin A
	↓ Estriol	↓ PAPP-A
	↓ MSAFP	
Ectopic pregnancy	↓ hCG	↓ Hematocrit (with rupture)
Edwards syndrome (trisomy 18)	↓ Estriol	↓ Inhibin A
	↓ hCG	↓ PAPP-A
	↓ MSAFP	
Gastroschisis	↑ MSAFP	
Molar pregnancy	(markedly) ↑ hCG	
Omphalocele	↑ MSAFP	
Patau syndrome (trisomy 13)	(mildly) ↑ MSAFP	↑ Inhibin A
Spina bifida (**meningocele or myelomeningocele**)	↑ MSAFP	
Triploidy	↑ hCG (with molar)	
Turner syndrome	↓ Estriol	↓ Inhibin A (with hydrops)
	↓ hCG (with hydrops)	↓ PAPP-A
	↓ MSAFP	

Please note that these listed laboratory findings are provided for narrowing the information for review purposes only. Additional fetal abnormalities may exist with these atypical laboratory findings.
hCG, human chorionic gonadotropin; MSAFP, maternal serum α-fetoprotein; PAPP-A, pregnancy-associated plasma protein A.

FETAL BIOMETRY

Measurements obtained in the first trimester include yolk sac, gestational sac, crown rump length, and NT. These are discussed in the following chapters. Although standard fetal biometry of the second and third trimesters is also discussed in the following chapters of this book, Table 22-5 provides a brief synopsis for a rapid review.

ARTIFACTS IN OBIMAGING

Obstetric sonography involves careful analysis of vital fetal and maternal structures. Often, artifacts will be observed during an obstetric sonogram. It is important to know that artifacts exist and why they occur (Table 22-6).

BIOPHYSICAL PROFILE SCORING

The purpose of biophysical profile scoring is to investigate for signs of fetal hypoxia and to assess overall fetal wellbeing. Each examination of the fetus lasts 30 minutes. The sonographic examination is scored according to specific fetal movements (Table 22-7). The highest possible sonographic score is 8 points, or 2 points for each criterion accomplished. The nonstress test, also referred to as fetal cardiotocography, is worth 2 additional points. Therefore, if combined with a nonstress test, the highest possible score is 10 for a biophysical profile. It is important to note that different parameters may be utilized at some institutions.



SOUND OFF

A purpose of biophysical profile scoring is to investigate for signs of fetal hypoxia. Each examination of the fetus lasts 30 minutes.

TABLE 22-5 Table of standard fetal measurements and explanation

Standard Fetal Measurement	Explanation
Abdominal circumference	Measured in an axial plane, and taken around the abdomen at the level of the umbilical vein and fetal stomach. Other structures that may be seen, including the transverse thoracic spine, right adrenal gland, and fetal gallbladder.
Head circumference	Measured at the outer perimeter of the skull at the level of the third ventricle, thalamus, cavum septum pellucidum, and falx cerebri.
Femur length	Measured at the long axis of the femoral shaft when the ultrasound beam is perpendicular to the shaft.
Biparietal diameter	Measured from the outer edge of the proximal skull to the inner edge of the distal skull at the level of the third ventricle, thalamus, cavum septum pellucidum, and falx cerebri.

TABLE 22-6 Artifacts frequently observed during an obstetric sonogram

Artifact	Description
Comet tail artifact	A type of reverberation artifact, caused by several small, highly reflective interfaces such as gas bubbles
Posterior (acoustic) enhancement	Produced when the sound beam is barely attenuated through a fluid or a fluid-containing structure
Reverberation artifact	Caused by a large acoustic interface and subsequent production false echoes
Ring-down artifact	Artifact that appears as a solid streak or a chain of parallel bands radiating away from a structure
Shadowing	Caused by attenuation of the sound beam

TABLE 22-7 Biophysical profile scoring

Criteria	Conditions for Normal Score in 30 min	Score
Thoracic movements	At least one episode of simulated fetal breathing lasting at least 30 s (observed by watching the fetal diaphragm)	2 points
Fetal movements	At least three or more gross fetal body movements (simultaneous trunk and limb movement)	2 points
Fetal tone	At least one flexion to extension of a limb or one hand opening and closing	2 points
Amniotic fluid	At least one pocket of fluid that measures 1 cm in vertical diameter in two perpendicular planes	2 points
Nonstress test	At least two fetal heart accelerations (more than 15 beats/min and more than 15 s) together with one fetal movement	2 points

Adapted from Norton ME. Callen's Ultrasonography in Obstetrics and Gynecology. 6th Ed. Philadelphia: Elsevier; 2016:728.

FETAL PRESENTATION

Determining fetal lie and presentation is a significant element of an obstetric sonogram. Fetal lie can be described as longitudinal or transverse. A longitudinal lie is present when the fetus lies along the longitudinal axis of the uterus, whereas transverse is when the fetus lies transversely within the

uterus. Figure 22-1 provides some insight into how to determine fetal situs in the longitudinal lie (Fig. 22-1).

SOUND OFF

A longitudinal lie is present when the fetus lies along the longitudinal axis of the uterus, whereas transverse is when the fetus lies transversely within the uterus.

Presentation of the fetus is determined by identifying the fetal anatomy that is closest to the internal os of the cervix. Cephalic presentation, or head first, is the most common presentation. A breech presentation can be further described as complete, incomplete (footling), or frank. A complete breech is when the fetal legs are flexed at the hips, and there is flexion of the knees as well. Frank breech presentation is when the fetal buttocks are closest to the cervix, whereas footling breech is when there is extension of at least one of the legs toward the cervix (Fig. 22-2). For the transverse lie, a sagittal orientation to the mother will yield a transverse image of the fetus, while a transverse orientation to the mother will yield a sagittal image of the fetus.

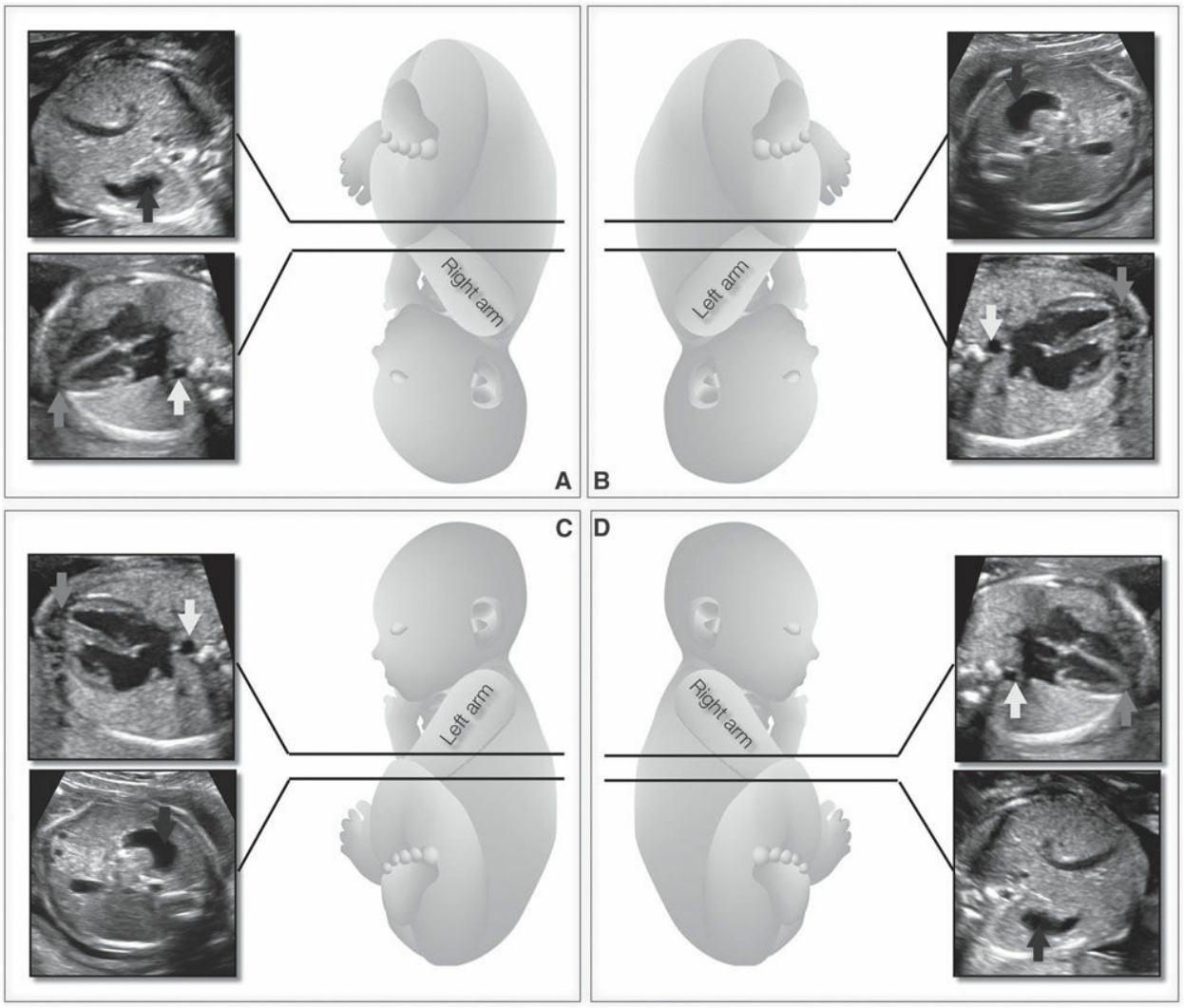


Figure 22-1 Determining fetal situs in longitudinal lie. In **(A)**, the fetus is in a cephalic presentation with the fetal spine close to the left uterine wall, resulting in the right side being anterior and left side posterior. In **(B)**, the fetus is in a cephalic presentation with the fetal spine close to the right uterine wall, resulting in the left side being anterior and right side posterior. In **(C)**, the fetus is in a breech presentation with the fetal spine close to the left uterine wall, resulting in the left side being anterior and right side posterior. In **(D)**, the fetus is in a breech presentation with the fetal spine close to the right uterine wall, resulting in the right side being anterior and left side posterior. Note the corresponding transverse sonographic planes of the chest and abdomen. *Black arrows* point to fetal stomach, *gray arrows* to the apex of the heart, and *white arrows* to the descending aorta.

SOUND OFF

Presentation of the fetus is determined by identifying the fetal anatomy that is closest to the internal os of the cervix.

EXTRAUTERINE ABNORMALITIES ASSOCIATED WITH OBSTETRIC SONOGRAPHY

During a sonographic examination of the gravid patient, the sonographer must not only be aware of the fetal findings but also cognizant of the surrounding maternal pelvic anatomy, including the ovaries and adnexa. The most common pelvic mass associated with pregnancy is the corpus luteum cyst of the ovary. These cysts can have a complex appearance, or a thick wall, and may therefore mimic an ectopic pregnancy. The corpus luteum cyst of pregnancy is further discussed in Chapter 23. Large ovarian cysts or masses can lead to ovarian torsion. If a patient presents with a large ovarian abnormality, further sonographic signs of ovarian torsion must be investigated. Ovarian torsion is discussed in Chapter 18, in the gynecologic section.

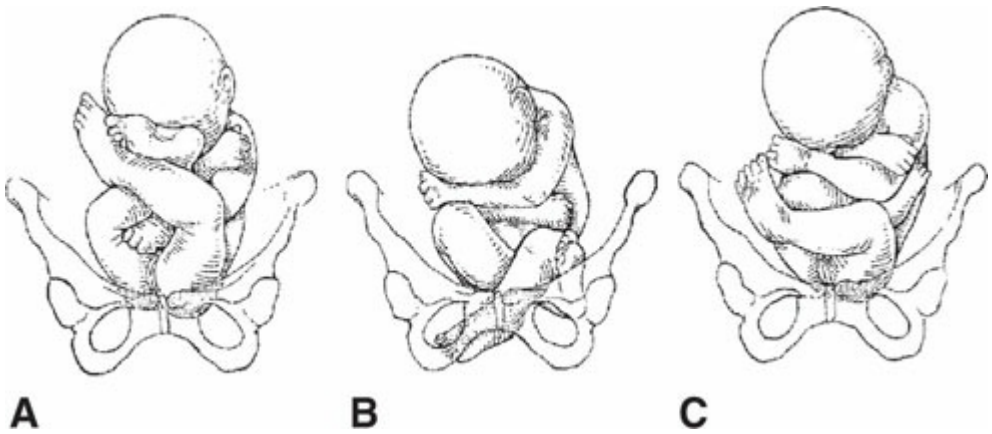


Figure 22-2 Types of breech. Frank **(A)**, incomplete **(B)**, and complete **(C)** are considered the three types of breech presentations.

SOUND OFF
The most common pelvic mass associated with pregnancy is the corpus luteum cyst of the ovary.

Pregnant patients who complain of right lower quadrant pain could be suffering from coexisting acute appendicitis. Signs of appendicitis are discussed in Chapter 10, in the abdominal section. The appendix may be visualized with endovaginal imaging as well. Pregnant patients complaining of right upper quadrant pain could have gallstones. Gallbladder disease is further discussed in Chapter 3.

Hydronephrosis is common during late pregnancy. Dilation of the renal collecting system is most often secondary to the large size of the uterus with subsequent transient asymptomatic obstruction of the ureters. However, some patients will often suffer from back pain. A thorough analysis for urinary calculi must be performed in these situations. Kidney stones are further discussed in Chapter 7.

ANALYZING AN OBSTETRIC REGISTRY QUESTION

Registry examinations can be intimidating. Unfortunately, clinical history during late pregnancy may not be helpful. For obstetric questions, laboratory findings and an accurate recognition of sonographic anatomy are vital to answering the question correctly. Here are a couple of steps that you can use to give you a better chance at answering these complex questions. Read the question below and look at the image (Fig. 22-3).

The above image is of the gravid uterus of a 39-year-old patient who presented to the ultrasound department with a history of elevated MSAFP. She states that the fetus appears to have been moving regularly, and she has had no pain or vaginal bleeding. What is the most likely diagnosis?

A. Spina bifida
B. Trisomy 18
C. Endometriosis
D. Anencephaly

Step 1: Look at the Image and Try to Answer the Question Without Looking at the Answers Provided

As you study, you need to look at as many sonographic images as you can. There are images provided for quick reference. The more sonographic images you look at, the better prepared you will be to answer image-based questions. Try to determine what part of the fetus is being shown in the image. This step may eliminate some of the incorrect answers immediately.

Step 2: If You Don’t Know the Answer Right Away from the Image, Then Look at the Question, and Begin to Break it Down

Let us assume that you have no idea what the answer is from looking at the image. Then you move on to step 2, which is breaking the question down. This step is complicated, but it will help.



Figure 22-3

The first part of the question provides the age of the patient, which is 39 years. By simply knowing what advance maternal age is (35), we know that she is at increased risk for having a complicated pregnancy, and that she is more likely to have a fetus with an abnormality.

Look at the answers provided. Is there one that you can eliminate solely on the patient's age or irrelevance? There is one, endometriosis doesn't make sense. Mark it off the list! You now have a 33% chance of answering the question correctly. We now move on to the next part of the patient's history, which is the elevated MSAFP. Look at the answers and see if there are any that you can eliminate that are not linked with elevated MSAFP. There is one choice that can be eliminated. Trisomy 18 is typically not linked with an elevated MSAFP. Now, you have a 50% chance at getting the question correct. This is where the following chapters will help. You must know your sonographic findings to correctly answer these questions. This is an image of the fetal head. The correct answer is anencephaly. The cranium is absent above the orbits with anencephaly, as seen in this image.

REVIEW QUESTIONS

1. Which of the following is not part of the biophysical profile?
   a. Fetal swallowing
   b. Flexion of the limb
   c. Amniotic fluid
   d. Fetal breathing

2. For the normal biophysical profile, the amniotic fluid pocket should

measure:
a. Greater than 4 cm in two perpendicular planes
b. At least 1 cm in two perpendicular planes
c. Greater than 5 cm in two perpendicular planes
d. At least 3 cm in two perpendicular planes

3. What is the term for the fetal presentation that is head down?
a. Breech
b. Crown
c. Cephalic
d. Vertical

4. Fetal presentation is determined by identifying the fetal part that is closest to the:
a. Placenta
b. External os of the cervix
c. Maternal umbilicus
d. Internal os of the cervix

5. What is defined as the area located posterior to the broad ligaments and adjacent to the uterus, which contains the ovaries and fallopian tubes?
a. Adnexa
b. Paraovarian
c. Pouch of Douglas
d. Space of Retzius

6. All of the following may be visualized at the correct level of the head circumference except:
a. Third ventricle
b. Thalamus
c. Cavum septum pellucidum
d. Falx cerebelli

7. Typically, with a miscarriage, the serum hCG value will be:
a. Elevated
b. Decreased
c. This laboratory finding is not helpful
d. Unchanged

8. Typically, with anencephaly, the MSAFP value will be:
a. Elevated
b. Decreased
c. This laboratory finding is not helpful

d. Unchanged

9. Typically, with gastroschisis, the MSAFP value will be:
   a. Elevated
   b. Decreased
   c. This laboratory finding is not helpful
   d. Unchanged

10. The quadruple screen includes an analysis of all of the following except:
    a. hCG
    b. alpha-Fetoprotein
    c. Inhibin A
    d. PAPP-A

11. The reduction in blood return to the maternal heart caused by the gravid uterus compressing the maternal inferior vena cava describes:
    a. Edwards syndrome
    b. Pulmonary obstructive syndrome
    c. Supine hypotensive syndrome
    d. Recumbent hypotensive syndrome

12. Which of the following would be the least likely indication for a first-trimester sonogram?
    a. Evaluate pelvic pain
    b. Define the cause of vaginal bleeding
    c. Gender identification
    d. Diagnosis of multiple gestations

13. All of the following would be an indication for a third-trimester sonogram except:
    a. Evaluate NT
    b. Evaluate fetal presentation
    c. Evaluate fetal growth
    d. Evaluate gestational age

14. What is described as the number of pregnancies in which the patient has given birth to a fetus at or beyond 20 weeks gestational age or an infant weighing more than 500 g?
    a. Gravidity
    b. Parity
    c. Primigravida
    d. Primiparous

15. The number of pregnancies is defined as:
    a. Gravidity
    b. Parity
    c. Primigravida
    d. Primiparous

16. In the TPAL designation, the “L” refers to:
    a. Living children
    b. Lethal anomalies
    c. Live births
    d. Lost pregnancies

17. The second trimester typically refers to weeks:
    a. 12 through 26
    b. 13 through 26
    c. 10 through 28
    d. 26 through 42

18. The clinical manifestations of supine hypotensive syndrome include all of the following except:
    a. Proteinuria
    b. Tachycardia
    c. Nausea
    d. Pallor

19. Painless second-trimester vaginal bleeding is most often associated with:
    a. Placental abruption
    b. Ectopic pregnancy
    c. Miscarriage
    d. Placenta previa

20. All of the following are observed during a biophysical profile except:
    a. Fetal tone
    b. Thoracic movement
    c. Fetal breathing
    d. Fetal circulation

21. Which of the following would not be decreased in the presence of Edwards syndrome?
    a. Estriol
    b. hCG
    c. alpha-Fetoprotein
    d. All would be decreased

22. All of the following are produced by the placenta except:
    a. alpha-Fetoprotein
    b. hCG
    c. PAPP-A
    d. Inhibin A

23. A myelomeningocele is associated with:
    a. Down syndrome
    b. Spina bifida
    c. Edwards syndrome
    d. Patau syndrome

24. The anechoic space along the posterior aspect of the fetal neck is the:
    a. Nuchal fold
    b. Nuchal cord
    c. Nuchal translucency
    d. Rhombencephalon

25. The premature separation of the placenta from the uterine wall before the birth of the fetus describes:
    a. Placenta previa
    b. Placental abruption
    c. Ectopic cordis
    d. Subchorionic hamartoma

26. Something that is idiopathic is said to be:
    a. Caused by a functional abnormality
    b. Related to fetal development
    c. From an unknown cause
    d. Found incidentally

27. Which of the following forms of fetal presentation is the most common?
    a. Cephalic
    b. Complete breech
    c. Frank breech
    d. Transverse

28. Biophysical profile scoring is conducted:
    a. Until the fetus cooperates
    b. For 10 minutes
    c. For 45 minutes
    d. For 30 minutes

29. What is the fetal presentation when the fetal buttocks are closest to the cervix?
    a. Footling breech
    b. Frank breech
    c. Complete breech
    d. Transverse

30. Which of the following would not typically produce an elevation in hCG?
    a. Down syndrome
    b. Anembryonic pregnancy
    c. Triploidy
    d. Molar pregnancy

31. The triple screen typically includes an analysis of:
    a. hCG, alpha-fetoprotein, and estriol
    b. Fetal NT, alpha-fetoprotein, and inhibin A
    c. hCG, alpha-fetoprotein, and inhibin A
    d. hCG, alpha-fetoprotein, and PAPP-A

32. The dilation of the renal collecting system secondary to the obstruction of normal urine flow defines:
    a. Nephrocalcinosis
    b. Hydronephrosis
    c. Renal calculi
    d. Urinary stasis

33. The physiologic ovarian cyst that develops after ovulation has occurred is the:
    a. Theca internal cyst
    b. Graafian cyst
    c. Corpus luteum cyst
    d. Cystic teratoma

34. The protein that is produced by the yolk sac, fetal gastrointestinal tract, and the fetal liver is:
    a. alpha-fetoprotein
    b. hCG
    c. PAPP-A
    d. Inhibin A

35. Which of the following best describes the optimal instance to take the femur length measurement?

a. When the epiphyseal plates are clearly identified and the shaft is parallel to the sound beam
b. When the diaphysis of the femur is parallel to the sound beam
c. When the long axis of the femoral shaft is perpendicular to the sound beam
d. When the femoral shaft is parallel to the sound beam

36. The abdominal circumference should include all of the following except:
a. The fetal stomach
b. The fetal thoracic spine
c. The umbilical vein
d. The kidneys

37. Which of the following artifacts is produced when the sound beam is barely attenuated through a fluid or a fluid-containing structure?
a. Reverberation artifact
b. Comet tail artifact
c. Posterior shadowing
d. Acoustic enhancement

38. Which of the following artifacts is caused by attenuation of the sound beam?
a. Reverberation artifact
b. Comet tail artifact
c. Posterior shadowing
d. Posterior enhancement

39. Which of the following would be least likely associated with an elevation in MSAFP?
a. Anencephaly
b. Turner syndrome
c. Spina bifida
d. Myelomeningocele

40. Which of the following is also referred to as trisomy 13?
a. Down syndrome
b. Edwards syndrome
c. Turner syndrome
d. Patau syndrome

SUGGESTED READINGS

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Sanders RC, Hall-Terracciano B. Clinical Sonography: A Practical Guide. 5th Ed. Philadelphia: Wolters Kluwer, 2016:61–93 & 399.

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23

The First Trimester

Introduction

This chapter provides the normal progression of a singleton pregnancy and the sonographic findings consistent with an intrauterine pregnancy during the first trimester. In addition, first-trimester pathology is also presented, with emphases on the specific sonographic and clinical findings of each abnormality.

Key Terms

abortion—the complete expulsion or partial expulsion of the conceptus

adnexal ring sign—the sonographic sign that describes the appearance of an ectopic pregnancy within the fallopian tube

amnion—the wall of the inner sac (amniotic cavity) that contains the embryo and amniotic fluid; echogenic curvilinear structure that may be seen during the first trimester within the gestational sac

amniotic cavity—the cavity that contains simple-appearing amniotic fluid and the developing embryo

ampulla (fallopian tube)—the longest and most tortuous segment of the fallopian tube; area of the tube in which fertilization takes place and a common location for ectopic pregnancies to implant

anembryonic gestation—an abnormal pregnancy in which there is no evidence of a fetal pole or yolk sac within the gestational sac; also referred to as a blighted ovum

aneuploid—a condition of having an abnormal number of chromosomes

blastocyst—the stage of the conceptus that implants within the decidualized endometrium

blighted ovum—see key term anembryonic gestation

bradycardia—a low heart rate

choriocarcinoma—the most malignant form of gestational trophoblastic disease with possible metastasis to the liver, lungs, and vagina

chorion—the outer membrane of a gestation that surrounds the amnion and the developing embryo

chorion frondosum—the part of the chorion, covered by chorionic villi, that is the fetal contribution of the placenta

chorionic cavity—the space between the chorionic sac and the amniotic sac that contains the secondary yolk sac; also referred to as the extraembryonic coelom

chorionic sac—the gestational sac; also see key term chorion

chorionic villi—fingerlike projections of gestational tissue that attach to the decidualized endometrium and allow transfer of nutrients from the mother to the fetus

choroid plexus—specialized cells within the ventricular system responsible for cerebrospinal fluid production

conception—the combination of a female ovum with a male sperm to produce a zygote; also referred to as fertilization

corpus luteum cyst—physiologic ovarian cyst that develops after ovulation has occurred

corpus luteum of pregnancy—the corpus luteum that is maintained during an early pregnancy for the purpose of producing estrogen and primarily progesterone

crown rump length—the measurement of the embryo/fetus from the top of the head to the rump

decidua basalis—the endometrial tissue at the implantation site, and the maternal contribution of the placenta

decidual reaction—the physiologic effect on the endometrium in the presence of a pregnancy

discriminatory zone—the level of human chorionic gonadotropin beyond which an intrauterine pregnancy is consistently visible

double decidual sign—the normal sonographic appearance of the decidua capsularis and decidua parietalis, separated by the anechoic fluid-filled uterine cavity

double sac sign—see key term double decidual sign

eclampsia—a sequela of preeclampsia in which uncontrollable maternal hypertension and proteinuria lead to maternal convulsions and possibly fetal and maternal death

ectopic pregnancy—a pregnancy located outside the endometrial cavity of the uterus

embryo—term given to the developing fetus before 10 weeks' gestation

embryonic demise—the death of an embryo before 10 weeks' gestation

extraembryonic coelom—see key term chorionic cavity

falx cerebri—a double fold of dura mater located within midline of the brain

fimbria—the fingerlike extension of the fallopian tube located on the infundibulum

focal myometrial contraction—localized, painless contractions of the myometrium in the gravid uterus that should resolve within 20 to 30 minutes

gestational age—the way in which a pregnancy can be dated based on the first day of the last menstrual cycle; also referred to as menstrual age

gestational trophoblastic disease—a disease associated with an abnormal proliferation of the trophoblastic cells during pregnancy; may also be referred to as a molar pregnancy

Graafian follicle—the name for the dominant follicle prior to ovulation

hematocrit—the laboratory value that indicates the amount of red blood cells in blood

hematopoiesis—the development of blood cells

heterotopic pregnancy—coexisting ectopic and intrauterine pregnancies

human chorionic gonadotropin—hormone produced by the trophoblastic cells of the early placenta; may also be used as a tumor marker in nongravid patients and males

hydatidiform mole—the most common form of gestational trophoblastic disease in which there is excessive growth of the placenta and high levels of human chorionic gonadotropin; typically benign

hyperemesis gravidarum—excessive vomiting during pregnancy

idiopathic—from an unknown origin

implantation bleeding—a bleed that occurs at the time in which the conceptus implants into the decidualized endometrium

infundibulum—the distal segment of the fallopian tube

intradecidual sign—the appearance of a small gestational sac in the uterine cavity surrounded by the thickened, echogenic endometrium

intrauterine contraceptive device—a reversible form of contraception that

is manually placed in the uterine cavity to prevent pregnancy; also referred to as an intrauterine device

invasive mole—a type of gestational trophoblastic disease in which a molar pregnancy invades into the myometrium and may also invade through the uterine wall and into the peritoneum

limb buds—early embryonic structures that will eventually give rise to the extremities

mean sac diameter—the measurement of the gestational sac to obtain a gestational age; achieved by adding the measurements of the length, width, and height of the gestational sac and dividing by 3

menstrual age—see key term gestational age

methotrexate—a chemotherapy drug used to attack rapidly dividing cells like those seen in an early pregnancy; this drug is often used to manage ectopic pregnancies

miscarriage—the spontaneous end of a pregnancy before viability

missed abortion—fetal demise with a retained fetus

morula—the developmental stage of the conceptus following the zygote

multiloculated—having more than one internal cavity

multiparity—having had several pregnancies

nuchal translucency—the anechoic space along the posterior aspect of the fetal neck

pelvic inflammatory disease—infection of the female genital tract that may involve the ovaries, uterus, and/or the fallopian tubes

physiologic bowel herniation—the normal developmental stage when the midgut migrates into the base of the umbilical cord

preeclampsia—pregnancy-induced maternal high blood pressure and excess protein in the urine after 20 weeks' gestation

pseudogestational sac—the appearance of an abnormally shaped false gestational sac within the uterine cavity as a result of an ectopic pregnancy; this often corresponds with the accumulation of blood and secretions within the uterine cavity

rhombencephalon—the primary brain vesicle also referred to as the hindbrain; becomes the cerebellum, pons, medulla oblongata, and fourth ventricle

secondary yolk sac—the structure responsible for early nutrient transfer to the embryo; the yolk sac seen during a sonographic examination of the early gestation

subchorionic hemorrhage—a bleed between the endometrium and the gestational sac at the edge of the placenta

triploid—having three sets of each chromosome or 69 total

trisomy 18—chromosomal aberration in which there is a third chromosome 18; also referred to as Edwards syndrome

trisomy 21—chromosomal aberration in which there is a third chromosome 21; also referred to as Down syndrome

trophoblastic cells—the cells that surround the gestation that produce human chorionic gonadotropin

Turner syndrome—a chromosomal aberration where one sex chromosome is absent; may also be referred to as monosomy X

uterine leiomyoma—a benign, smooth muscle tumor of the uterus; may also be referred to as a fibroid or uterine myoma

vitelline duct—the structure that connects the developing embryo to the secondary yolk sac

zygote—the cell formed by the union of two gametes; the first stage of a fertilized ovum

NORMAL CONCEPTION AND THE FIRST 6 WEEKS

A mature ovum is released through ovulation at around day 14 of the menstrual cycle because the Graafian follicle ruptures and liberates the ovum into the peritoneal cavity. The fimbria of the fallopian tube transports the ovum into the distal portion of the tube, the infundibulum. Conception, also referred to as fertilization, is the union of an ovum and a sperm. A sperm, which can live up to 72 hours, unites with the egg in the distal one-third of the fallopian tube, most likely in the ampulla. Conception usually occurs within 24 hours after ovulation.

The combination of the sperm and ovum produces a structure referred to as the zygote. The zygote undergoes rapid cellular division and eventually forms into a cluster of cells called the morula. The morula continues to differentiate and form a structure referred to as the blastocyst. The outer tissue layer of the blastocyst is comprised of syncytiotrophoblastic tissue, also referred to as trophoblastic cells. The trophoblastic cells are the cells that produce the pregnancy hormone human chorionic gonadotropin (hCG). The inner part of the blastocyst will develop into the embryo, amnion, umbilical cord, and the primary and secondary yolk sacs. The outer part, the trophoblastic tissue, will develop into the placenta and chorion.



SOUND OFF

The trophoblastic cells are the cells that produce the pregnancy hormone hCG.

On day 20 or 21 of the menstrual cycle, the blastocyst begins to implant into the decidualized endometrium at the level of the uterine fundus. By 28 days, complete implantation has occurred, and all early connections have been established between the gestation and the mother. The blastocyst makes these link with the maternal endometrium via small projections of tissue called chorionic villi. The implantation of the blastocyst within the endometrium may cause some women to experience a small amount of vaginal bleeding. This is referred to as implantation bleeding.

The fourth week of gestation is an extremely dynamic stage in the pregnancy. The primary yolk sac regresses during week 4, and two separate membranes are formed. The outer membrane is the chorionic sac or gestational sac. Within the gestational sac is the amnion or amniotic sac. By the end of week 4, the secondary yolk sac becomes wedged between these two membranes in an area called the chorionic cavity or extraembryonic coelom.

The developing embryo is located between the yolk sac and the amnion at 4 weeks. At this time, the alimentary canal is formed. It will become the foregut, midgut, and hindgut. The neural tube also begins to develop at this time. The neural tube will become the fetal head and spine. By 5 weeks, suspicion of pregnancy abounds, because the woman misses the scheduled onset of menses for the month. Within the developing gestation, the embryonic heart begins to beat for the first time. By 6 weeks, all internal and external structures are in the process of forming. Sonographic findings are additionally discussed in this chapter.



SOUND OFF
The gestational sac is also referred to as the chorionic sac.

LAST MENSTRUAL PERIOD

Obtaining an accurate last menstrual period (LMP) can be a vital part of the sonographic examination of a pregnant patient. Menstrual age or gestational age is used by obstetricians, radiologists, and sonographers to date a pregnancy. They are calculated using the LMP. An accurate LMP is significant in determining whether the pregnancy is progressing normally. The obstacle of an inaccurate LMP provided by the patient can be overcome by referencing the level of hCG found in the maternal circulation and relating those findings with sonographic findings.

HUMAN CHORIONIC GONADOTROPIN AND THE DISCRIMINATORY ZONE

The laboratory test used to detect pregnancy is hCG. This hormone is produced throughout pregnancy by the placenta. In the first trimester, hCG maintains the corpus luteum cyst of the ovary so that the corpus luteum can continue to produce progesterone. The sustained production of progesterone maintains the thickness of the endometrium, thus allowing implantation to occur. Clinically, hCG can be detected in the maternal urine and serum (blood).



SOUND OFF

In the first trimester, hCG maintains the corpus luteum of the ovary so that the corpus luteum can continue to produce progesterone.

Both blood and urine tests can be qualitative, answering the question, "Is the patient pregnant?" But only blood can be quantitative, answering the question, "How pregnant is the patient?" hCG is detected in the maternal blood as early as 23 days' menstrual age.

hCG can be measured using several methods. Most assays for hCG are now calibrated against the Third International Standard, but some may still use the Second International Standard. The laboratory performing the test will provide the reference range. However, a gestational sac, the earliest definitive sign of an intrauterine pregnancy (IUP), should generally be visualized between 1,000 and 2,000 mIU per mL with transvaginal sonography. The period given to describe the earliest sonographic detection of an IUP is termed the discriminatory zone or level.



SOUND OFF

A gestational sac, the earliest definitive sign of an IUP, should generally be visualized between 1,000 and 2,000 mIU per mL with transvaginal sonography.

Based on quantitative hCG levels, sonographers can utilize the discriminatory zone and determine whether an IUP should be visualized. Typically, a 5-mm gestational sac will be seen at approximately 5 menstrual weeks. Normal hCG levels double every 48 hours in the first trimester. High and low levels of hCG compared with LMP and sonographic findings can be indicative of an abnormal pregnancy (Table 23-1). The hCG level will continue to rise until the end of the first trimester, at which time it plateaus

and slowly decreases with advancing gestation. However, research has shown that an hCG level above the discriminatory level in conjunction with a normal sonogram does not necessarily exclude the possibility of a normal IUP. Consequently, sequential hCG levels and sonograms may be warranted.

TABLE 23-1 Human chorionic gonadotropin (hCG) levels compared with normal pregnancy

Nature of Pregnancy	hCG Level
Ectopic pregnancy	↓
Anembryonic pregnancy	↓
Abortion (miscarriage)	↓
Twin pregnancy	↑
Complete molar pregnancy	(markedly) ↑



SOUND OFF
Normal hCG levels double every 48 hours in the first trimester.

NORMAL SONOGRAPHIC FINDINGS DURING THE FIRST TRIMESTER

The following sections provide an analysis of the maternal uterus and fetus in the first trimester. The sonographer should be mindful of the potential biologic effect of ultrasound on the fetus. Specifically, the use of color Doppler exposure in the first trimester should be limited, and the ALARA principle (as low as reasonably achievable) be practiced. The thermal index, which is the amount of energy required to raise tissue temperature 1°C, should be kept below 1.

Decidual Reaction (Weeks 3 to 4)

The decidual reaction of the endometrium is essentially the first sonographically identifiable sign of a pregnancy. In essence, the endometrium is preparing itself for the implantation of the conceptus. The decidualized endometrium will appear thick and echogenic as a result of the continued production of progesterone by the corpus luteum. A decidual reaction is considered to be a nonspecific sonographic finding of pregnancy because the endometrium can also appear thick and echogenic during the secretory phase of the endometrial cycle and in the presence of an ectopic

pregnancy. A correlation between hCG levels and sonographic findings should be performed.

Gestational Sac (Weeks 4 to 5)

The first definitive sonographic sign of an IUP is identification of the gestational sac within the decidualized endometrium. The blastocyst is the developmental stage of the conceptus that implants into the uterine cavity. The blastocyst gives rise to the gestational sac, or chorionic sac. The early gestational sac, which is first seen at 5 weeks, appears as a small, anechoic sphere within the decidualized endometrium. It will grow at a rate of 1 mm per day in early pregnancy.



SOUND OFF

The first definitive sonographic sign of an IUP is identification of the gestational sac within the decidualized endometrium.

The intradecidual sign denotes the appearance of the small gestational sac in the uterine cavity surrounded by the thickened, echogenic endometrium. The intradecidual sign can be misdiagnosed because it may resemble the pseudogestational sac of an ectopic pregnancy. To differentiate an intrauterine gestational sac from the pseudogestational sac, sonographers can assess the endometrium for evidence of the double sac sign or double decidual sign (Fig. 23-1). The double sac sign denotes the typical appearance of the two distinct layers of decidua, the decidua capsularis (inner layer) and decidua parietalis (outer layer), separated by the anechoic fluid-filled uterine cavity. Table 23-2 and Figure 23-2 provide both a diagram and an explanation of the embryologic tissues present in the early gestation.

Both the intradecidual sign and double sac sign are sonographic findings that were initially discovered and relied upon in the past with transabdominal pelvic sonography. However, high-resolution transvaginal sonography can, in most cases, clearly depict the endometrium and its contents much more readily than transabdominal imaging. Therefore, it is safe to assume that a round or an oval-shaped fluid collection within the endometrium of a patient with a positive pregnancy test, and whose hCG level is above the discriminatory zone, is a gestational sac. Nonetheless, it is vital that other clinical findings, such as vaginal bleeding and pain, be correlated with sonographic findings.

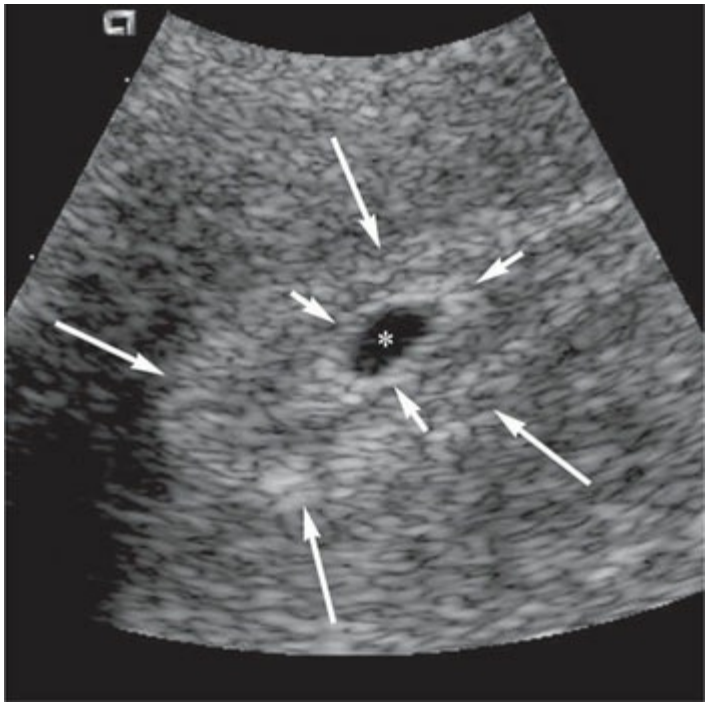


Figure 23-1 Gestational sac at 5.0 weeks' gestation. The gestational sac (*) is seen as a round fluid collection within the endometrium, with no structures yet seen within it. The gestational sac is surrounded by two echogenic rings, an inner ring (*short arrows*) and an outer ring (*long arrows*), corresponding to the two layers of the decidua. This is referred to as the double sac sign or double decidual sign.

TABLE 23-2 A list of various embryologic tissues and their description

Embryologic Tissues	Description
Chorionic cavity	The space between the gestational sac and the amniotic sac. The location of the secondary yolk sac.
Chorion frondosum	The decidualized tissue at the implantation site containing the chorionic villi. The fetal contribution of the placenta.
Chorion laeve	The portion of the chorion that does not contain chorionic villi.
Chorionic villi	Fingerlike extension of trophoblastic tissue that invades the decidualized endometrium.
Decidua basalis	The endometrial tissue at the implantation site. The maternal contribution of the placenta.
Decidua capsularis	The portion of the decidua opposite the uterine cavity, across from the decidua basalis.
Decidua parietalis (vera)	The decidualized tissue along the uterine cavity adjacent to the decidua basalis.

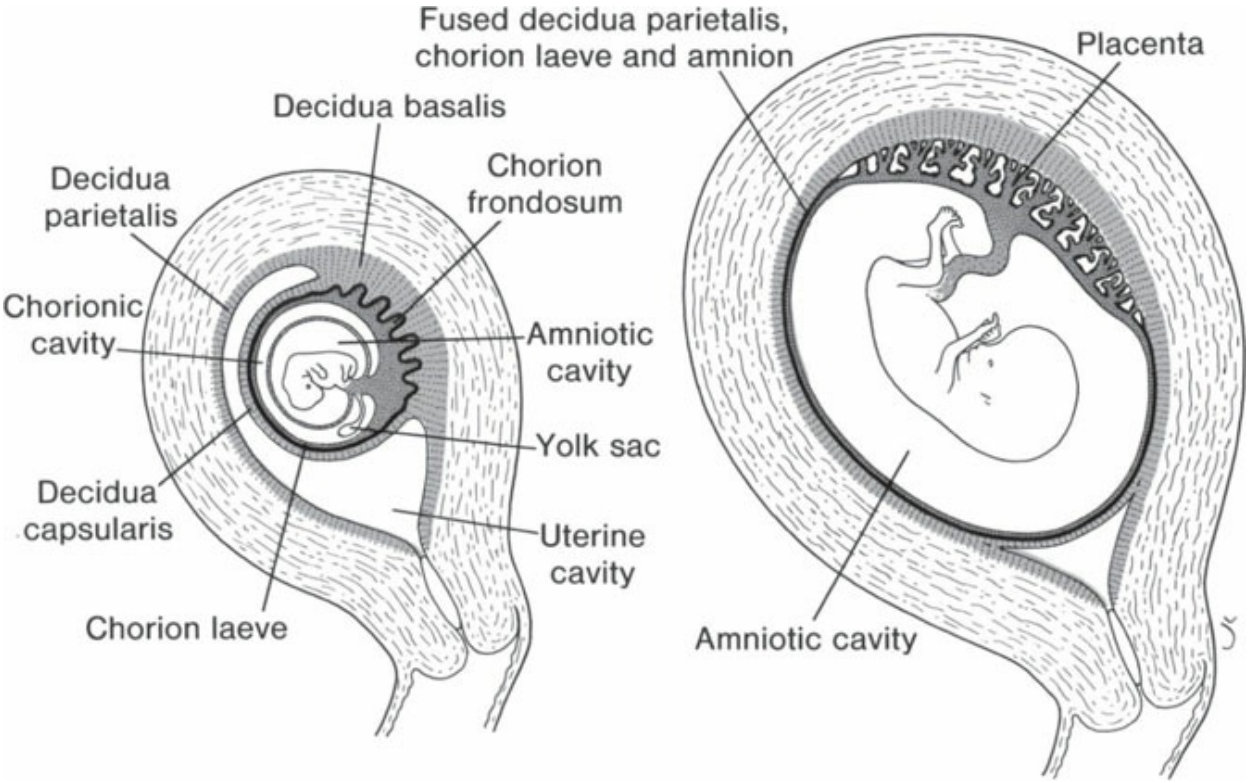


Figure 23-2 Relation of fetal membranes to wall of the uterus.

The measurement of the gestational sac is the earliest sonographic measurement that can be obtained to date the pregnancy. A mean sac diameter (MSD) is achieved by adding the measurements of the length, width, and height of the gestational sac and dividing by 3. The gestational sac measurement is a relatively accurate form of dating that can be used until a fetal pole is sonographically recognized. Although modern sonography equipment calculates the MSD for sonographers, there is also a simple formula that can be used. By adding 30 to the MSD (measurement in millimeters). sonographers can obtain an estimate for the gestational age in days.

When the gestational sac seems visually disproportional to the size of the embryo, that is, too small or too large compared to the size of the embryo, an MSD measurement can be exceedingly beneficial in determining whether asymmetry truly exists. An irregularly shaped gestational sac and an MSD of >25 mm that does not contain a fetal pole are both signs potential pregnancy failure.

SOUND OFF

By adding 30 to the MSD (measurement in millimeter), sonographers can obtain an estimate for the gestational age in days.

Secondary Yolk Sac (5.5 Weeks)

The first structure seen with sonography within the gestational sac is the secondary yolk sac (Fig. 23-3). It appears within the gestational sac as a round, anechoic structure surrounded by a thin, echogenic rim. It is located within the chorionic cavity, between the amnion and the chorion. This cavity may also be referred to as the extraembryonic coelom or extracelomic space. The yolk sac produces alpha-fetoprotein and plays an important role in angiogenesis and hematopoiesis during early embryologic development. It is connected to the embryo by the vitelline duct, also referred to as the omphalomesenteric duct, which contains one artery and one vein. It may be visualized during a first-trimester sonographic examination. The yolk sac can be measured during the first trimester and should be imaged and evaluated for irregular shape, echogenicity, and size. Abnormal appearances of the yolk sac are discussed further in this chapter (see "Embryonic Demise and Pregnancy Failure" section).

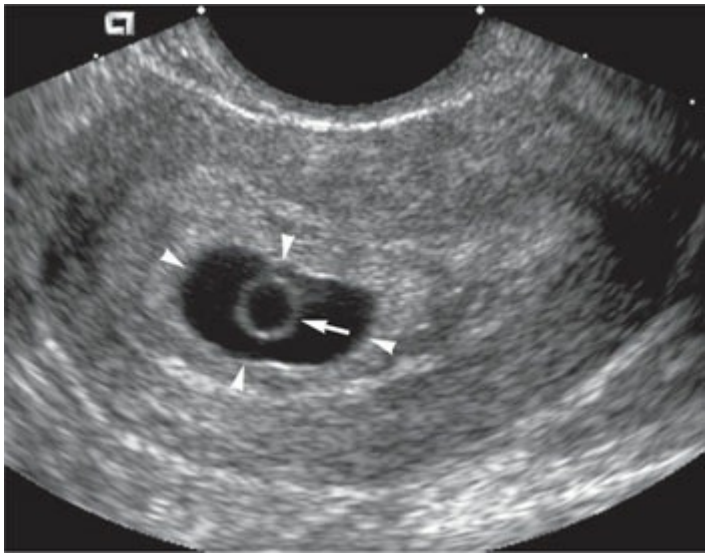


Figure 23-3 Gestational sac and secondary yolk sac at 5.5 weeks' gestation. The gestational sac (*arrowheads*) contains the secondary yolk sac (*arrow*). No embryo is seen at this time.

SOUND OFF
The yolk sac is connected to the embryo by the vitelline duct, also referred to as the omphalomesenteric duct, which contains one artery and one vein.

Chorionic and Amniotic Cavities (5.5 Weeks)

The gestational sac consists of two cavities: the chorionic cavity and amniotic cavity. The chorionic cavity lies between the amnion and the chorion. It contains the yolk sac and fluid. The amniotic cavity contains

simple-appearing amniotic fluid and the developing embryo. The amniotic membrane, or amnion, can be seen within the gestational sac as a thin, echogenic line loosely surrounding the embryo (Fig. 23-4). The amnion and chorion typically fuse around the middle of the first trimester, but may not be totally fused until 16 weeks' gestation.

SOUND OFF
The yolk sac is located within the chorionic cavity.

Embryo (5 to 6 Weeks)

By 6 weeks, the embryo can be seen located within the amniotic cavity adjacent to the yolk sac, with transvaginal sonography. The documentation of fetal heart activity is performed using motion mode (M-mode). Occasionally, a tiny heartbeat is often seen before an embryo can be measured, with sonographic documentation of heart activity being present between 5 and 6 weeks. Heart motion can be detected in a 4-mm embryo, with motion certainly evident within the 5-mm embryo. The embryo will grow at a rate of 1 mm per day in the first trimester. Embryonic heart rate is considered normal at 100 to 110 bpm between 5 and 6 weeks. The heart rate increases to 150 bpm by 9 weeks. From second trimester to term, the fetal heart rate is typically around 150 bpm although it will vary with gestation age. Bradycardia is associated with a poor prognosis and is often the first sonographic sign of an eminent embryologic demise (see "Embryonic Demise and Pregnancy Failure" section).

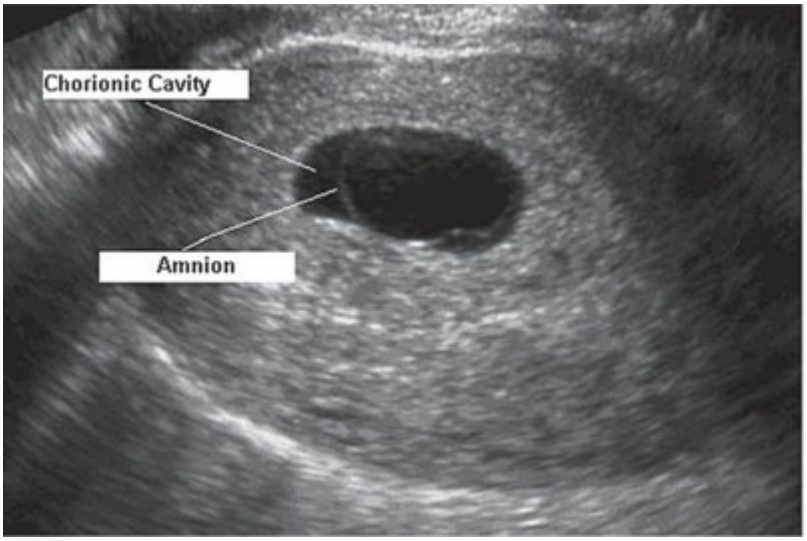


Figure 23-4 Chorionic cavity and amnion. The chorionic cavity and amnion are seen within this image of an early pregnancy.

The most accurate sonographic measurement of pregnancy is the crown

rump length. The crown rump length (CRL) can be taken when a fetal pole is identified and should not include the yolk sac or fetal limb buds within the measurement (Fig. 23-5). This measurement can be taken throughout the first trimester, and typically until second-trimester biometric measurements can be obtained.

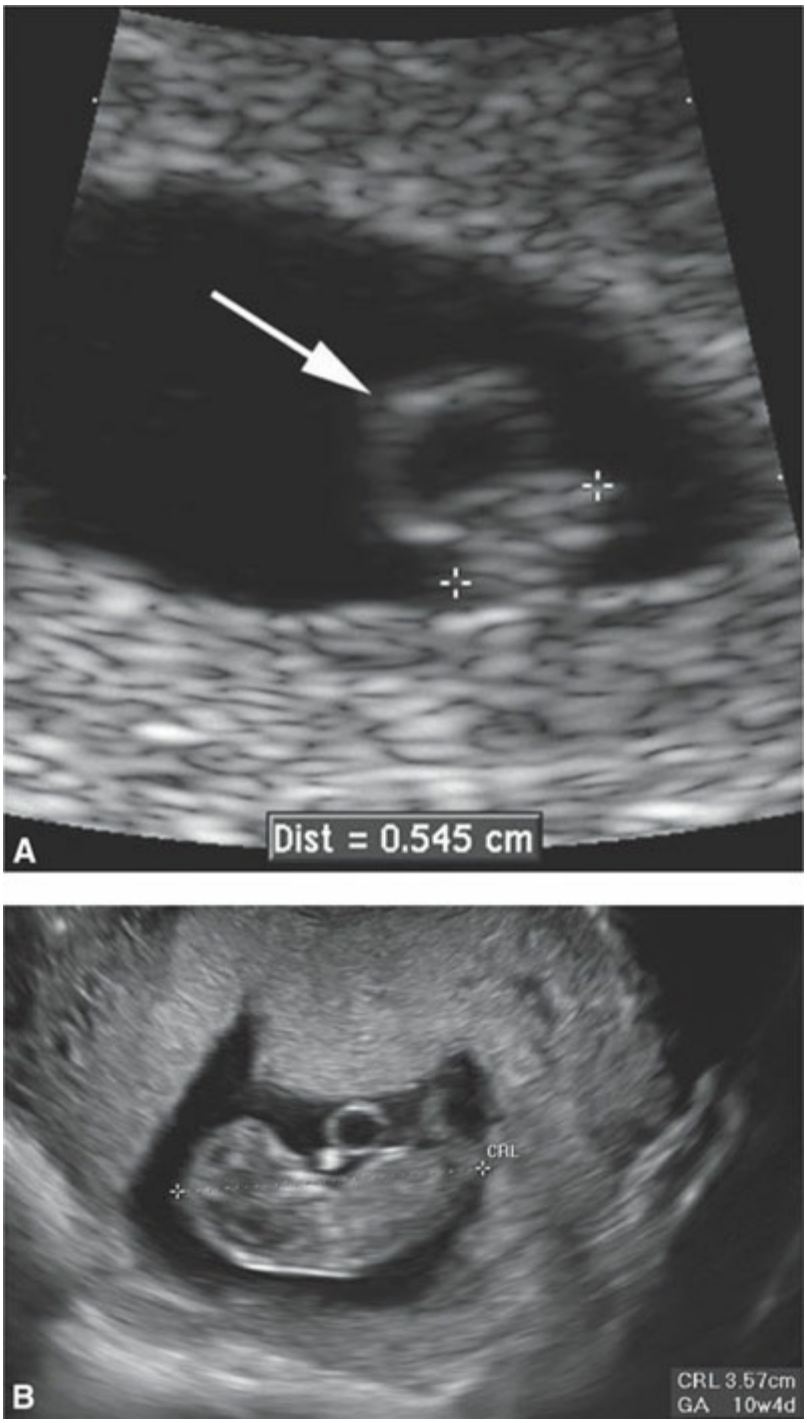


Figure 23-5 Crown rump length (*CRL*). **A.** CRL (*between calipers*) at 6.5 weeks. The yolk sac can be clearly identified (*arrow*) adjacent to the embryo. **B.** CRL (*between calipers*) at 10 weeks and 4 days.

SOUND OFF
The most accurate sonographic measurement of pregnancy is the CRL.

Embryo (7 to 8 Weeks)

Fetal limb buds are readily identified by 7 weeks. The fetal head at this time is proportionally larger than the body. Within the fetal head, a cystic structure may be noted. This most often represents the rhombencephalon, or hindbrain (Fig. 23-6). The rhombencephalon will eventually develop into the fourth ventricle and several other essential brain structures. As early as 8 weeks, the stomach may be visualized in the upper abdomen as well.

SOUND OFF
Within the fetal head, a cystic structure may be noted. This most often represents the rhombencephalon, which will develop into the fourth ventricle and other essential brain structures.

Embryo (9 to 12 Weeks)

Physiologic bowel herniation begins at 8 weeks, which marks the developmental stage when the midgut migrates into the base of the umbilical cord (Fig. 23-7). This phenomenon is developmentally normal. The sonographer should determine the gestational age based on CRL and understand that physiologic herniation is normal during this early stage of maturity. Conversely, if physiologic bowel herniation does not resolve by 12 weeks, a follow-up examination is often warranted.

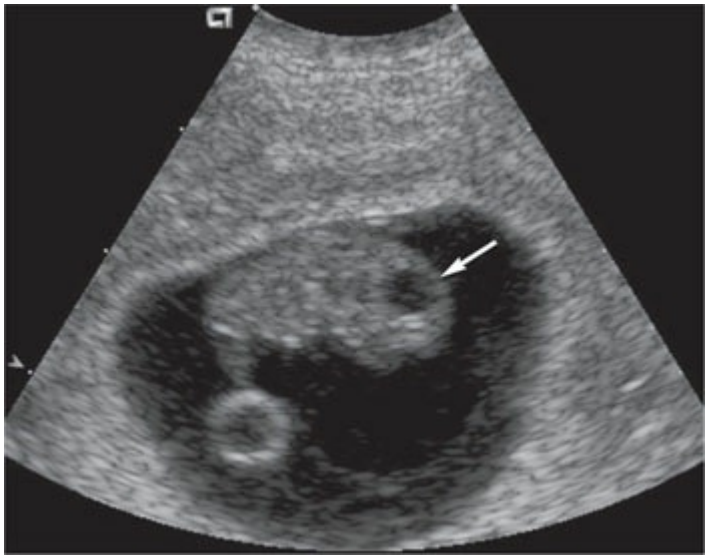


Figure 23-6 Rhombencephalon. The rhombencephalon (*arrow*) is seen within the

head of this 8-week embryo, appearing as a cyst.



Figure 23-7 Physiologic bowel herniation. Transverse image of the fetal abdomen at 11.5 weeks' gestation demonstrating the normal herniation of the bowel (*arrow*) into the base of the umbilical cord.

SOUND OFF
If physiologic bowel herniation does not resolve by 12 weeks, a follow-up examination is often warranted.

At the end of the first trimester, the fetal limbs are much more readily identifiable with sonography. Inside the fetal head, the lateral ventricles may be noted, containing the echogenic choroid plexus. The cerebral hemispheres can also be separated by the echogenic, linear falx cerebri, which lies within the midline of the brain (Fig. 23-8). Fetal movement, the stomach, urinary bladder, umbilical cord, extremities, and spine can also be noted by the end of the first trimester. With transvaginal sonography, the fetal kidneys may be seen between 13 and 14 weeks. Fetal abnormalities, such as neural tube defects, abdominal wall defects, cardiac defects, facial features including the nasal bones and clefts, and disorders of the extremities, can be identified with high-resolution endovaginal sonography. However, in many institutions, a detailed examination of fetal anatomy is usually not performed at this time. Follow-up sonographic examinations and clinical correlation are warranted when fetal structural abnormalities are suspected during a first-trimester sonogram.



Figure 23-8 Choroid plexus within the lateral ventricles. Choroid plexus (*arrows*) is seen within the lateral ventricle of this 13-week gestation fetus.

Placenta and Umbilical Cord

The developing placenta may be noted at the end of first trimester as a well-defined, crescent-shaped homogeneous mass of tissue, along the margins of the gestational sac (Fig. 23-9). The placenta is formed by the decidua basalis, the maternal contribution of the placenta, and the chorion frondosum, the fetal contribution. The umbilical cord is visible during the latter half of the first trimester as a tortuous structure connecting the fetus to the developing placenta.

Nuchal Translucency and Nasal Bone (11 to 14 Weeks)

The evaluation of the nuchal translucency (NT) has become a vital part of early first-trimester screening. The term nuchal refers to the neck. Thus, this translucency is represented by a thin membrane along the posterior aspect of the fetal neck, which can be measured sonographically (Fig. 23-10). The most common abnormalities associated with increased NT are trisomy 21, trisomy 18, Turner syndrome, and congestive heart failure. When NT is combined with first-trimester laboratory findings, such as hCG and pregnancy-associated plasma protein A results, a high-detection rate for these and other fetal abnormalities can be achieved.

The measurement of this area is performed in the sagittal plane to the fetus, with the fetus in a neutral position (Fig. 23-11). The NT is optimally measured between 11 and 13 weeks' 6 days gestation, when the CRL

measures between 45 and 84 mm based on recommendations by The Fetal Medicine Foundation, although laboratory specifications may vary. Care should be taken as to not confuse the amnion for a prominent NT, because the fetus may be resting on the amnion. The normal range of thickness of the NT is based on the gestational age, although most often a measurement greater than 3 mm between 11 and 13 weeks 6 days is considered abnormal and warrants a follow-up examination, referral for fetal echocardiography, and fetal karyotyping. The cutoff measurement for NT screening for some institutions may be as high as 3.5 mm however; thus, the sonographer should be aware of institutional protocols. The guidelines for obtaining the NT measurement have been established by the American Institute of Ultrasound in Medicine and can be found at www.aium.org. They are summarized in Table 23-3.

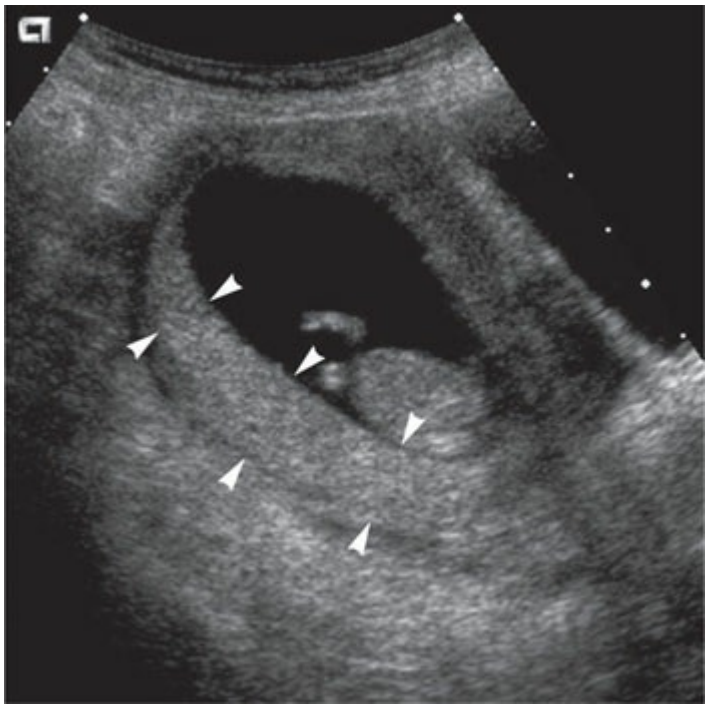


Figure 23-9 Placenta at 11 weeks. The developing placenta (*arrowheads*) is seen in this early pregnancy.

SOUND OFF
The NT is optimally measured between 11 and 13 weeks' 6 days gestation, when the CRL measures between 45 and 84 mm.

It has been recognized that with many Down syndrome fetuses, the nasal bone is either hypoplastic or absent between 11 and 13 weeks' gestation. Thus, the sonographic assessment of the nasal bone can be performed as part of a screening first-trimester protocol. There are specific guidelines for these

images, including the task of obtaining a midsagittal plane view of the fetus and gently rocking the transducer to ensure that the nasal bone can be visualized separate from the overlying nasal skin (Fig. 23-12). In a normal fetus, this will provide an "equal sign" in the area of the nasal bone and overlying nasal skin.

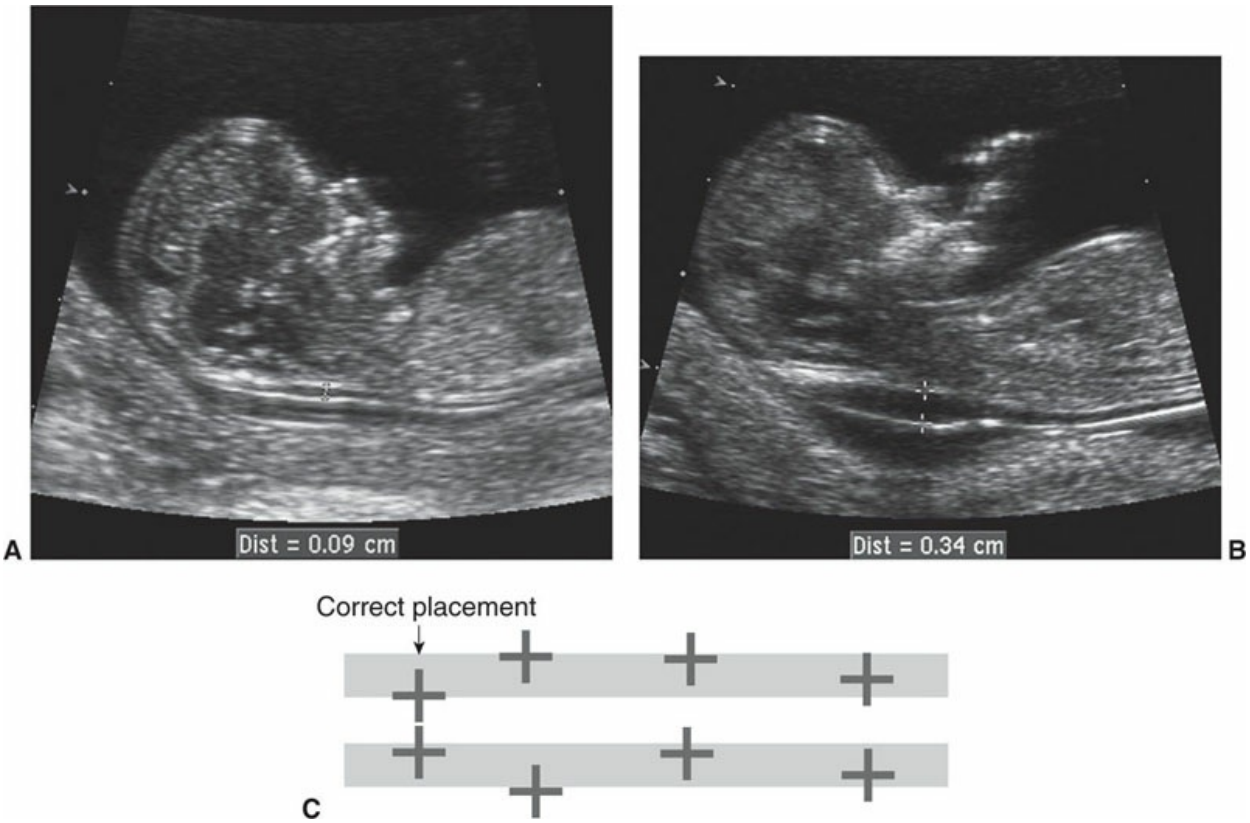


Figure 23-10 Nuchal translucency (NT). **A.** Normal NT. **B.** Abnormal NT. **C.** The *first set of calipers* is the correct placement for the NT measurement according to the American Institute of Ultrasound in Medicine.

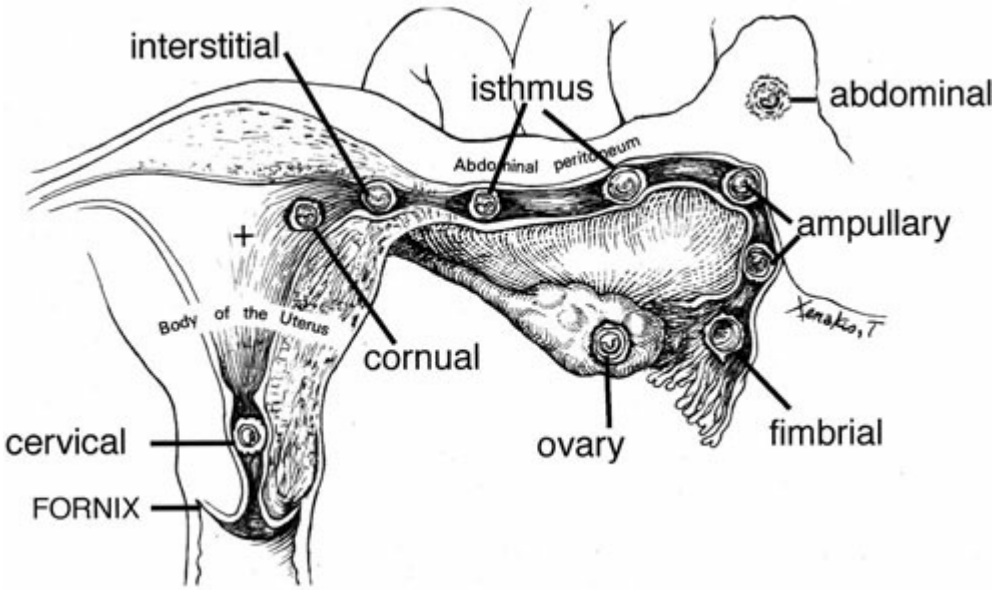


Figure 23-11 Possible ectopic pregnancy locations.

Corpus Luteum of Pregnancy

The most common pelvic mass associated with pregnancy is the ovarian corpus luteum cyst. The corpus luteum of pregnancy is a functional cyst that is maintained during the first trimester by hCG, which is produced by the developing placenta. As a result, the corpus luteum secretes progesterone and thereby maintains the thickness of the endometrium. Typically, the corpus luteum measures between 2 and 3 cm and regresses near the end of the first trimester although it may continue to grow as large as 10 cm. The sonographic appearance of the corpus luteum is variable. It may appear as a simple cyst, as a complex cyst with hemorrhagic components, as a hypoechoic mass, or have a thick echogenic rim that display increased color flow seen with color Doppler. This circumferential rim of vascularity often produces as low-resistance spectral Doppler waveform. For this reason, a corpus luteum cyst could be confused for an ectopic pregnancy because ectopic pregnancies can appear as an adnexal ring. Thus, a careful examination of the relationship of the cyst to the ovary and the components of the cyst should be undertaken. Images and additional information on corpus luteum cysts are provided in Chapter 18.

TABLE 23-3 Sonographic guidelines for a nuchal translucency (NT) measurement

Guidelines for NT Measurement
1. The margins of the NT edges must be clear enough for proper placement of the calipers.
2. The fetus must be in the midsagittal plane.
3. The image must be magnified so that it is filled by the fetal head, neck, and upper thorax.
4. The fetal neck must be in a neutral position, not flexed and not hyperextended.
5. The amnion must be seen as separate from the NT line.
6. The (+) calipers on the ultrasound must be used to perform the NT measurement.
7. Electronic calipers must be placed on the inner borders of the nuchal space with none of the horizontal crossbar itself protruding into the space.
8. The calipers must be placed perpendicular to the long axis of the fetus.
9. The measurement must be obtained at the widest space of the NT.

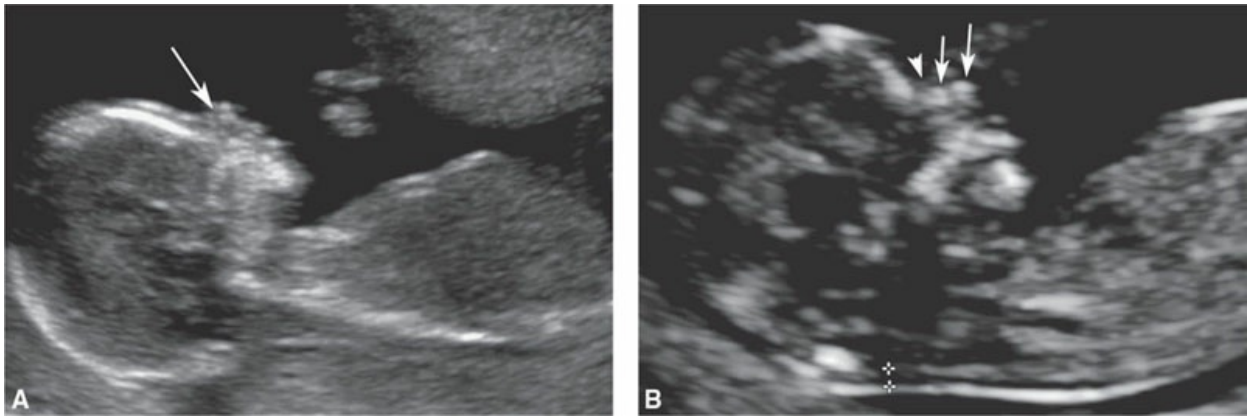


Figure 23-12 Nasal bone. **A.** Absent nasal bone (*arrow*). **B.** Normal nasal bone (*arrow*) and overlying skin (*arrowhead*).

CLINICAL FINDINGS OF THE CORPUS LUTEUM OF PREGNANCY

1. Asymptomatic
2. Pain associated with hemorrhage and enlargement of cyst

SONOGRAPHIC FINDINGS OF THE CORPUS LUTEUM OF PREGNANCY

1. Simple cyst appearance
2. A cysts with a thick, echogenic rim around it (may be difficult to differentiate from other solid and cystic adnexal masses)
3. Hemorrhagic cyst appearance, including complex components or entirely echogenic depending on the amount of blood and stage of lysis

SOUND OFF

The most common pelvic mass associated with pregnancy is the ovarian corpus luteum cyst.

FIRST-TRIMESTER PATHOLOGY

Ectopic Pregnancy

An ectopic pregnancy, also referred to as an extrauterine pregnancy (EUP), is the most common cause of pelvic pain with a positive pregnancy test. It can lead to pregnancy loss and, in some cases, maternal death. An EUP is defined as a pregnancy located anywhere other than the endometrial or uterine cavity. Women with a history of assisted reproductive therapy (technology), fallopian tube scarring, and/or pelvic inflammatory disease are among the list of patients who are at high risk for an EUP (Table 23-4). The most common location of an EUP is within the fallopian tube, specifically the ampullary

portion of the tube. Other locations for ectopic implantation include the isthmus of the tube, the fimbria, abdomen, interstitial portion of the fallopian tube (cornu of the uterus), ovary, and cervix, with the least common locations being the latter two (Fig. 23-13). Although rare, patients can have a coexisting EUP and IUP. This is termed a heterotopic pregnancy. Patients who are undergoing assisted reproductive therapy are also at increased risks for heterotopic pregnancies.

SOUND OFF

The most common location of an EUP is within the fallopian tube, specifically the ampullary portion of the tube.

TABLE 23-4 Contributing factors for ectopic pregnancy

Previous ectopic pregnancy
Previous tubal surgery (including tubal sterilization)
History of pelvic inflammatory disease (salpingitis)
Undergoing infertility treatment
Previous or present use of an intrauterine contraceptive device
Multiparity
Advanced maternal age

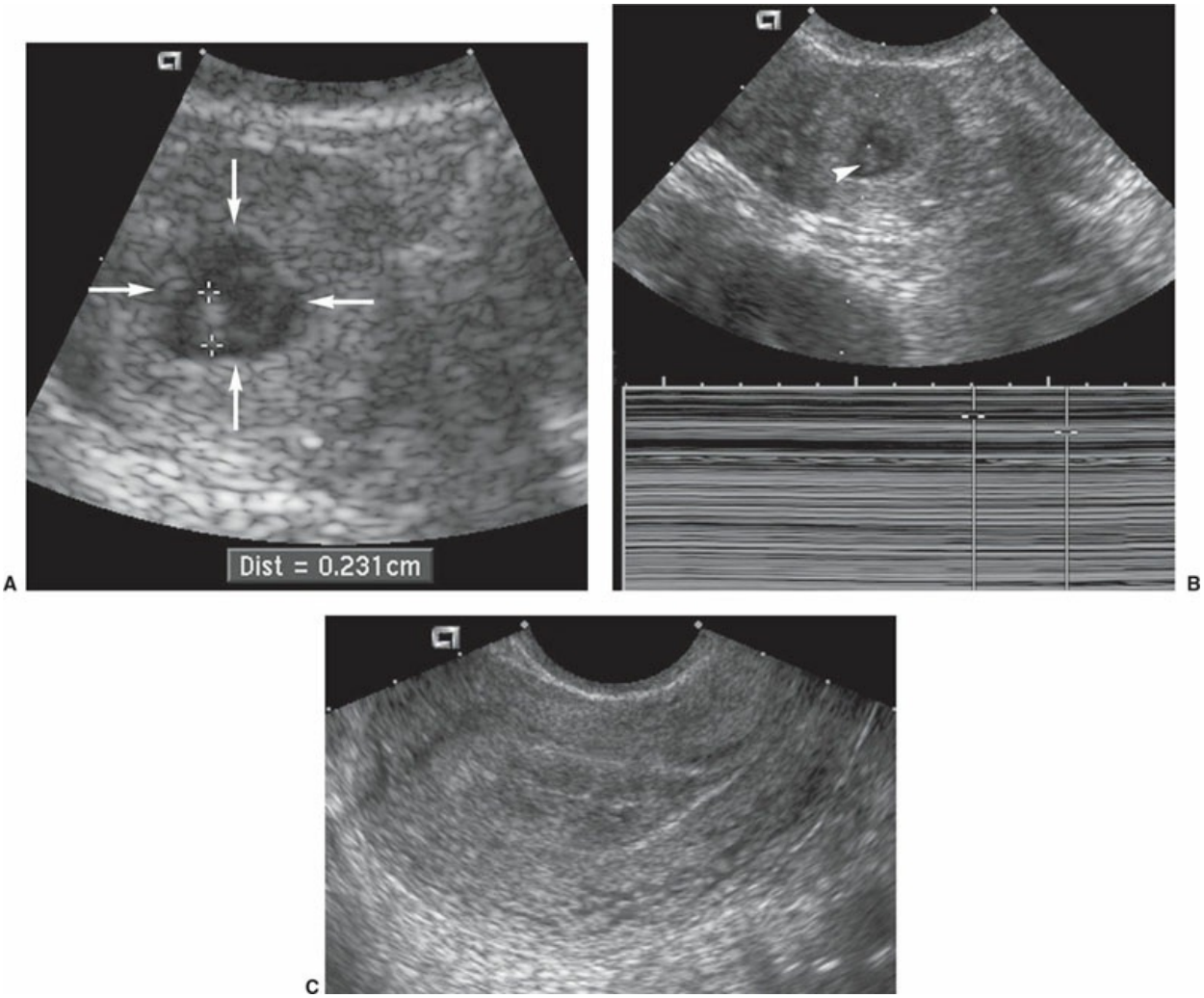


Figure 23-13 Ectopic pregnancy with an extrauterine gestational sac containing a live embryo. **A.** Transvaginal view of the right adnexa demonstrating an extrauterine gestational sac (*arrows*) containing an embryo (*calipers*). **B.** The embryo (*arrowhead*) does have cardiac activity documented by M-mode (*calipers*). **C.** Sagittal transvaginal image of the uterus revealing a thickened endometrium with no visible gestational sac.

The classic clinical triad of an EUP includes pain, vaginal bleeding, and a palpable abdominal/pelvic mass. Other clinical findings include amenorrhea, positive pregnancy test, low hCG compared to a normal IUP based on the gestational age, shoulder pain (secondary to intraperitoneal hemorrhage with diaphragmatic irritation), low hematocrit (with rupture), and cervical motion tenderness. hCG can be helpful, because with a normal IUP, the hCG level should double every 48 hours, whereas with an EUP, the hCG will have a slower rise. Sonographically, an EUP may be obvious, offering evidence of an extrauterine gestational sac that contains a fetus and yolk sac. Other sonographic findings include the adnexal ring sign, a complex adnexal mass located between the ovary and the uterus, a large amount of free fluid within the pelvis and in Morison pouch (with complex free fluid representing hemoperitoneum), a pseudogestational sac, and a poorly decidualized

endometrium (Fig. 23-14).

An EUP that implants within the intramural portion of the fallopian tube may be referred to as an interstitial pregnancy, and in the past, was referred to as a cornual pregnancy. This portion of the uterus is highly vascular and is prone to excessive hemorrhage. Interstitial pregnancies are considered potentially life threatening because the pregnancy may progress normally until spontaneous rupture occurs. In the presence of an interstitial pregnancy, sonography will yield a gestational sac that is located in the superolateral portion of the uterus. Care must be taken to assess for thinning of the myometrium surrounding the gestation that is located within the interstitial portion of the fallopian tube.

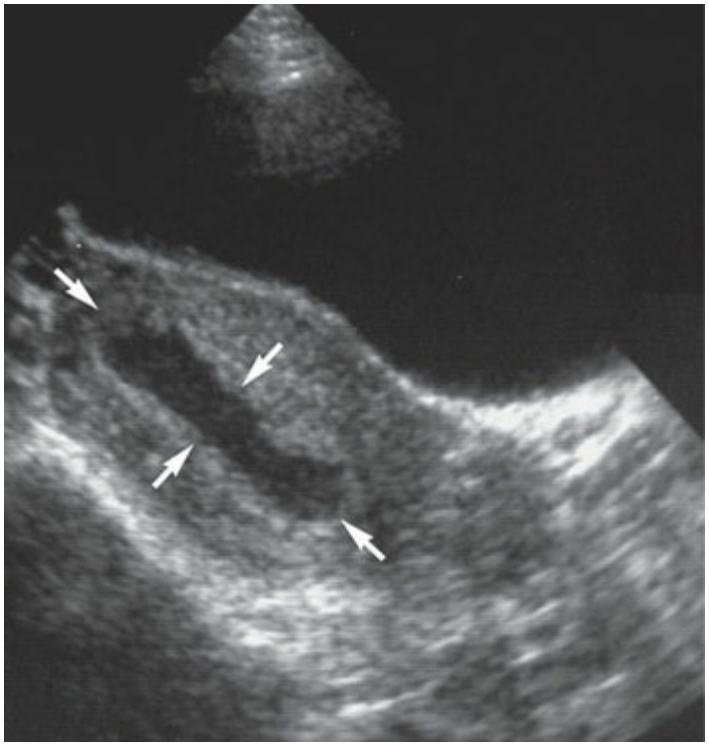


Figure 23-14 Ectopic pregnancy with an irregular-appearing gestational sac. Sagittal transabdominal image of the uterus demonstrating an irregular endometrial fluid collection (arrows), which may be referred to as a pseudogestational sac. No yolk sac and embryo are seen. This was found to be in association with an ectopic pregnancy in the adnexa.

SOUND OFF

The classic clinical triad of an EUP includes pain, vaginal bleeding, and a palpable abdominal/pelvic mass.

Several treatment options exist when an ectopic pregnancy is identified. Methotrexate is a drug used to medically treat an EUP. It can either be injected into the ectopic pregnancy with sonographic guidance or taken

intramuscularly. Methotrexate destroys rapidly dividing cells, such as those that comprise the developing EUP. This drug works well with many ectopic pregnancies when they are confined to the fallopian tube and are small in diameter, typically less than 4 or 5 cm.

CLINICAL FINDINGS OF ECTOPIC PREGNANCY

1. Classic clinical triad—pain, vaginal bleeding, palpable abdominal/pelvic mass
2. Amenorrhea
3. Positive pregnancy test
4. Low beta-hCG compared with normal intrauterine gestation
5. Shoulder pain (secondary to intraperitoneal hemorrhage with diaphragmatic irritation)
6. Low hematocrit (with rupture)
7. Cervical motion tenderness

SONOGRAPHIC FINDINGS OF ECTOPIC PREGNANCY

1. Extrauterine gestational sac containing a yolk sac or an embryo
2. Adnexal ring sign
3. Complex adnexal mass
4. Large amount of free fluid within the pelvis or in Morison pouch (hepatorenal space)
5. Complex free fluid could represent hemoperitoneum
6. Pseudogestational sac
7. Poor decidual reaction
8. Endometrial cavity containing blood

Gestational Trophoblastic Disease

Benign gestational trophoblastic disease (GTD), often referred to as a molar pregnancy or a hydatidiform mole, is a group of disorders that result from an abnormal combination of male and female gametes (Table 23-5). The common forms of GTD can be described as either a complete molar pregnancy or partial (incomplete) molar pregnancy, with complete being the most common. The term trophoblast in the title of this disease relates to the cells that surround the developing gestation. As stated earlier, trophoblastic cells are those cells that produce hCG. GTD results in the excessive growth of the trophoblastic cells. Therefore, there are excessive amounts of hCG in the maternal circulation. Although the cause of molar pregnancy is unknown, it has been speculated that perhaps in these situations, a normal sperm fertilizes an empty ovum.

SOUND OFF

The most common form of GTD is the complete molar pregnancy.

Although most molar pregnancies are typically benign, they do have malignant potential. The complete molar pregnancy has a higher malignant potential compared to the partial molar pregnancy. The most common forms of malignant GTD are the invasive mole and choriocarcinoma. Because this disease has this malignant potential, other imaging modalities and hCG monitoring are typically warranted. The most common sites of metastatic involvement are the lungs, liver, and vagina. However, other organs may be affected. Patients who present with the diagnosis of molar pregnancy are commonly referred for chest radiographs or other studies for further evaluation of metastasis. Treatment for GTD includes dilation and curettage, hCG monitoring, hysterectomy, and possibly chemotherapy.

Clinical findings of GTD include hyperemesis gravidarum, a markedly elevated hCG level (potentially higher than 100,000 mIU per mL), heavy vaginal bleeding with the possible passage of grape-like molar clusters, hypertension, uterine enlargement, and even hyperthyroidism and possible preeclampsia or eclampsia. Sonographic findings of a complete molar pregnancy include a large complex mass within the uterus with a "vesicular, snowstorm appearance" containing multiple cystic spaces, representing hydropic chorionic villi (Fig. 23-15). Color Doppler interrogation of the abnormal placental tissue often reveals hypervascularity around the tissue but not within it. The ovarian mass associated with a molar pregnancy and elevated hCG is the theca lutein cyst. These masses are typically bilateral and appear as large, multiloculated ovarian masses.

CLINICAL FINDINGS OF MOLAR PREGNANCY

1. Hyperemesis gravidarum
2. Markedly elevated hCG level (potentially >100,000 mIU per mL)
3. Heavy vaginal bleeding (with the possible passage of grape-like molar clusters)
4. Enlarged uterus
5. Possible preeclampsia or eclampsia
6. Hypertension
7. Hyperthyroidism

TABLE 23-5 Classification of gestational trophoblastic disease and important details to remember

Classification of Gestational Trophoblastic Disease	Important Facts

Hydatidiform molar pregnancy: complete	Most common form of gestational trophoblastic disease Characterized by hydropic chorionic villi Absence of the fetus and amnion Benign with malignant potential Markedly elevated hCG
Hydatidiform molar pregnancy: partial or incomplete	May be accompanied by a coexisting **triploid** fetus, parts of fetus, or amnion Minimal malignant potential Normal or minimally elevated hCG
Invasive molar pregnancy (chorioadenoma destruens)	Molar pregnancy that invades into the myometrium and may also invade through the uterine wall and into the peritoneum Result of malignant progression of hydatidiform moles
Choriocarcinoma	Most malignant form of trophoblastic disease with possible metastasis Result of malignant progression of a hydatidiform molar pregnancy Most common sites for metastasis are the liver, lungs, and vagina

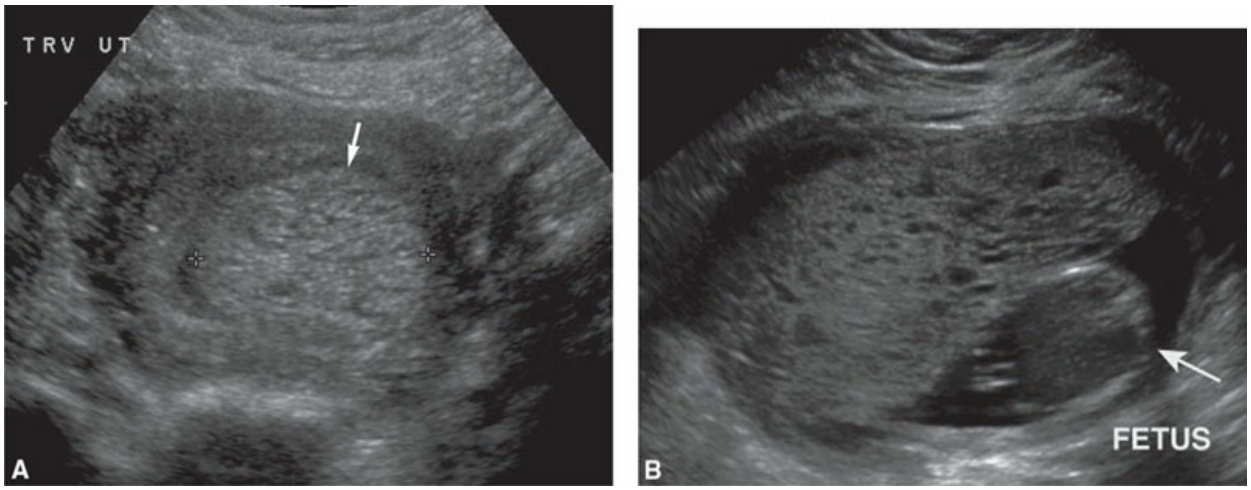


Figure 23-15 Complete and partial hydatidiform mole. **A.** Transverse image of the uterus demonstrating the uterine cavity filled with an echogenic mass (*arrow*, *calipers*) that contains small cystic spaces representing hydropic chorionic villi. **B.** Partial molar pregnancy demonstrating a hydropic placenta with a coexisting fetus.

SONOGRAPHIC FINDINGS OF COMPLETE MOLAR PREGNANCY

1. Complex mass within the uterus
2. Color Doppler may reveal hypervascularity around the mass but not within it

3. “Vesicular snowstorm appearance” secondary to placental enlargement
4. Multiple, variable-sized cysts replacing the placental tissue (hydropic chorionic villi)
5. Bilateral ovarian theca lutein cysts (large, bilateral, multiloculated ovarian masses)

CLINICAL FINDINGS OF PARTIAL MOLAR PREGNANCY

1. Normal physical exam
2. Normal or slightly evaluated hCG level
3. Smaller than normal uterus or possibly normal size uterus based on gestational age
4. Possible vaginal bleeding

SONOGRAPHIC FINDINGS OF PARTIAL MOLAR PREGNANCY

1. Complex mass within the uterus partially filling the uterine cavity adjacent to the gestational sac
2. “Vesicular snowstorm appearance” secondary to placental enlargement
3. Multiple, variable-sized cysts replacing the placental tissue (hydropic chorionic villi)
4. Triploid fetus



SOUND OFF

The ovarian mass associated with a molar pregnancy and elevated hCG is the theca lutein cyst.

Blighted Ovum or Anembryonic Gestation

A blighted ovum or anembryonic gestation is diagnosed when there is no evidence of a fetal pole or yolk sac within the gestational sac. Although empty, the gestational sac often has an irregular shape with a poor decidual reaction. Patients present with vaginal bleeding, a low hCG, and reduction in pregnancy symptoms.

CLINICAL FINDINGS OF BLIGHTED OVUM

1. Vaginal bleeding
2. Reduction of pregnancy symptoms
3. Low hCG

SONOGRAPHIC FINDINGS OF BLIGHTED OVUM

1. Large, irregular gestational sac without an embryo or a yolk sac

2. Absent or minimal gestational sac growth
3. Poor decidual reaction

Embryonic Demise and Pregnancy Failure

Embryonic demise, sometimes referred to as fetal demise, is defined as the death of the embryo or fetus. With transvaginal imaging, cardiac activity should be detected in the pole that measures 4 to 5 mm. The causes of embryonic death are often idiopathic but may be linked with chromosomal abnormalities. Clinically, patients present small for dates and typically have vaginal bleeding with a closed cervix.

The normal embryonic heart rate at 6 weeks is typically between 100 and 110 beats per minute (bpm). By 7 weeks, the bpm should be at least 120. Between 8 and 9 weeks, the bpm can increase slightly and then plateau at approximately 150 bpm. Sonography provides a definitive diagnosis of embryonic demise when there is no detectable fetal heart motion with real-time imaging. Absent cardiac activity when the CRL is below 7 mm is suspicious for pregnancy failure. An impending embryonic demise is associated with embryonic bradycardia. A heart rate that is less than 90 bpm at around 6 weeks is considered abnormal. In addition, the majority of pregnancies with less than 80 bpm will eventually go on to miscarry.

It is important to evaluate the appearance of the yolk sac during the first-trimester sonographic examination, because a yolk sac that is echogenic, large, abnormally shaped, or calcified carries an increased risk for ensuing embryonic demise. Specifically, a yolk sac that measure over 7 mm in diameter has been linked with a high rate of pregnancy failure. An abnormally small gestational sac, in relation to the CRL, is also an indicator of a poor prognosis.

Clinical Findings of Embryonic or Fetal Demise

1. Vaginal bleeding
2. Small for dates
3. Closed cervix
4. Low (based on LMP) hCG

Sonographic Findings of Embryonic or Fetal Demise

1. No detectable fetal heart activity in a pole that measures 4 to 5 mm
2. Irregularly shaped fetus
3. Irregularly sized gestational sac
4. Irregular-appearing yolk sac (misshapen, calcified, large, or echogenic)

SOUND OFF
The normal embryonic heart rate at 6 weeks is typically between 100 and 110 beats per minute. A heart rate that is less than 90 bpm at around 6 weeks is considered abnormal.

Miscarriage and Abortion

The termination of a pregnancy before viability is termed a miscarriage or an abortion. There are several categories of abortions, including threatened, complete, incomplete, missed, inevitable, septic, and elective (Table 23-6). Clinical findings consistent with a miscarriage include vaginal bleeding, pelvic cramping, and the passage of the products of conception. Many miscarriages are idiopathic. However, first-trimester miscarriages have been linked with ovarian abnormalities, aneuploid fetuses, maternal infections, physical abuse, trauma, drug abuse, maternal endocrine abnormalities, and anatomic factors. Often, hCG levels are lower than normal with miscarriage compared to those in a normal IUP. The sonographic findings of a miscarriage are variable, although if a fetus is present, careful analysis must be made to determine the presence of a fetal heart beat. If the fetus has demised but retained in the uterus, as seen with a missed abortion, it may appear to be irregular in appearance as the body attempts to break down fetal tissues.

TABLE 23-6 Types of abortion, a description, and typical sonographic findings

Types of Abortion	Description	Sonographic Findings
Threatened abortion	Vaginal bleeding before 20 weeks' gestation; closed cervical os	Low fetal heart rate
Complete (spontaneous) abortion	All products of conception expelled	No intrauterine products of conception identified Prominent endometrium, which may contain hemorrhage
Incomplete abortion	Part of the products of conception expelled	Thickened and irregular endometrium Enlarged uterus
Missed abortion	Fetal demise with retained fetus	No detectable fetal heart motion detected Abnormal fetal shape

Inevitable abortion	Vaginal bleeding with dilated cervix	Low-lying gestational sac Open internal os of cervix

Subchorionic Hemorrhage

Small, benign subchorionic hemorrhages can be seen during a routine first-trimester sonogram. A subchorionic hemorrhage is essentially a bleed between the endometrium and the gestational sac, and therefore may be referred to as a perigestational hemorrhage. A subchorionic hemorrhage results from the implantation of the fertilized ovum into the uterus with subsequent low-pressure bleeding or spotting. The patient may complain of uterine cramping as well. Sonographically, a subchorionic hemorrhage appears as an anechoic, crescent-shaped area adjacent to the gestational sac at the margin of the placenta (Fig. 23-16). Recent bleeds are often hyperechoic or isoechoic to the placenta, whereas older bleeds may appear anechoic or even hypoechoic depending on the age of the hemorrhage. A subchorionic hemorrhages can be confused for a twin gestational sac. Although large bleeds may be associated with miscarriage and stillbirth, fetal activity is often a reassuring sign that the pregnancy will progress normally.

CLINICAL FINDINGS OF SUBCHORIONIC HEMORRHAGE

1. Vaginal bleeding or spotting
2. Uterine cramping
3. Closed cervix

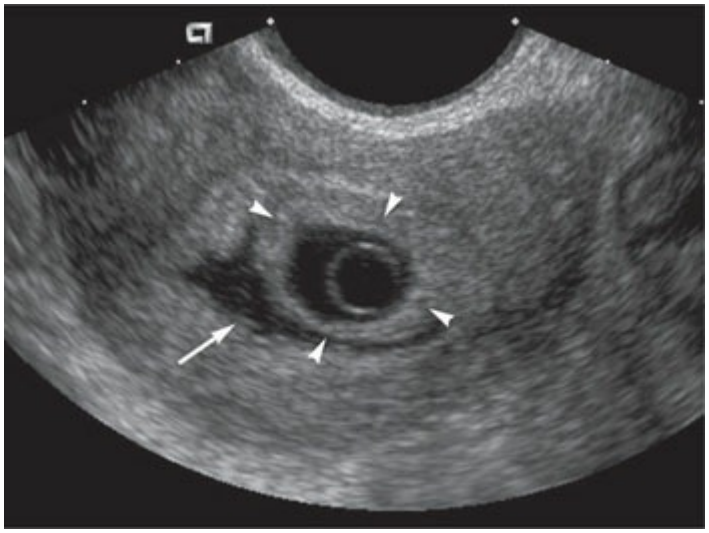


Figure 23-16 Subchorionic hemorrhage. Transverse view of the uterus demonstrating a crescent-shaped fluid collection (*arrow*) adjacent to the gestational sac (*arrowheads*).

SONOGRAPHIC FINDINGS OF SUBCHORIONIC HEMORRHAGE

1. Crescent-shaped anechoic, echogenic, or hypoechoic area adjacent to the gestational sac (depends on the age of the hemorrhage)
2. May resemble a second gestational sac

UTERINE LEIOMYOMA AND PREGNANCY

A uterine leiomyoma, also referred to as a fibroid, is a common benign pelvic mass that can often be identified during a first-trimester sonographic examination. These tumors, although benign, have been associated with an increased risk for early pregnancy failure, especially in women who are pregnant with multiple gestations. The two most important sonographic findings of fibroids during pregnancy are location and size. The location of a fibroid is easily identified with sonography, with cervical and lower uterine fibroids being of most relevance, because they may pose a dilemma at delivery. Fibroids are stimulated by estrogen and can consequently experience rapid growth during pregnancy, although this does not always occur. Thus, sonography can also be used to assess the size of these masses and provide important data for follow-up examinations.



SOUND OFF

Fibroids are stimulated by estrogen and can consequently experience rapid growth during pregnancy.

The most common sonographic appearance of a fibroid is that of a solid, hypoechoic, myometrial mass. Fibroids must be differentiated from focal myometrial contractions, which are smooth muscle contractions that can be noted on an ultrasound examination. Fibroids will consistently alter the shape of the myometrium, whereas true myometrial contractions typically disappear within 20 to 30 minutes. Leiomyomas are also discussed in Chapter 17 of this text.

CLINICAL FINDINGS OF A UTERINE LEIOMYOMA (WITH PREGNANCY)

1. Positive pregnancy test
2. Pelvic pressure
3. Menorrhagia
4. Palpable pelvic mass
5. Enlarged, bulky uterus (if multiple)
6. Urinary frequency

7. Dysuria
8. Constipation

SONOGRAPHIC FINDINGS OF UTERINE LEIOMYOMA

1. Hypoechoic mass within the uterus
2. Posterior shadowing
3. Degenerating fibroids may have calcifications or cystic components
4. Multiple fibroids appear as an enlarged, irregularly shaped, diffusely heterogeneous uterus

Intrauterine Contraceptive Device and Coexisting Pregnancy

Occasionally, an intrauterine contraceptive device (IUCD) may not be effective, and thus allow pregnancy to occur and implant within the uterus. If this occurs, the IUCD will be seen as an echogenic structure within the uterine cavity adjacent to the gestational sac. The IUCD will often produce acoustic shadowing. Its location to the gestational sac should be reported. IUCDs are also discussed in Chapter 21 of this text.

REVIEW QUESTIONS

1. What structure connects the embryo to the yolk sac?
   a. Vitelline duct
   b. Yolk stalk
   c. Amnion
   d. Chorionic stalk

2. What is the name of the dominant follicle prior to ovulation?
   a. Graafian
   b. Corpus luteum
   c. Morula
   d. Corpus albicans

3. Fertilization typically occurs within ____ after ovulation.
   a. 40 hours
   b. 12 hours
   c. 24 hours
   d. 56 hours

4. The most common site of fertilization is within the:
   a. Isthmus of the uterine tube

b. Uterine fundus
c. Cornu of the uterine tube
d. Ampulla of the uterine tube

5. With a normal pregnancy, the first structure noted within the decidualized endometrium is the:
   a. Yolk sac
   b. Chorionic sac
   c. Amniotic cavity
   d. Embryo

6. The structure created by the union of sperm and egg is the:
   a. Blastocyst
   b. Zygote
   c. Morula
   d. Ampulla

7. The trophoblastic cells produce:
   a. Estrogen
   b. Progesterone
   c. Follicle-stimulating hormone
   d. hCG

8. Sonographically, a normal-appearing 7-week IUP is identified. Within the adnexa, an ovarian cystic structure with a thick, hyperechoic rim is also discovered. What does this ovarian mass most likely represent?
   a. Theca lutein cyst
   b. Corpus luteum cyst
   c. Corpus albicans
   d. Ectopic pregnancy

9. What is the stage of the conceptus that implants within the decidualized endometrium?
   a. Blastocyst
   b. Morula
   c. Zygote
   d. Ovum

10. Another name for the chorionic sac is the:
    a. Chorionic cavity
    b. Extraembryonic coelom
    c. Amniotic sac
    d. Gestational sac

11. What is often used to medically treat an ectopic pregnancy?
    a. Dilatation and curettage
    b. Dilatation and evacuation
    c. Open surgery
    d. Methotrexate

12. What structure lies within the extraembryonic coelom?
    a. Gestational sac
    b. Embryo
    c. Yolk sac
    d. Amnion

13. What hormone, produced by the corpus luteum, maintains the thickened endometrium?
    a. Estrogen
    b. Progesterone
    c. hCG
    d. Luteinizing hormone

14. What is the most common form of GTD?
    a. Complete molar pregnancy
    b. Partial molar pregnancy
    c. Invasive mole
    d. Choriocarcinoma

15. In the first trimester, normal hCG levels will:
    a. Double every 48 hours
    b. Triple every 24 hours
    c. Double every 24 hours
    d. Double every 12 hours

16. Compared with a normal IUP, the ectopic pregnancy will have a:
    a. High hCG
    b. Low hCG
    c. Markedly elevated hCG
    d. High AFP

17. Which of the following locations for an ectopic pregnancy would be least likely?
    a. Isthmus of the tube
    b. Ampulla of the tube
    c. Ovary

d. Interstitial of the tube

18. The first sonographically identifiable sign of pregnancy is the:
    a. Amnion
    b. Yolk sac
    c. Decidual reaction
    d. Chorionic cavity

19. The first structure noted within the gestational sac is the:
    a. Yolk sac
    b. Embryo
    c. Decidual reaction
    d. Chorionic sac

20. NT measures are typically obtained between:
    a. 1 and 5 weeks
    b. 5 and 8 weeks
    c. 8 and 11 weeks
    d. 11 and 14 weeks

21. The normal gestational sac will grow:
    a. 2 mm per day
    b. 3 mm per day
    c. 1 cm per day
    d. 1 mm per day

22. During a first-trimester sonogram, you note a round, cystic structure within the fetal head. This most likely represents the:
    a. Prosencephalon
    b. Mesencephalon
    c. Rhombencephalon
    d. Proencephalon

23. The migration of the embryologic bowel into the base of the umbilical cord at 9 weeks is referred to as:
    a. Physiologic bowel herniation
    b. Pseudo-omphalocele
    c. Omphalocele
    d. Gastroschisis

24. During a 12-week sonogram, bilateral echogenic structures are noted within the lateral ventricles of the fetal cranium. These structures most likely represent:

a. Cerebral tumors
b. Cerebral hemorrhage
c. Anencephalic remnants
d. Choroid plexus

25. The most common pelvic mass associated with pregnancy is the:
a. Uterine leiomyoma
b. Dermoid cyst
c. Theca luteum cyst
d. Corpus luteum cyst

26. All of the following are associated with an abnormal NT except:
a. Trisomy 21
b. Trisomy 16
c. Trisomy 18
d. Turner syndrome

27. What hormone maintains the corpus luteum during pregnancy?
a. Estrogen
b. Progesterone
c. Follicle-stimulating hormone
d. hCG

28. The most common cause of pelvic pain with pregnancy is:
a. Ectopic pregnancy
b. Heterotopic pregnancy
c. Missed abortion
d. Molar pregnancy

29. The most common location of an ectopic pregnancy is the:
a. Ovary
b. Interstitial portion of the uterine tube
c. Cornual portion of the uterine tube
d. Ampullary portion of the uterine tube

30. All of the following are contributing factors for an ectopic pregnancy except:
a. Pelvic inflammatory disease
b. Assisted reproductive therapy
c. IUCD
d. Advanced paternal age

31. All of the following are clinical features of an ectopic pregnancy except:

a. Pain
b. Vaginal bleeding
c. Shoulder pain
d. Adnexal ring

32. In the early gestation, where is the secondary yolk sac located?
a. Chorionic cavity
b. Base of the umbilical cord
c. Embryonic cranium
d. Amniotic cavity

33. All of the following are sonographic findings consistent with ectopic pregnancy except:
a. Decidual thickening
b. Complex free fluid within the pelvis
c. Bilateral, multiloculated ovarian cysts
d. Complex adnexal mass separate from the ipsilateral ovary

34. All of the following are consistent with a complete hydatidiform mole except:
a. Heterogeneous mass within the endometrium
b. Bilateral theca lutein cysts
c. Hyperemesis gravidarum
d. Low hCG

35. A malignant form of GTD is:
a. Choriocarcinoma
b. Hydatidiform mole
c. Anembryonic
d. Hydropic villi

36. A sonographic examination was performed on a pregnancy patient who complained of vaginal bleeding. Sonographically, a crescent-shaped anechoic area is noted adjacent to the gestational sac. The gestational sac contained a 6-week single live IUP. What is the most likely diagnosis?
a. Ectopic pregnancy
b. Molar pregnancy
c. Subchorionic hemorrhage
d. Anembryonic gestation

37. All of the following would be associated with a lower-than-normal hCG level except:
a. Ectopic pregnancy

b. Molar pregnancy
c. Blighted ovum
d. Spontaneous abortion

38. All of the following are clinical findings consistent with a complete molar pregnancy except:
a. Vaginal bleeding
b. Hypertension
c. Uterine enlargement
d. Small for dates

39. Which of the following is the most likely metastatic location for GTD?
a. Rectum
b. Pancreas
c. Spleen
d. Lungs

40. All of the following may be sonographic findings in the presence of an ectopic pregnancy except:
a. Pseudogestational sac
b. Corpus luteum cyst
c. Adnexal ring
d. Low beta-hCG

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24

The Fetal Head and Brain

Introduction

It is vital for the sonographer to have a thorough understanding of both cranial and intracranial anatomy. This chapter provides a summary of the significant anatomy of the cranium and brain. It also provides the information pertaining to abnormalities of the fetal head and brain.

Key Terms

acrania—the absence of the cranial vault above the bony orbits

agenesis of the corpus callosum—the congenital absence of corpus callosum which may be partial or complete

alobar holoprosencephaly—the most severe form of holoprosencephaly

anencephaly—a neural tube defect that is described as the absence of the cranium and cerebral hemispheres

anophthalmia—the absence of the eye(s)

Apert syndrome—genetic disorder that includes craniosynostosis, midline facial hypoplasia, and syndactyly

aperture(s)—an opening in a structure

aqueduct of Sylvius—see key term cerebral aqueduct

aqueductal stenosis—the abnormal narrowing of the cerebral aqueduct

arachnoid cyst(s)—benign cysts within the brain that do not communicate with the ventricular system

arachnoid granulations—nodular structures located along the falx cerebri that reabsorb cerebrospinal fluid into the venous system

arachnoid membrane—the middle layer of the meninges

arachnoid villi—see key term arachnoid granulations

Arnold–Chiari II malformation—a group of cranial abnormalities associated with spina bifida

basal ganglia—a group of nuclei within the brain that function in several ways, including information processing and emotional response

Beckwith–Wiedemann syndrome—a growth disorder syndrome synonymous with enlargement of several organs, including the skull, tongue, and liver

brachycephalic—round skull shape

brain stem—the lower part of the brain composed of the pons, midbrain, and medulla oblongata

cavum septum pellucidum—a normal midline brain structure identified in the anterior portion of the brain between the frontal horns of the lateral ventricles

cebocephaly—close-set eyes (hypotelorism) and a nose with a single nostril

cephalic index—the ratio used for assessing fetal head shape

cerebellar vermis—the portion of the cerebellum, located within the midline of the brain, that connects its two hemispheres

cerebral aqueduct—the duct that connects the third ventricle of the brain to the fourth ventricle; also referred to as the aqueduct of Sylvius

cerebral peduncles—paired structures located anterior to the cerebral aqueduct

cerebrospinal fluid—the protective and nourishing fluid of the brain and spinal cord produced by the cells of the choroid plexus

choroid plexus—specialized cells within the ventricular system responsible for cerebrospinal fluid production

cistern—a prominent space within the skull that contains cerebrospinal fluid; a cistern is created by the separation of the arachnoid membrane and pia mater

cisterna magna—the largest cistern in the skull; located in the posterior portion of the skull

colpocephaly—the abnormal lateral ventricle shape in which there is a small frontal horn and enlarged occipital horn

communicating hydrocephalus—the obstruction of cerebrospinal fluid from a source outside the ventricular system

corpus callosum—a thick band of white matter that provides communication between right and left halves of the brain

corrected-BPD—represents the biparietal diameter of a standard-shaped fetal head with the same cross-sectional area

craniosynostosis—the premature closure of the cranial sutures with subsequent fusion of the cranial bones

cyclopia—fusion of the orbits

Dandy–Walker complex—a spectrum of posterior fossa abnormalities that involves the cystic dilatation of the cisterna magna and fourth ventricle

Dandy–Walker malformation—congenital brain malformation in which there is enlargement of the cisterna magna, agenesis of the cerebellar vermis, and dilation of the fourth ventricle

dangling choroid sign—a sonographic sign associated with ventriculomegaly when the choroid plexus is noted hanging freely within the dilated lateral ventricle

dilatation—an enlargement or expansion of a structure

dolichocephaly—an elongated, narrow head shape; may also be referred to as scaphocephaly

dura mater—the dense, fibrous outer layer of the meninges

ependyma—the lining of the ventricles within the brain

exencephaly—a form of acrania in which the entire cerebrum is located outside the skull

facies—the features or appearance of the face

falx cerebri—a double fold of dura mater located within midline of the brain

folate—a vitamin that has been shown to significantly reduce the likelihood of neural tube defects; also referred to as folic acid

foramen magnum—the opening in the base of the skull through which the spinal cord exits

gastroschisis—herniation of abdominal contents through a right-sided, periumbilical abdominal wall defect

germinal matrix—a group of thin-walled blood vessels and cells within the subependymal layer of the fetal brain responsible for brain cell migration during fetal development

glomus (of choroid plexus)—the largest part of the choroid plexus

gyri—folds in the cerebral cortex

holoprosencephaly—a group of brain abnormalities consisting of varying degrees of fusion of the lateral ventricles, absence of the midline structures, and associated facial anomalies

hydranencephaly—a fatal condition in which the entire cerebrum is replaced by a large sac containing cerebrospinal fluid

hydrocephalus—refers to the dilatation of the ventricular system caused by an increased volume of cerebrospinal fluid, resulting in increased intraventricular pressure

hydrops (fetal)—an abnormal accumulation of fluid in at least two fetal body cavities

hypoplasia—incomplete growth of a structure or an organ

hypotelorism—reduced distance between the orbits

hypoxia—a shortage of oxygen or decreased oxygen in the blood

interhemispheric fissure—groove within the midline of the brain that divides the two cerebral hemispheres

interthalamic adhesion—the mass of tissue, located in the third ventricle within the midline of the brain, which connects the two lobes of the thalamus; also referred to as the massa intermedia

intracranial hemorrhage—general term used to denote a hemorrhage within the cranium

intraventricular hemorrhage—hemorrhage located within the ventricles of the brain

lissencephaly—“smooth brain”; condition where there is little to no gyri or sulci within the cerebral cortex

lobar holoprosencephaly—the least severe form of the holoprosencephaly

macrocephaly—an enlarged head circumference

massa intermedia—see key term interthalamic adhesion

Meckel–Gruber syndrome—a fetal syndrome associated with microcephaly, occipital encephalocele, polydactyly, and polycystic kidneys

median cleft lip—a subdivision within the middle of the lip

mega cisterna magna—an enlargement of the cisterna magna as defined by a depth of more than 10 mm

meninges—the coverings of the brain and spinal cord

meningocele—herniation of the cranial or spinal meninges because of an open cranial or a spinal defect

mesencephalon—the primary brain vesicle also referred to as the midbrain; it eventually becomes the cerebral peduncles, quadrigeminal plate, and cerebral aqueduct

mesocephalic—normal head shape

microcephaly—small head

monoventricle—one large ventricle within the brain associated with

holoprosencephaly

myelomeningocele—mass that results from spina bifida that contains the spinal cord and the meninges

neural plate—the early embryologic structure that develops into the central nervous system

neural tube—embryologic formation that results from fusion of the two folded ends of the neural plate

noncommunicating hydrocephalus—the obstruction of cerebrospinal fluid from a source within of the ventricular system

omphalocele—an anterior abdominal wall defect where there is herniation of the fetal bowel and other abdominal organs into the base of the umbilical cord

parenchyma—the functional part of an organ

Patau syndrome—a chromosomal aberration in which there is a third chromosome 13; also referred to as trisomy 13

pia mater—the innermost layer of the meninges

porencephaly—a condition in which a cyst, most often caused by an intraparenchymal hemorrhage, communicates with a lateral ventricle

proboscis—fleshy, tongue-like appendage that is typically located within the midline above the orbits in association with cyclopia and holoprosencephaly

prosencephalon—the primary brain vesicle also referred to as the forebrain; it eventually becomes the lateral ventricles, cerebral hemispheres, third ventricle, thalamus, hypothalamus, pineal gland, and pituitary gland

rhombencephalon—the primary brain vesicle also referred to as the hindbrain; it eventually becomes the cerebellum, pons, medulla oblongata, and fourth ventricle

scaphocephaly—see key term dolichocephaly

schizencephaly—a cerebral malformation associated with the development of fluid-filled clefts

spinal dysraphism—a group of neural tube defects that describe some manifestation of incomplete closure of the spine

subarachnoid space—an area located between the arachnoid membrane and the pia mater

subependymal (layer)—the area just beneath the ependymal lining the lateral ventricles

sulci—grooves within the brain

suture (skull)—a flexible, connective tissue that lies between the cranial bones

thalamus—a brain structure that allows communication between the senses; also performing many other functions

thanatophoric dysplasia—the most common lethal skeletal dysplasia characterized by a cloverleaf skull with frontal bossing and hydrocephalus

TORCH infections—an acronym that stands for toxoplasmosis, other infections, rubella, cytomegalovirus, and herpes simplex virus; this group of infections may be acquired by a woman during pregnancy

triploidy—a fetus that has three of every chromosome

trisomy 8—chromosomal aberration in which there is a third chromosome 8; also referred to as Warkany syndrome 2

trisomy 13—chromosomal aberration in which there is a third chromosome 13; also referred to as Patau syndrome; often associated with holoprosencephaly

trisomy 18—chromosomal aberration in which there is a third chromosome 18; also referred to as Edwards syndrome

trisomy 21—chromosomal aberration in which there is a third chromosome 21; also referred to as Down syndrome

vein of Galen aneurysm—an arteriovenous malformation that occurs within the fetal brain and is associated with congestive heart failure

EMBRYOLOGIC DEVELOPMENT OF THE FETAL BRAIN

By 4.5 weeks, the neural plate, the structure that will form the central nervous system, has developed. The neural plate will give rise to the neural tube, which will become the spine and the brain. Initially, the brain is divided into three primary vesicles termed the prosencephalon (forebrain), mesencephalon (midbrain), and rhombencephalon (hindbrain). These vesicles will continue to develop and form critical brain structures. Sonographically, the rhombencephalon may be noted within the fetal cranium during the first trimester (Fig. 23-6 in Chapter 23).

NORMAL FETAL SKULL AND BRAIN ANATOMY

The skull consists of eight cranial bones (Table 24-1). These bones are connected by structures known as sutures (Table 24-2). Fetal sutures may be noted during a routine sonographic examination as hypoechoic spaces between the bones. Because of the flexibility of sutures, the fetal cranial bones remain slightly mobile until delivery to facilitate the passage of the

skull through the birth canal. Premature fusion of the sutures is termed craniosynostosis. Consequently, craniosynostosis leads to an irregular-shaped skull.

SOUND OFF
Premature fusion of the sutures is termed craniosynostosis.

TABLE 24-1 Cranial bones and their locations

Cranial Bone(s)	Location
Frontal bone	Anterior
Parietal bones	Superior and lateral
Temporal bones	Inferior and lateral
Occipital bone	Posterior
Sphenoid bone	Lateral
Ethmoid bone	Anterior (between orbits)

Spaces that exist between the forming fetal bones are referred to as fontanelles or "soft spots" (Table 24-3). Several fontanelles persist in the postnatal period and into infancy. Fontanelles are often utilized as sonographic windows during neurosonographic examinations to evaluate newborns for intracranial hemorrhage or suspected brain anomalies. The anterior fontanel, when completely filled with bone, is referred to as the bregma, whereas the posterior fontanel is referred to as the lambda. The foramen magnum is the opening in the base of the cranium through which the spinal cord travels.

Midline fetal brain anatomy and those structures that lie on both sides of the midline should be routinely evaluated during an obstetric sonogram (Table 24-4). These structures are discussed in the following sections.

TABLE 24-2 Fetal sutures and their locations

Suture	Location
Coronal suture	Between the frontal and two parietal bones
Sagittal suture	Between the two parietal bones
Lambdoidal suture	Between the parietal bones and occipital bone
Squamosal sutures	Between the parietal bones and temporal bones
Metopic suture	Located within the frontal bone along the midline of the

	forehead

The Cerebrum

The brain can be divided into two main parts, the cerebrum and the cerebellum. The cerebrum is the largest part of the brain. The normal cerebrum contains multiple sulci and gyri. There are six cerebral lobes: the frontal lobe, two temporal lobes, two parietal lobes, and the occipital lobe.

The cerebrum can be further divided into a right and left hemisphere by the interhemispheric fissure. The falx cerebri, a double fold of dura mater, is located within the interhemispheric fissure and can readily be noted on a fetal sonogram as an echogenic linear formation coursing through the midline of the fetal brain (Fig. 24-1). The cerebral hemispheres are linked in the midline by the corpus callosum, a thick band of tissue that provides communication between the right and left halves of the brain.

TABLE 24-3 Locations of the fontanelles and when they close

Fontanelle	Location	Closure
Anterior or frontal	Bordered by the frontal and parietal bones	By 18 mo
Posterior or occipital	Bordered by the occipital and parietal bones	By 6 mo
Anterolateral or sphenoidal	Bordered by the frontal, parietal, and sphenoid bones	By 2 yr
Posterolateral or mastoid	Bordered by the mastoid and occipital bones	By 2 yr

TABLE 24-4 Brain structures located within the midline (left column) and those that are located on both sides of the midline (right column)

Midline Brain Anatomy	Bilateral Brain Structures
Falx cerebri	Hemispheres of the cerebellum
Interhemispheric fissure	Hemispheres of the cerebrum
Corpus callosum	Lobes of the thalamus
Cavum septum pellucidum	Foramen of Monro (interventricular foramina)
Third ventricle	Lateral ventricles
Aqueduct of Sylvius (cerebral aqueduct)	Choroid plexus (within lateral ventricles)

Fourth ventricle

Cerebellar vermis

Cisterna magna

Interthalamic adhesion (massa intermedia)

Brain stem (pons, midbrain, and medulla oblongata)

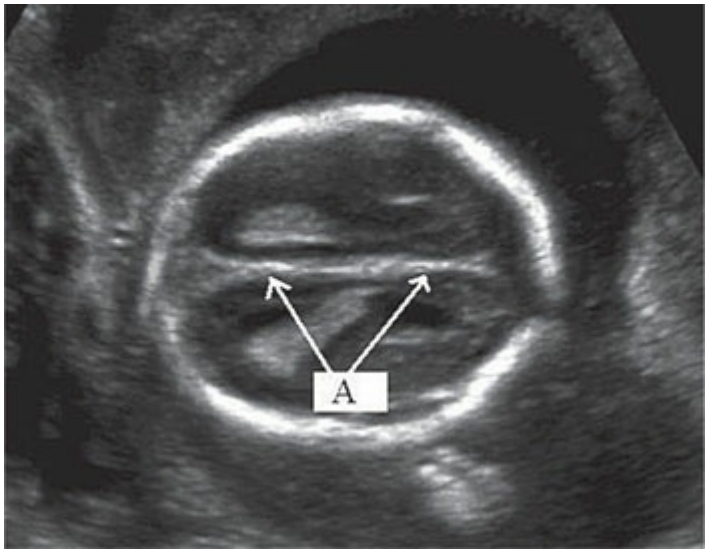


Figure 24-1 Falx cerebri. Transaxial view of the fetal cranium demonstrating the echogenic falx cerebri (*A*).

SOUND OFF
The falx cerebri separates the cerebral hemispheres, whereas the corpus callosum connects the cerebral hemispheres and allows communication between the two lobes.

The meninges are three protective tissues layers that cover the brain and the spinal cord. The innermost layer of the meninges is the pia mater, the middle layer is the arachnoid membrane, and the dense, outermost layer is the dura mater.

The Corpus Callosum

The corpus callosum forms late in gestation, but should be completely intact between 18 and 20 weeks. As stated earlier, the corpus callosum connects the two lobes of the cerebrum. The corpus callosum consists of four parts. Fetal development of the corpus callosum is from anterior to posterior. Thus, the rostrum, genu, body, and splenium develop, respectively. The sonographic appearance of the corpus callosum is that of an echogenic band of tissue

within the midline of the brain connecting the two cerebral hemispheres. The absence of all or part of the corpus callosum is referred to as agenesis of the corpus callosum.

The Cavum Septum Pellucidum

The cavum septum pellucidum (CSP) is a midline brain structure located in the anterior portion of the brain between the frontal horns of the lateral ventricles. It will appear as an anechoic "box-shaped" structure in the axial scan plane (Fig. 24-2). Although the CSP should always be seen between 18 and 37 weeks, the closure of this structure is normal in later gestation and often occurs before birth or shortly thereafter. The CSP does not communicate with the ventricular system, and its absence is associated with multiple cerebral malformations, including agenesis of the corpus callosum.

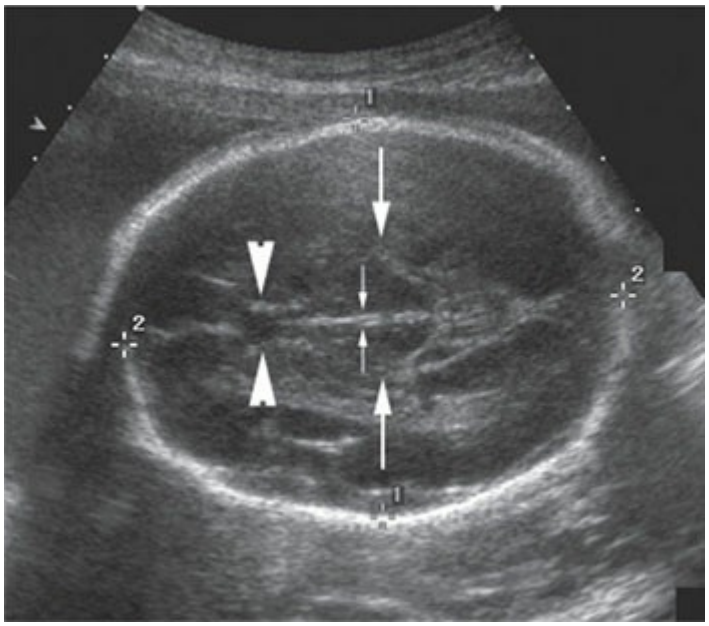


Figure 24-2 Level of the biparietal diameter and occipitofrontal diameter. Axial view of the fetal head, at the level used for measurement of the biparietal diameter, demonstrating the paired thalami (*large arrows*) with the slitlike third ventricle between them (*small arrows*), and the cavum septum pellucidum (*arrowheads*). The falx is the linear bright echo in the midline anterior to the cavum septum pellucidum, separating the cerebral hemispheres. The + *calipers* labeled "1" are placed on the leading edge of the cranial bone at the near and far sides of the skull (i.e., on the external aspect of the near side and the internal aspect of the far side) to measure the biparietal diameter. The + *calipers* labeled "2" are placed in the middle of the visible cranial bone anteriorly and posteriorly to measure the occipitofrontal diameter.

SOUND OFF

The CSP does not communicate with the ventricular system, and its absence is associated with multiple cerebral malformations, including

agenesis of the corpus callosum.

The Thalamus

The thalamus, a vital brain structure that has numerous functions, is a significant landmark for sonographers to locate within the fetal brain (see Fig. 24-2). The two lobes of the thalamus are located on both sides of the third ventricle. The massa intermedia or interthalamic adhesion passes through the third ventricle to connect the two lobes of the thalamus. The thalamus should not be confused with the cerebral peduncles, which are more inferiorly positioned in the brain.

The Ventricular System

The ventricular system is composed of four ventricles, whose primary function is to provide cushioning for the brain (Fig. 24-3). Each ventricle is lined by a membrane called the ependyma. The paired lateral ventricles are located on both sides of the falx cerebri within the cerebral hemispheres. They are frequently referred to as right and left ventricles but may also be called the first and second ventricles. The divisions of lateral ventricles, called the horns of the lateral ventricles, like the lobes of the cerebrum, correlate with the adjacent cranial bones. Thus, each lateral ventricle consists of a frontal, a temporal, and an occipital horn. In addition to the horns, the lateral ventricle also has a segment referred to as the body, which is located between the frontal and occipital horns. The point at which the body, temporal horn, and occipital horn meet is the trigone or atrium of the lateral ventricle. Within the atria of both lateral ventricles lies the echogenic configuration of the choroid plexus, the mass of cells responsible for the production of cerebrospinal fluid (CSF) in the fetus (Fig. 24-4). Choroid plexus may also be found in the roof of the third and fourth ventricles.



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Choroid plexus, which is mostly located within the atria of the lateral ventricles, is responsible for producing CSF.

Each lateral ventricle communicates with the third ventricle in the midline of the brain at the foramen of Monro, or the paired interventricular foramina. The third ventricle is located between the two lobes of the thalamus. Essentially, part of the thalamus, the interthalamic adhesion or massa intermedia, passes through the third ventricle and can be visualized when enlarged or surrounded by CSF. The third ventricle connects to the fourth ventricle inferiorly by means of a long, tubelike structure called the aqueduct

of Sylvius or the cerebral aqueduct.

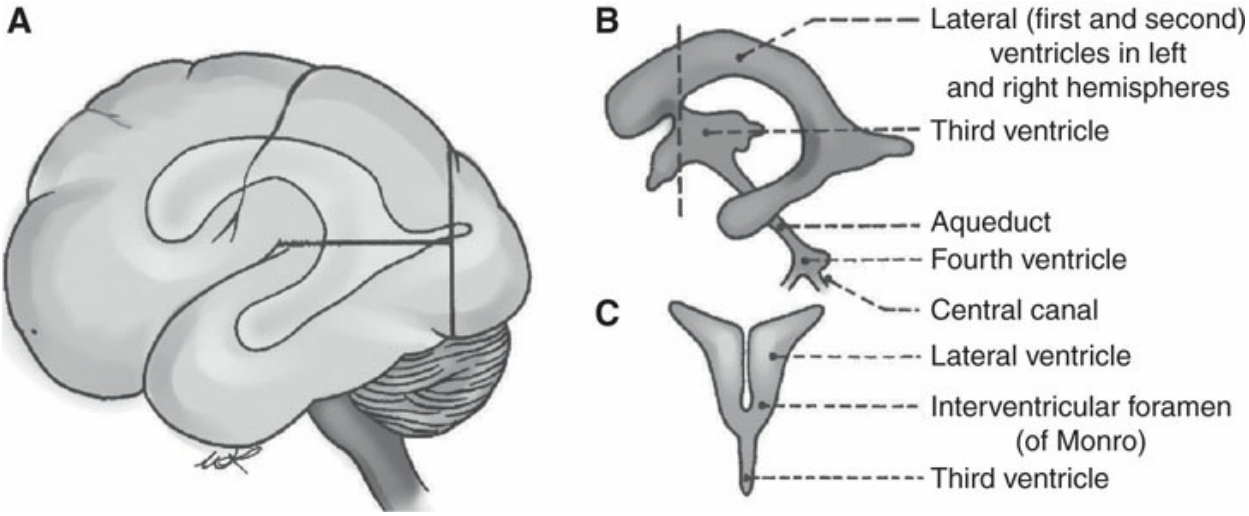


Figure 24-3 Cerebral ventricles. **A.** Sagittal view of the left cerebral hemisphere showing the contour of the lateral ventricles and their relation to the cerebral lobes. **B.** Sagittal outline of the four ventricles. **C.** Coronal section of the lateral and third ventricles at the level of the dotted line in **(B)**, showing their communicating interventricular foramen.



Figure 24-4 Normal choroid plexus. The normal choroid plexus is seen as prominent echogenic structures within each lateral ventricle. In early gestation, the choroid plexus fill the lateral ventricle (*between calipers*).

The fourth ventricle is located anterior to the cerebellum within the midline of the brain. The fourth ventricle has three apertures or openings through which CSF travels. There are two lateral apertures that are also referred to as the foramina of Luschka. These two apertures allow CSF to travel from the fourth ventricle to the subarachnoid space around the brain. Another opening of the fourth ventricle, located in the midline, is the median aperture, which is also referred to as the foramen of Magendie. This opening

allows CSF to pass from the fourth ventricle to the cisterna magna and subarachnoid space.

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The third ventricle connects to the fourth ventricle inferiorly by means of a long, tubelike structure called the aqueduct of Sylvius or the cerebral aqueduct.

The Creation, Flow, and Reabsorption of Cerebrospinal Fluid

The greater part of CSF is produced by the cells of the choroid plexus that are located within the trigone of the lateral ventricles. CSF moves from the lateral ventricles into the third ventricle through the foramina of Monro. From the third ventricle, CSF travels to the fourth ventricle through the cerebral aqueduct. Once in the fourth ventricle, the fluid can exit either through the median aperture or the lateral apertures. CSF also flows inferiorly and around the spinal cord. Arachnoid granulations, also referred to as arachnoid villi, are responsible for the reabsorption of CSF into the venous system. This process occurs at the superior sagittal sinus, located along the superior surface of the cerebrum within its midline.

The Cisterna Magna

The cisterna magna, located in the posterior fossa of the cranium, is the largest cistern in the head. On sonography, the cisterna magna appears as an anechoic, fluid-filled space, posterior to the cerebellum, between the cerebellar vermis and the interior surface of the occipital bone (Fig. 24-5). It is considered common to find some small septations within the cisterna magna.



Figure 24-5 Cisterna magna and the fourth ventricle. Axial image demonstrating the cisterna magna (*between calipers*) and the location of the fourth ventricle (*arrowhead*).

The Cerebellum

The cerebellum is located in the posterior fossa of the cranium. The cerebellum consists of two hemispheres—right and left—that are coupled at the midline by the cerebellar vermis (Fig. 24-6). The cerebellar tonsils, named for their shape, are located on the undersurface of the cerebellum and become distorted with spina bifida and Arnold–Chiari malformations. The normal cerebellum is a dumbbell-shaped or figure eight-shaped structure noted in the posterior cranium of the fetus. The two hemispheres of the cerebellum should be symmetric, although hypoplasia of one cerebellar hemisphere can occur, resulting in the hypoplastic hemisphere appearing smaller than normal.

SOUND OFF
The normal cerebellum is a dumbbell-shaped or figure eight-shaped structure noted in the posterior cranium of the fetus.

FETAL HEAD MEASUREMENTS

Biparietal Diameter

The biparietal diameter (BPD) measurement of the fetal head can be taken

after the first trimester has ended, typically starting between 13 and 14 weeks. The BPD is obtained in the axial plane at the level of the CSP, thalamus, and falx cerebri. This is the same level as the third ventricle, which may be seen between the two lobes of the thalamus. The cranial bones must be symmetric on both sides of the head, and the measurement is obtained from the outer table of the proximal parietal bone to the inner table of the distal parietal bone. That means, the measurement is obtained from leading edge to leading edge (Fig. 24-7).



Figure 24-6 Cerebellum. Axial view of the posterior fossa demonstrating the normal contour of the cerebellum, with rounded cerebellar hemispheres (*arrows*) on either side of the more echogenic cerebellar vermis (*arrowhead*).

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The BPD is obtained in the axial plane at the level of the CSP, thalamus, and falx cerebri. This is the same level as the third ventricle, which may be seen between the two lobes of the thalamus.

Head Circumference

The head circumference (HC) measurement can be taken at the same time of gestation and at the same level of the cranium as the BPD. Thus, the HC is obtained in the axial plane at the level of the CSP, thalamus, falx cerebri, and a measurement around the entire cranium is obtained. This is the same level as the third ventricle, which may be seen between the two lobes of the thalamus.

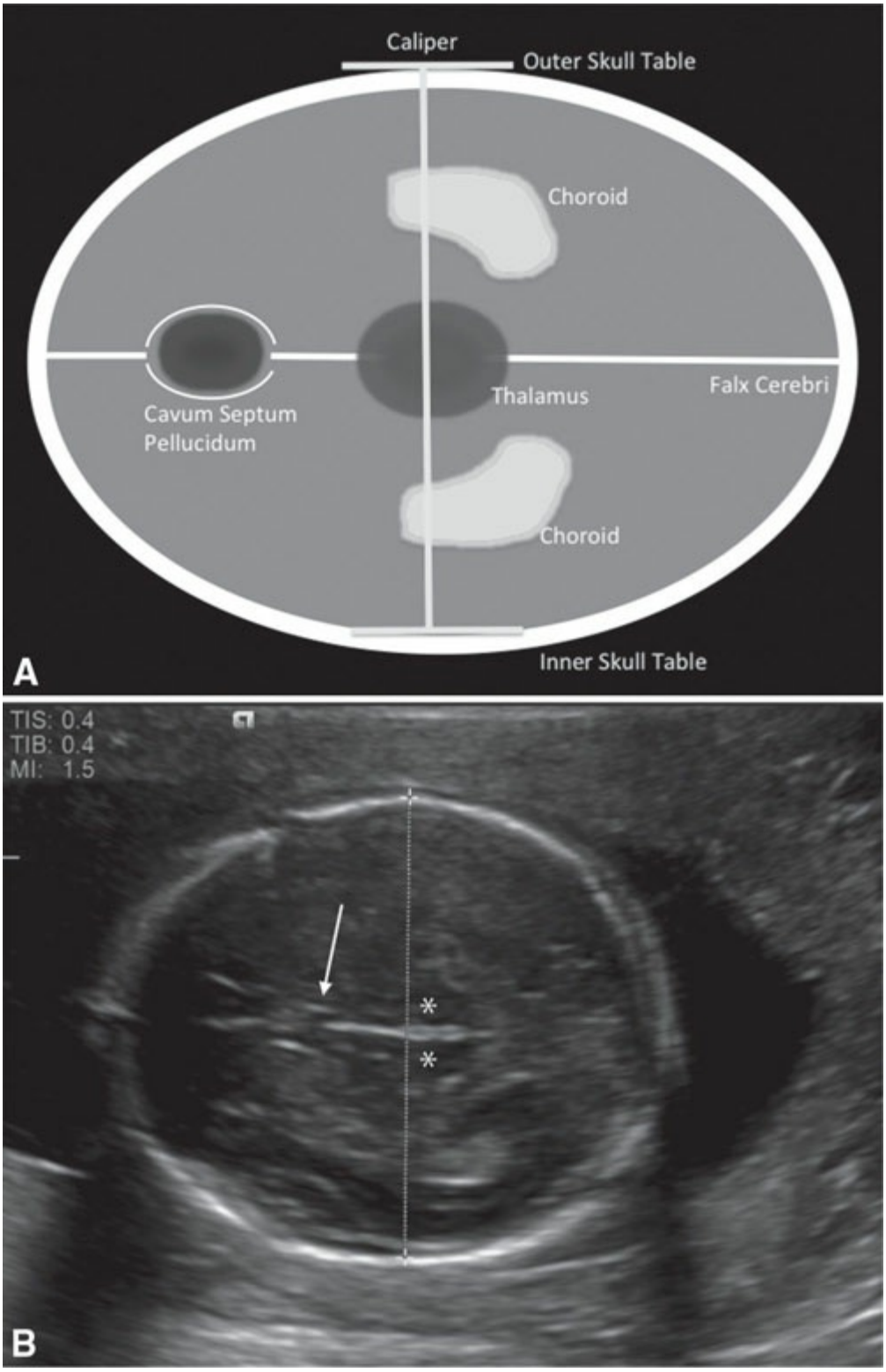


Figure 24-7 Biparietal diameter. **A.** Drawing of the level of the bipareital diameter. **B.** This measurement is obtained on an axial image of the fetal head at the level of the thalami (*asterisk*) and cavum septum pellucidum (*arrow*).

The cranial bones must be symmetric on both sides of the head (Fig. 24-8). The HC can also be obtained by measuring the occipitofrontal diameter (OFD) and taking an outer-to-outer diameter measurement at the level of the BPD. Some authors suggest that the HC measurement is typically more

accurate than BPD because this measurement is independent of the fetal head shape, consequently providing a more consistent parameter for estimating gestational age.

Occipitofrontal Diameter

The OFD is obtained at the same level of the BPD and HC. For the OFD, one caliper is placed in the anterior midline in the middle of the frontal bone, whereas the other is placed in the middle of the echogenic line of the occipital bone (see Fig. 24-2). The OFD may also be called the frontooccipital diameter. The OFD can be used in conjunction with the BPD to obtain the corrected-BPD, which represents the BPD of the standard-shaped head of the same cross-sectional area. That means, the corrected-BPD is "shape-corrected" and is equivalent to the HC, independent of the shape of the skull. OFD can also be added to the BPD and multiplied by 1.62 to obtain an HC.

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The corrected-BPD is "shape-corrected" and is equivalent to the HC, independent of the shape of the skull.

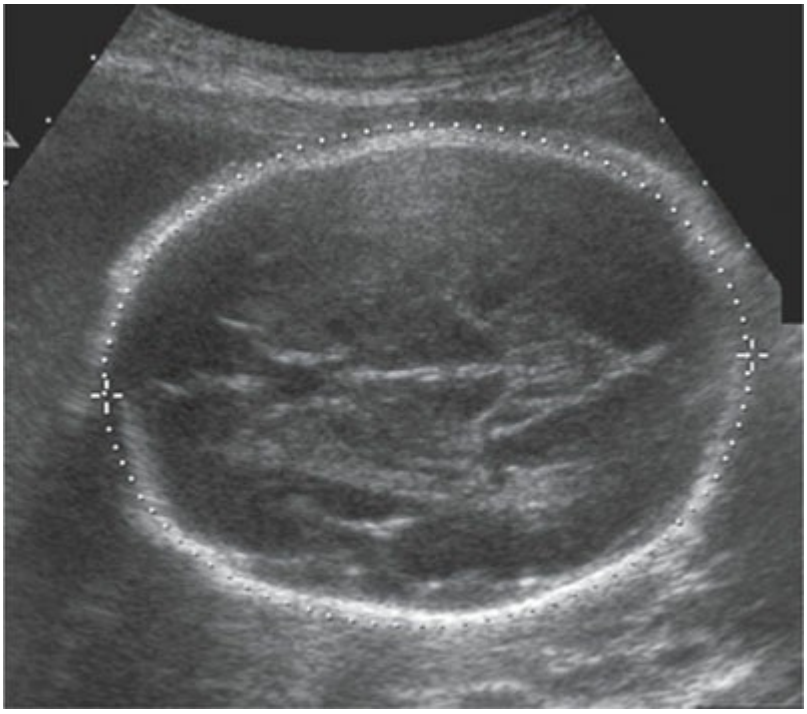


Figure 24-8 Head circumference. Head circumference measurement. On an image at the same level as that used to measure the biparietal diameter, the head circumference is measured with electronic *ellipse calipers* (+ … +) around the outer rim of the ossified cranium.

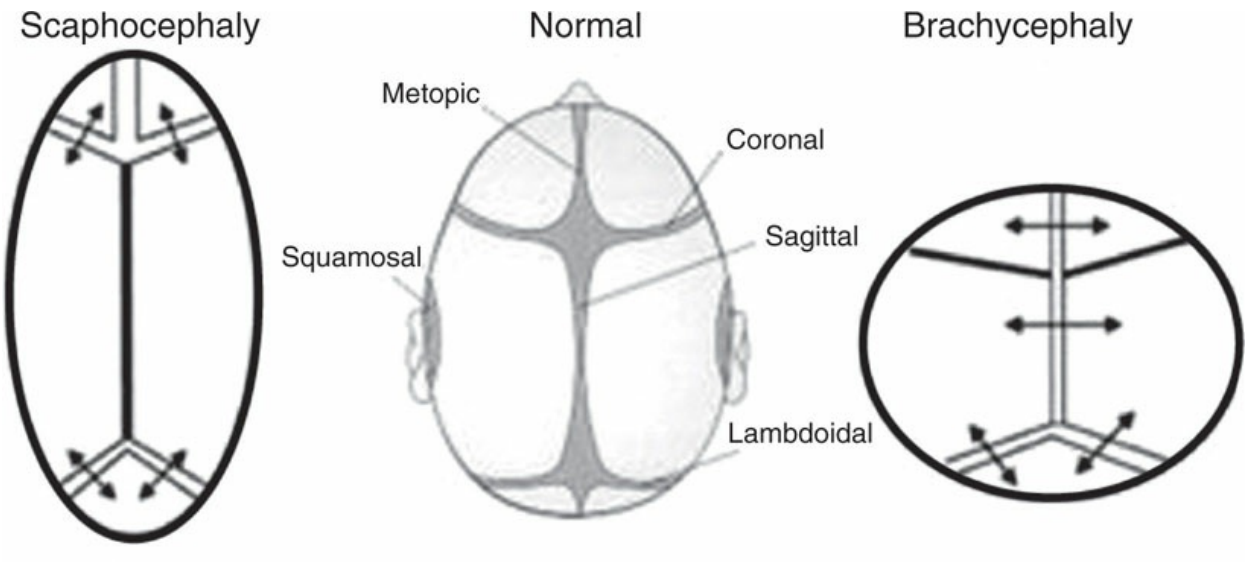


Figure 24-9 Head shapes. Scaphocephaly, which is also referred to as dolichocephaly, is considered to be elongated and narrow. Brachycephaly is described as a round and short head shape.

Cephalic Index and Fetal Head Shape

There can be much variability in the shape of the fetal head, and for that reason, the shape of the cranium should be evaluated closely with each examination. The cephalic index is a useful tool for indicating the shape of the fetal head. A brachycephalic (brachycephaly) head shape is one that is considered round or short and wide, whereas dolichocephaly, also referred to as scaphocephaly, denotes an elongated, narrow head shape (Fig. 24-9). Other abnormal skull shapes include strawberry, lemon, and cloverleaf. These abnormal shapes are associated with fetal anomalies (Table 24-5). The normal- to medium-sized skull is termed mesocephalic. The formula used to calculate the cephalic index considers the BPD and the OFD as in: cephalic index = BPD/OFD × 100. Fortunately, the formula is calculated by most of the present-day equipment. A cephalic index of less than 75 denotes a dolichocephalic shape, whereas an index of more than 85 denotes a brachiocephalic shape.

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A cephalic index of less than 75 denotes a dolichocephalic shape, whereas an index of more than 85 denotes a brachiocephalic shape.

Lateral Ventricle Measurement

The diameter of the lateral ventricle can be easily measured with sonography. The lateral ventricle is measured in the transaxial plane at the level of the atrium (see Fig. 24-4). The atrium of the lateral ventricle is the optimal site

for measuring the lateral ventricle, because it is the first region where ventricular enlargement occurs. The calipers are placed at the level of the glomus of the choroid plexus. The normal lateral ventricle does not typically measure more than 10 mm at the level of the atrium. Enlargement beyond 10 mm is referred to as ventriculomegaly.

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The normal lateral ventricle does not typically measure more than 10 mm at the level of the atrium.

TABLE 24-5 Fetal head shapes and associated anomalies[a]

Head Shape	Associated Anomalies
Lemon	Chiari II malformation
Strawberry	**Trisomy 18** (see Fig. 30-10)
Cloverleaf	**Thanatophoric dysplasia** (see Fig. 26-15)
Microcephaly	**TORCH infections**
	Trisomy 13 and **trisomy 18**
	Meckel–Gruber syndrome
	Fetal alcohol syndrome
Macrocephaly	Hydrocephalus
	Hydranencephaly
	Intracranial tumors
	Familial inheritance
	Beckwith–Wiedemann syndrome
Brachycephaly	Craniosynostosis
	Trisomy 21
	Trisomy 18
Dolichocephaly	Craniosynostosis

[a] Please note that this is a condensed list. Other anomalies and syndrome may be present. For review purposes, keep these in mind.

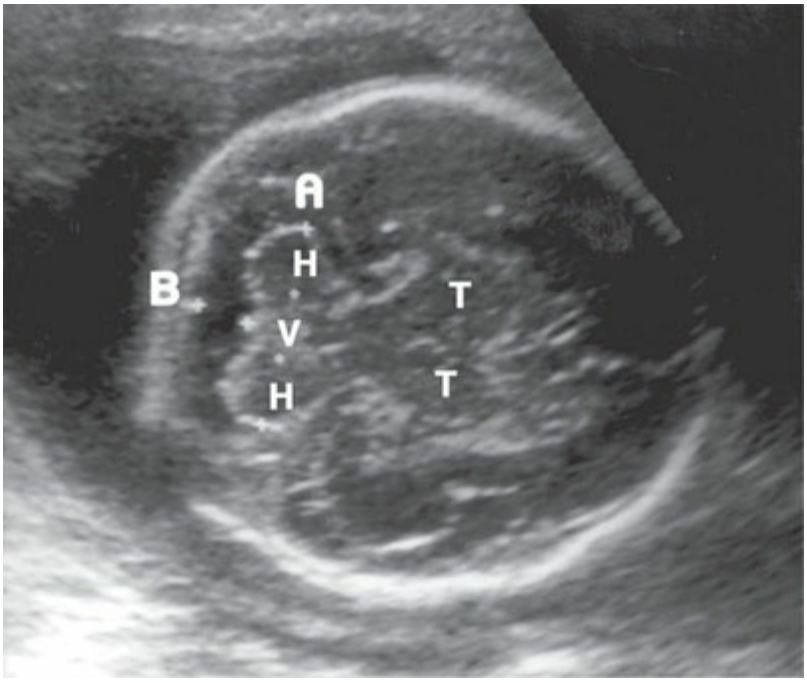


Figure 24-10 Posterior fossa measurements at 32 weeks. The cisterna magna (*B, calipers*) is measured from the posterior margin of the cerebellar vermis (*V*) to the inner margin of the occipital bone. Calipers (*A*) indicate the proper measurement for the transcerebellar diameter. *H,* cerebellar hemispheres; *T,* thalami.

Transcerebellar Measurement

The cerebellum grows at a rate of 1 mm per week between 14 and 21 weeks and thus correlates agreeably with the gestational age of the fetus. That means, the cerebellum of a 16-week fetus will measure approximately 16 mm. The cerebellum is measured in the transverse plane at the same level as the cisterna magna and thalamus (Fig. 24-10).

Cisterna Magna Measurement

Sonographic measurement of the depth of the cisterna magna can be performed as well (see Fig. 24-10). The depth of the cisterna magna should not measure more than 10 mm or less than 2 mm in the transcerebellar plane. Measurement more than 10 mm is consistent with mega cisterna magna and Dandy–Walker complex, whereas a measurement of less than 2 mm is worrisome for Arnold–Chiari II malformation.

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The depth of the cisterna magna should not measure more than 10 mm or less than 2 mm in the transcerebellar plane

CEREBRAL MALFORMATIONS

Ventriculomegaly and Hydrocephalus

The abnormal enlargement of the ventricles within the brain is referred to as ventriculomegaly. Hydrocephalus refers to dilatation (dilation) of the ventricular system caused by an increased volume of CSF, resulting in increased intraventricular pressure. Hydrocephalus may be reserved for cases of ventriculomegaly that are more severe and are caused by some type of obstruction to the flow of CSF, resulting in a backup of the fluid in the cerebral ventricles. Therefore, obstructive hydrocephalus is the buildup of CSF within the ventricular system secondary to some type of obstruction.

Ventriculomegaly has been cited as the most common cranial abnormality. Suspicion of ventricular dilatation occurs when the atrial diameter measures more than 10 mm. The lateral ventricle that will be readily seen on sonography is most often the ventricle farthest from the transducer. The sonographic finding of the "dangling choroid" sign describes the echogenic choroid plexus, hanging limp, and surrounded by CSF, within the dilated lateral ventricle. This finding is exceedingly specific for ventriculomegaly (Fig. 24-11).



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The sonographic finding of the "dangling choroid" sign describes the echogenic choroid plexus, hanging limp, and surrounded by CSF, within the dilated lateral ventricle.

Hydrocephalus can be described further as mild, moderate, or severe. There are two main types of hydrocephalus, communicating and noncommunicating. Communicating hydrocephalus is apparent when the obstruction lies outside the ventricular system, whereas noncommunicating hydrocephalus is when the obstruction level is located within the ventricular system.

Although hemorrhagic obstruction and the subsequent enlargement of the ventricles can occur in utero, congenital obstruction of the ventricular system, by means of aqueductal stenosis, remains the most common cause of hydrocephalus in utero. There are also other etiologies of hydrocephalus, including many chromosomal aberrations and intrauterine infections.

SONOGRAPHIC FINDINGS OF VENTRICULOMEGALY

1. Atrium of the lateral ventricle measures >10 mm
2. Atrial measurement >15 mm is considered moderate to marked ventriculomegaly
3. Dangling choroid sign
4. Dilatation of any part of the ventricular system

Aqueductal Stenosis

Aqueductal stenosis, as stated previously, is the most common cause of hydrocephalus in utero. The cerebral aqueduct (aqueduct of Sylvius), located between the third and fourth ventricles of the brain, may be narrowed, thus preventing the flow of CSF from the third to the fourth ventricle. This obstruction level will cause the third ventricle and both the lateral ventricles to expand, whereas the fourth ventricle remains normal.



Figure 24-11 Dangling choroid sign. Axial view of the fetal cranium with ventriculomegaly demonstrating choroid plexus (*arrowheads*) dangling within the dilated ventricle.

SONOGRAPHIC FINDINGS OF AQUEDUCTAL STENOSIS

1. Atrium of the lateral ventricle measures >10 mm
2. Atrial measurement >15 mm is considered moderate to marked ventriculomegaly
3. Dangling choroid sign
4. Dilatation of the lateral ventricles and the third ventricle; the fourth ventricle remains normal

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Aqueductal stenosis is the most common cause of hydrocephalus in utero.

Hydranencephaly

Hydranencephaly is a fatal condition in which the entire cerebrum is replaced by a large sac containing CSF (Fig. 24-12). With hydranencephaly, the falx cerebri may be partially or completely absent, whereas the brain stem and basal ganglia are maintained and surrounded by CSF. The thalamus may be seen, but there will be no cerebral cortex identified.

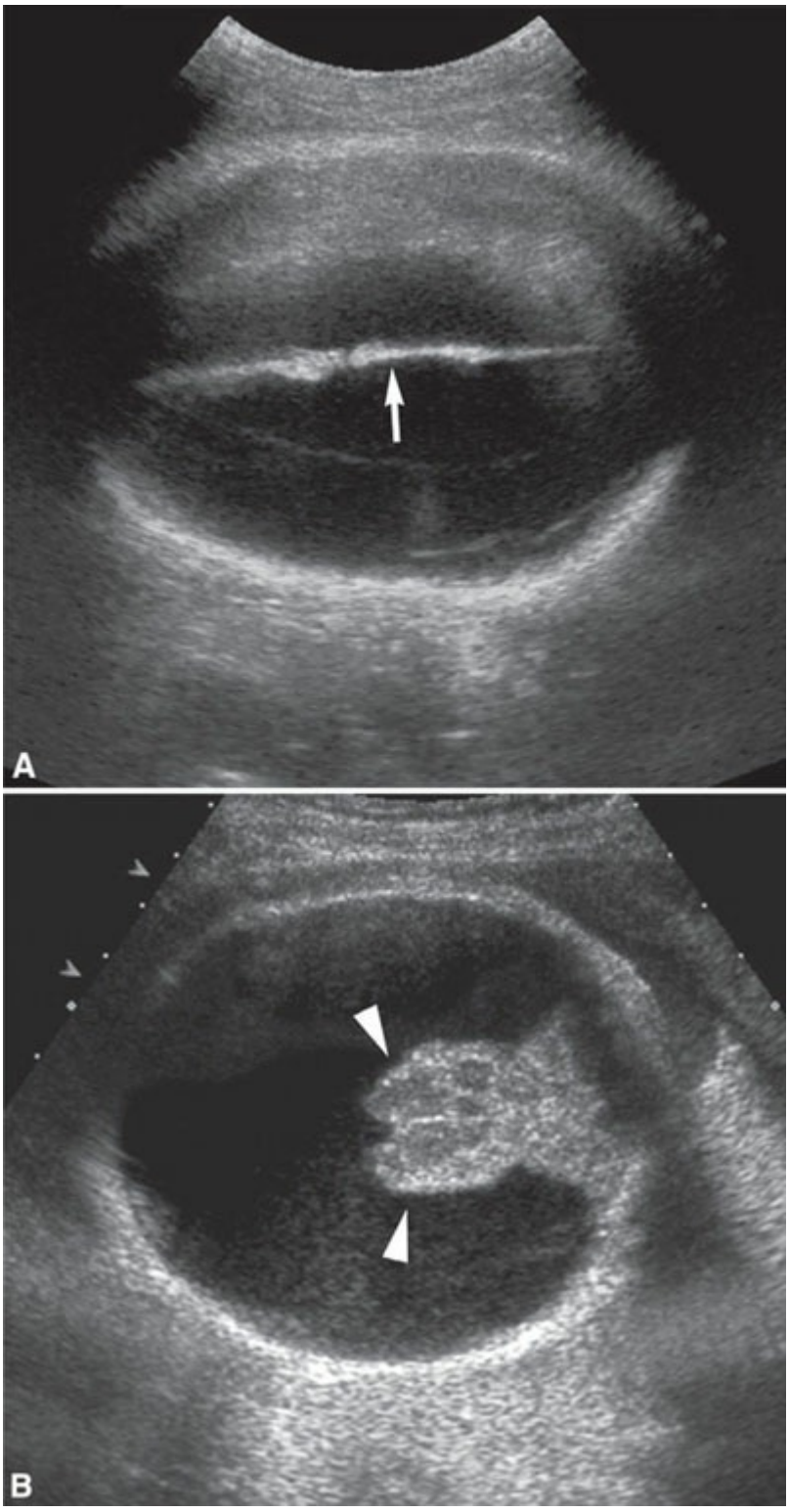


Figure 24-12 Hydranencephaly. **A.** Axial image of a fetus demonstrating a fluid-

filled cranium with no visible cerebral cortex. Part of the falx cerebri (*arrow*) is noted within the midline of the brain. All findings are consistent with hydranencephaly. **B.** Hydranencephaly with the thalamus seen (*arrowheads*).

There have been several postulations regarding the cause of hydranencephaly, including bilateral occlusion of the internal carotid arteries with subsequent destruction of the cerebral hemispheres. Another hypothesis is that intrauterine infections such as cytomegalovirus and toxoplasmosis lead to the destruction of the cerebral hemispheres. The brain may appear normal in the first trimester and then reflect hydranencephaly in the second or third trimester. Hydranencephaly can be difficult to differentiate with the sonographic findings of severe ventriculomegaly and alobar holoprosencephaly. It is important to note that with both severe ventriculomegaly and holoprosencephaly, there will typically be a rim of cerebral tissue maintained, whereas with hydranencephaly, there is no cerebral mantle present. Hydranencephaly is typically a fatal condition, with death occurring in the first year of life.

SONOGRAPHIC FINDINGS OF HYDRANENCEPHALY

1. Fluid-filled cranium
2. Absent or partial absence of the falx cerebri
3. Maintained brain stem, basal ganglia, and perhaps the thalamus
4. No identifiable cerebral cortex

Holoprosencephaly

Holoprosencephaly is a midline brain anomaly that is associated with not only brain aberrations but also atypical facial structures. It may be detected with endovaginal imaging as early as the first trimester. There are three main types of holoprosencephaly: alobar, semilobar, and lobar. With alobar, the cortex can take on three basic shapes resembling a “pancake,” “cup,” or “ball” (Fig. 24-13). Although the lobar form can be consistent with life, alobar holoprosencephaly is the most severe form, often resulting in neonatal death. Alobar holoprosencephaly is diagnosed when there is absence of the corpus callosum, CSP, third ventricle, interhemispheric fissure, and falx cerebri. There will also be evidence of a horseshoe-shaped monoventricle, and the lobes of the thalamus may be fused and echogenic in appearance (Fig. 24-14; Table 24-6). Conversely, the cerebellum and brain stem remain intact.

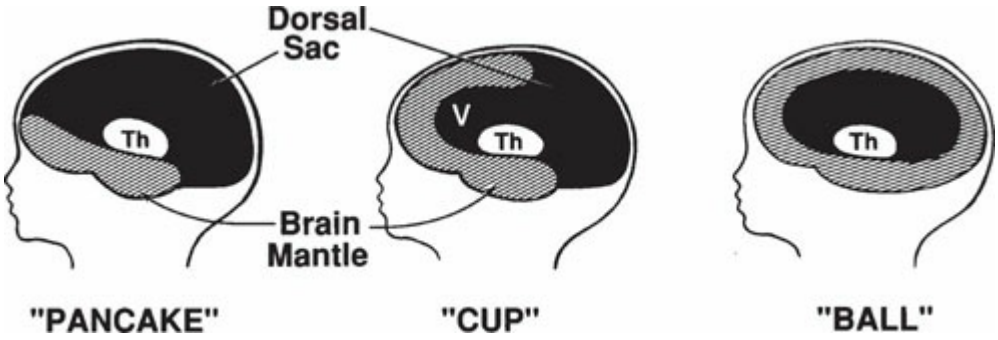


Figure 24-13 Sagittal drawing of pancake, cup, and ball holoprosencephaly morphology. The pancake type is described as having a flattened residual brain mantle at the base of the brain with a correspondingly large dorsal sac. The cup type has more brain mantle, but it does not cover the monoventricle. The dorsal sac communicates widely with the monoventricle. The ball type is described as when the brain mantle completely covers the monoventricle, and a dorsal sac may or may not be present. *Th,* thalami; *V,* ventricle.

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With holoprosencephaly, there will be evidence of a horseshoe-shaped monoventricle, and the lobes of the thalamus may be fused and echogenic in appearance.

Cyclopia, a condition in which the orbits are fused and contain a single eye, and proboscis, a false nose situated above the orbits, are two of the most disturbing external findings associated with holoprosencephaly. Other facial anomalies such as anophthalmia, hypotelorism, median cleft lip, and cebocephaly may be detected during a fetal sonogram as well. Chapter 25 further discusses facial abnormalities associated with holoprosencephaly. With the less devastating forms of holoprosencephaly, such as lobar, there are varying degrees of fusion of the midline structures. Infants with lobar holoprosencephaly may experience severe mental retardation. Trisomy 13, or Patau syndrome, is present in 50% to 70% of fetuses diagnosed with holoprosencephaly.

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Trisomy 13, or Patau syndrome, is present in 50% to 70% of fetuses diagnosed with holoprosencephaly.

SONOGRAPHIC FINDINGS OF ALOBAR HOLOPROSENCEPHALY

1. Horseshoe-shaped monoventricle
2. Fused echogenic thalami
3. Absence of the CSP, interhemispheric fissure, falx cerebri, corpus callosum, and

third ventricle
4. Normal cerebellum and brain stem

Dandy–Walker Malformation and Mega Cisterna Magna

Dandy–Walker malformation (DWM) is actually a classification within a larger group of anomalies referred to as the Dandy–Walker complex. Dandy–Walker complex is a spectrum of posterior fossa abnormalities that involve the cystic dilatation of the cisterna magna and fourth ventricle. DWM is thought to be caused by a developmental abnormality in the roof of the fourth ventricle. The sonographic findings of DWM include an enlarged cisterna magna that communicates with a distended fourth ventricle through a defect in the cerebellum (Figs. 24-15 and 24-16). The cerebellar vermis is either completely absent or hypoplastic. As a result, the tentorium, the structure that separates the cerebrum from the cerebellum, is elevated. There are often other midline brain abnormalities present as well. For instance, agenesis of the corpus callosum, ventriculomegaly, holoprosencephaly, and cephaloceles are all associated anomalies of DWM.

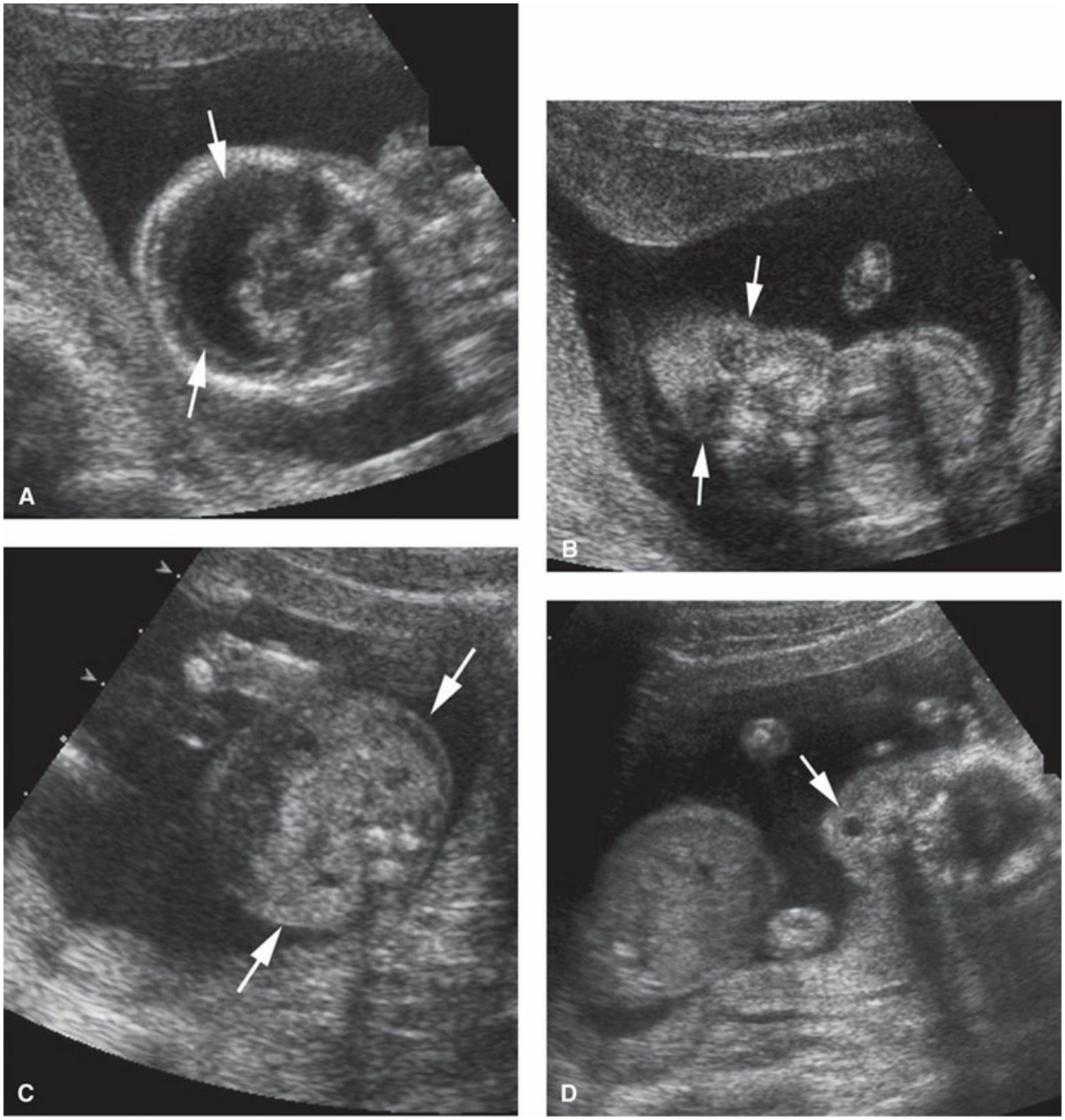


Figure 24-14 Holoprosencephaly and trisomy 13. **A.** Coronal image of fetal head demonstrating fusion of the ventricles into a large monoventricle (*arrows*) and absence of the falx, characteristic of alobar holoprosencephaly. **B.** Coronal image of the face showing the orbits (*arrows*) abnormally close together. **C.** Transverse image of fetal abdomen demonstrating enlarged, echogenic kidneys (*arrows*). **D.** Coronal image of face showing a midline facial defect (*arrow*).

TABLE 24-6 Facial anomalies associated with alobar holoprosencephaly

Facial Anomalies of Alobar Holoprosencephaly
Cyclopia
Hypotelorism

Proboscis
(Median) cleft lip
Anophthalmia
Cebocephaly

Mega cisterna magna, which is the enlargement of the cisterna magna without the involvement of the fourth ventricle, may be confused with DWM. Mega cisterna magna is present when only the cisterna magna is enlarged, measuring more than 10 mm in depth. Consequently, the fourth ventricle is normal with mega cisterna magna and enlarged with DWM. It is important to note that in the early second trimester, the inferior portion of the cerebellar vermis may not be formed, thus making it appear as if the fetus has partial agenesis of the vermis. For that reason, care must be taken to visualize an intact cerebellar vemis. If the cerebellar vermis is absent and the fourth ventricle is enlarged, then DWM must be suspected.

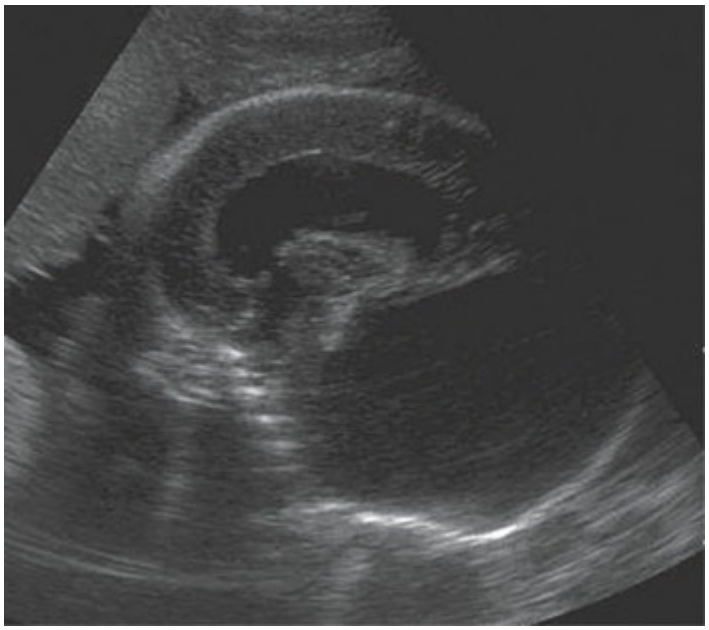


Figure 24-15 Sagittal image of Dandy–Walker malformation. This sagittal image of the fetal cranium demonstrates an enlarged posterior fossa.

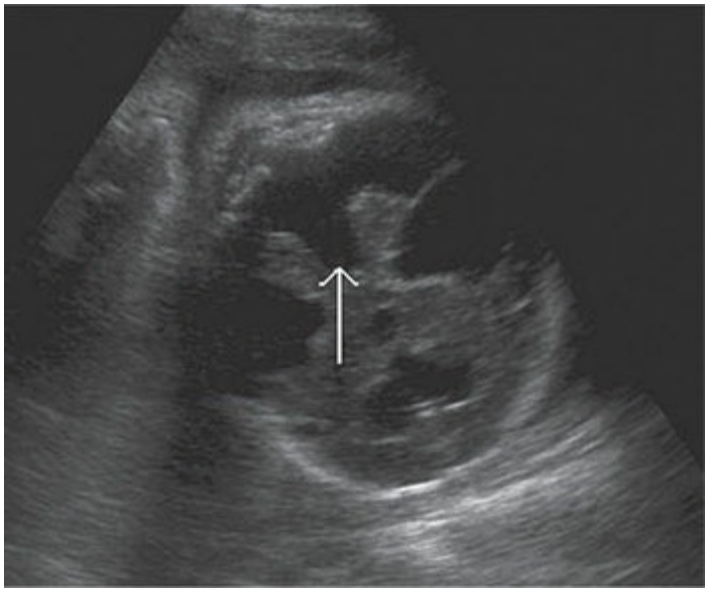


Figure 24-16 Axial image of Dandy–Walker malformation. The dilated fourth ventricle (*arrow*) is seen between the splayed lobes of the cerebellum, a finding consistent with Dandy–Walker malformation.

SONOGRAPHIC FINDINGS OF DANDY–WALKER MALFORMATION

1. Enlargement of the cisterna magna >10 mm in the anteroposterior dimension
2. Communication of the enlarged cisterna magna with a dilated fourth ventricle
3. Agenesis or hypoplasia of the cerebellar vermis
4. Varying degrees of ventriculomegaly

SONOGRAPHIC FINDINGS OF MEGA CISTERNA MAGNA

1. Enlargement of the cisterna magna >10 mm in the anteroposterior dimension
2. Normal cerebellum and fourth ventricle

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If the cerebellar vermis is absent and the fourth ventricle is enlarged, then DWM must be suspected.

Agenesis of the Corpus Callosum and Cavum Septum Pellucidum

The corpus callosum is a bridge of tissue located within the midline of the brain that connects the two cerebral hemispheres. It functionally provides a pathway for communication between the hemispheres and is completely formed by 18 weeks. The CSP, located inferior to the corpus callosum, and the corpus callosum develop at the same time. The congenital lack of these structures is termed agenesis, as in agenesis of the corpus callosum, and CSP. There can be partial or complete absence of the corpus callosum. Most often, if the corpus callosum is absent, the CSP will be absent as well. Their

nonexistence has been linked to as many as 50 to 200 different syndromes and anomalies such as Apert syndrome, holoprosencephaly, DWM, aqueductal stenosis, trisomy 18, trisomy 8, and trisomy 13.

There are several distinct sonographic findings consistent with agenesis of the corpus callosum, including the obvious absence of this structure. The "sunburst" manifestation of the sulci is a straightforward and discernible sonographic finding. In the normal brain, the sulci within the cerebrum typically travel parallel to the corpus callosum, but with agenesis of the corpus callosum, they tend to have a more perpendicular or radial arrangement and often appear to have a "spoke wheel" pattern. This pattern is better imaged in a sagittal plane to the fetal head (Fig. 24-17). Colpocephaly, small frontal horns and enlarged occipital horns, is often present as well and offers a distinct teardrop shape to the lateral ventricles. In addition, with absence of the CSP and corpus callosum, the third ventricle tends to migrate more superiorly and appear dilated.

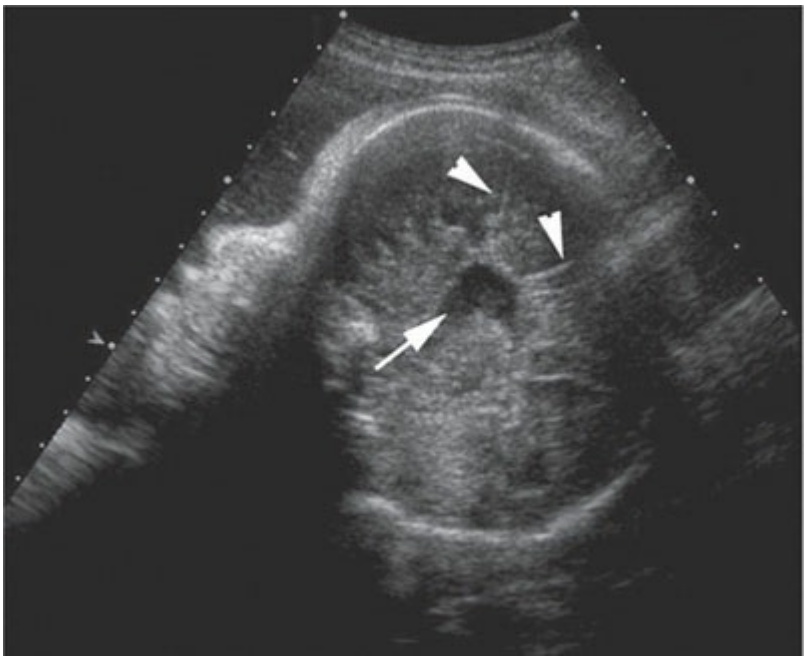


Figure 24-17 Apert syndrome with agenesis of the corpus callosum. Sagittal image of a fetus with Apert syndrome revealing agenesis of the corpus callosum with the typical spoke wheel pattern of the sulci (*arrowheads*) and the elevation and dilation of the third ventricle (*arrow*).

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With agenesis of the corpus callosum, the sulci tend to have a more perpendicular or radial arrangement, and often appear to have a "spoke wheel" pattern.

SONOGRAPHIC FINDINGS OF AGENESIS OF THE CORPUS CALLOSUM AND CAVUM SEPTUM PELLUCIDUM

1. Partial or complete absence of the corpus callosum and absence of the CSP (after 18 weeks)
2. "Sunburst" sign—radial arrangement of the sulci which produces a "spoke wheel" pattern
3. Colpocephaly—small frontal horns and enlarged occipital horns (teardrop-shaped lateral ventricles)
4. Elevated and dilated third ventricle

Schizencephaly

Schizencephaly is associated with the development of fluid-filled clefts within the cerebrum. The etiology of schizencephaly is unknown, although there may be an association with intrauterine exposure to some illicit drugs. It may be described as open lip or closed lip, with open lip being more readily identified in utero. The sonographic appearance of open lip schizencephaly is that of a cerebrum containing gray matter-lined clefts filled containing anechoic CSF (Fig. 24-18). There are several associated anomalies such as agenesis of the corpus callosum and CSP, and ventriculomegaly.

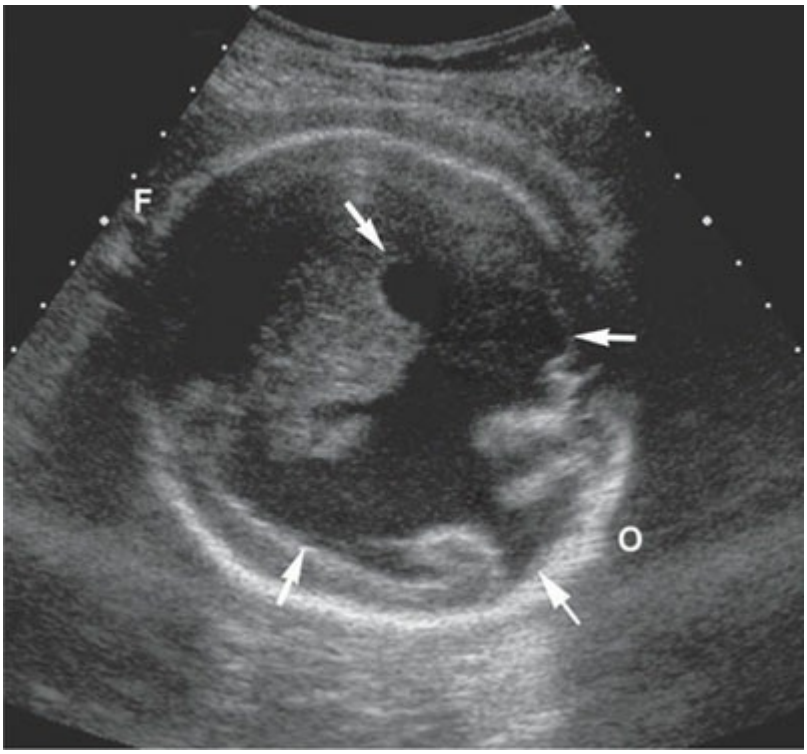


Figure 24-18 Schizencephaly. Axial image of head, frontal bone (*F*) to occiput (*O*), demonstrating a large irregular asymmetric fluid space (*arrows*) replacing portions of the parietal lobes and occipital lobes on each side, representing large clefts in the brain.

SONOGRAPHIC FINDINGS OF SCHIZENCEPHALY

1. Fluid-filled clefts within the cerebrum
2. Agenesis of the CSP and corpus callosum (50% of the time)
3. Ventriculomegaly

SOUND OFF

Schizencephaly is associated with the development of fluid-filled clefts within the cerebrum.

Porencephaly

Porencephaly is a rare condition in which a cyst communicates with the ventricular system. Porencephaly can occur after the fetus has experienced hemorrhage within one or both of the cerebral hemispheres. As the hemorrhage changes states, it will form into a cystic cavity and will eventually communicate with the lateral ventricle of the affected side (Fig. 24-19). This condition may be caused by ischemic events or vascular occlusion within the brain. Arachnoid cysts can be confused with porencephaly. It is important to note that arachnoid cysts will not communicate with the ventricular system.

SONOGRAPHIC FINDINGS OF PORENCEPHALY

1. Cystic mass that communicates with the lateral ventricle
2. Most often unilateral

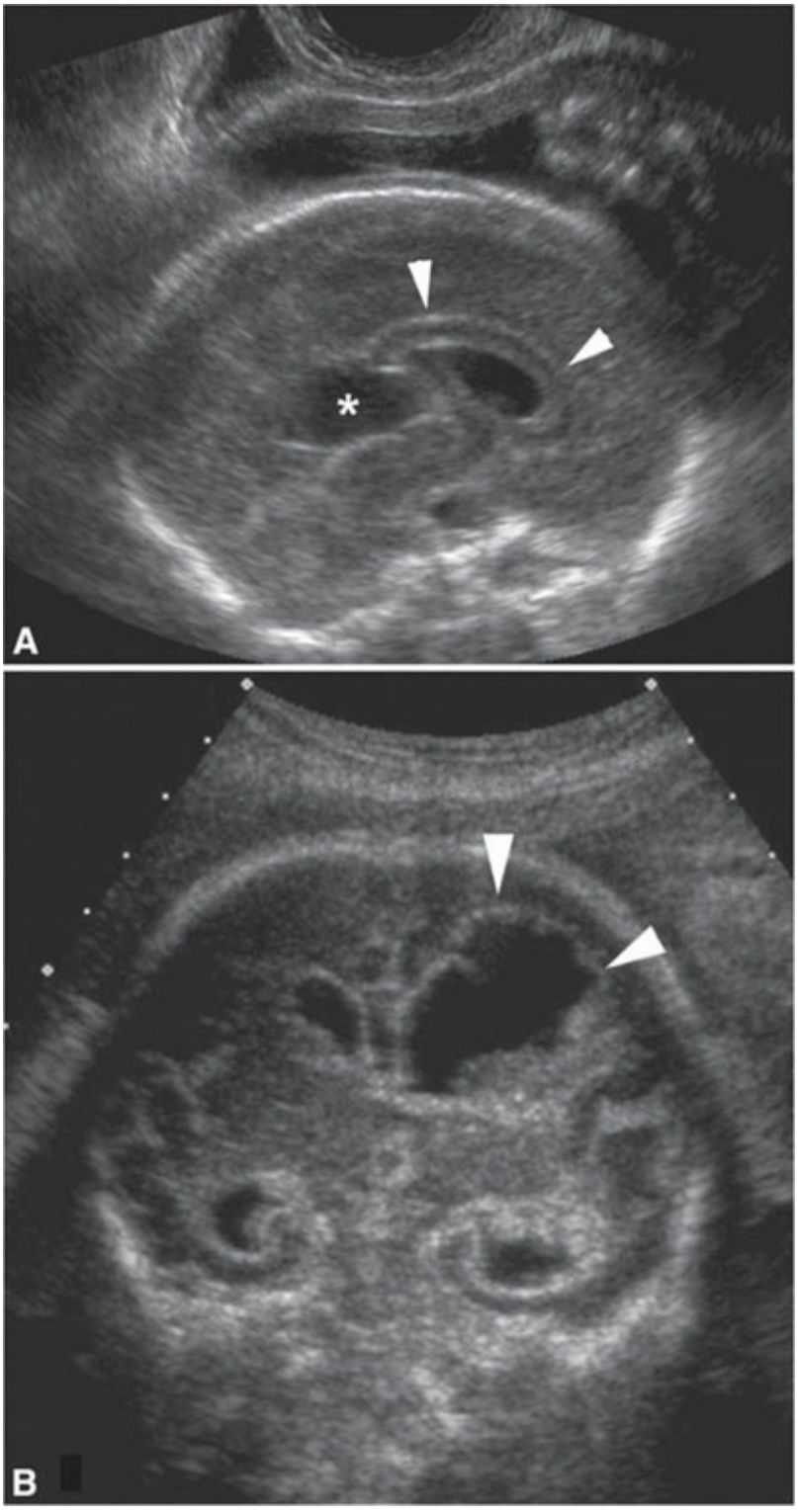


Figure 24-19 Porencephaly versus arachnoid cyst. **A.** An arachnoid cyst (*) is seen posterior to the corpus callosum (*arrowheads*) in this sagittal image. **B.** Porencephaly (*arrowheads*) is noted in this coronal image following an intracranial hemorrhage. Note that the porencephalic cyst communicates with the lateral ventricle.

Lissencephaly

Lissencephaly literally means “smooth brain.” It is a condition in which there are no gyri within the cerebral cortex. Agyria, and the absence of sulci within

the brain, is not typically diagnosed until the third trimester or postnatally and almost always carries a poor prognosis.

SONOGRAPHIC FINDINGS OF LISSENCEPHALY

1. Lack of sulci and gyri within the cerebrum

Choroid Plexus Cysts

Choroid plexus cysts are cysts located within the choroid plexus of the lateral ventricles. These small cysts are frequently encountered during a routine sonographic examination and typically regress by the end of the third trimester, although there is an association with trisomy 18. A choroid plexus cyst will be located within the choroid plexus of the lateral ventricle, measure more than 2 mm, appear round and anechoic, and have smooth walls (Fig. 24-20).

SONOGRAPHIC APPEARANCE OF A CHOROID PLEXUS CYST

1. Anechoic, round, smooth-walled cyst located within the choroid plexus of the lateral ventricle

SOUND OFF
Choroid plexus cysts often regress, although there is a slight association with Trisomy 18.

NEURAL TUBE DEFECTS AND THE BRAIN

Neural tube defects occur when the embryonic neural tube fails to close. Among the list of neural tube defects are cephaloceles, various spinal dysraphisms, anencephaly, and spina bifida. Anencephaly and spina bifida are the most common neural defects, occurring in 1 per 1,000 pregnancies. Although several causes have been implicated, such as maternal diabetes and the use of valproic acid (seizure medication), chromosomal anomalies, including Edwards syndrome (trisomy 18), Patau syndrome (trisomy 13), and triploidy, have all been linked with neural tube defects.

Fortunately, studies have shown that a supplement of 0.4 mg of folate (folic acid) in a woman's diet significantly reduces the likelihood of her fetus developing a neural tube defect. Screening for neural tube defects is achieved by a combination of sonography, amniocentesis, and/or maternal serum screening. Maternal serum screening, also referred to as the triple screen, combines the laboratory values of human chorionic gonadotropin, estriol,

and maternal serum alpha-fetoprotein (MSAFP), particularly, helpful for detecting neural tube defects is the MSAFP component of this test.

Alpha-Fetoprotein (AFP) is initially produced by the yolk sac, fetal gastrointestinal tract, and the fetal liver. AFP exits the fetus through an opening in the neural tube if one is present (i.e., an opening in the cranium or spine), thus allowing for a greater amount to pass into the maternal circulation. However, increased levels of AFP may not always mean that a neural tube defect is present. Elevated levels of AFP are also found with omphalocele, gastroschisis, multiple gestations, fetal demise, and incorrect gestational dating.

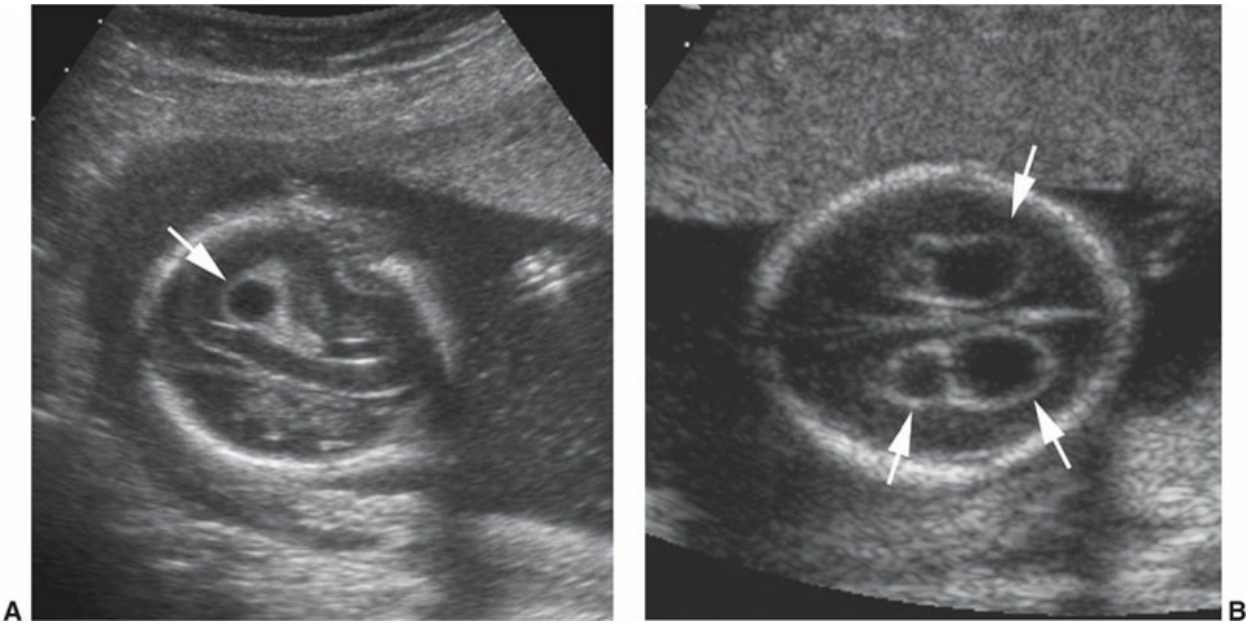


Figure 24-20 Choroid plexus cysts. **A.** Oblique image of fetal head showing single choroid plexus cyst (*arrow*). **B.** Axial image of fetal head showing multiple bilateral choroid plexus cysts (*arrows*).

SOUND OFF
AFP exits the fetus through an opening in the neural tube if one is present (i.e., an opening in the cranium or spine), thus allowing for a greater amount to pass into the maternal circulation.

Acrania (Anencephaly and Exencephaly)

Acrania remains one of the most common neural tube defects. Acrania is defined as the absence of the cranial vault above the bony orbits. It can be further divided into two main subtypes depending on the amount of cerebral tissue present, anencephaly and exencephaly. Anencephaly is considered when there are no cerebral hemispheres present, whereas exencephaly denotes a normal amount of cerebral tissue. Nonetheless, the cranium is

absent, making this condition fatal. The sonographic appearance of anencephaly has been described as having “froglike” facies, or bulging eyes, and absence of the cranial vault (Fig. 24-21).

CLINICAL FINDINGS OF ACRANIA/ANENCEPHALY

1. Elevated MSAFP

SONOGRAPHIC FINDINGS OF ACRANIA/ANENCEPHALY

1. Absent cranial vault
2. Some cerebral tissue may be present
3. “Froglike” facies or bulging eyes

SOUND OFF

The sonographic appearance of anencephaly has been described as having “froglike” facies, or bulging eyes, and absence of the cranial vault

Arnold–Chiari II Malformation and Spina Bifida

Arnold–Chiari II or Chiari II malformation is a group of cranial abnormalities associated with the neural tube defect spina bifida. Spina bifida may result in a mass that protrudes from the spine. This mass can be referred to as a meningocele or myelomeningocele, depending on its contents. The most common location of spina bifida is within the distal lumbosacral region (Fig. 24-22). Several notable changes occur within the brain and skull with spina bifida. The frontal bones become flattened and will yield a lemon shape to the cranium, which is referred to as the “lemon” sign, often referred to as scalloping of the frontal bones (Fig. 24-23). The cerebellum will become displaced inferiorly and posteriorly and appear curved in the presence of spina bifida, which is referred to as the “banana” sign (Fig. 24-24). As a result of the cerebellum being displaced inferiorly, the cisterna magna is completely obliterated. Posterior fossa abnormalities and their sonographic findings are provided in Table 24-7. A posterior fossa abnormality such as Chiari II malformation should be suspected if the cisterna magna is not visualized. The lateral ventricles will also be distorted in shape. The frontal horns will be small and slitlike, whereas the occipital horns will be enlarged, a condition known as colpocephaly.

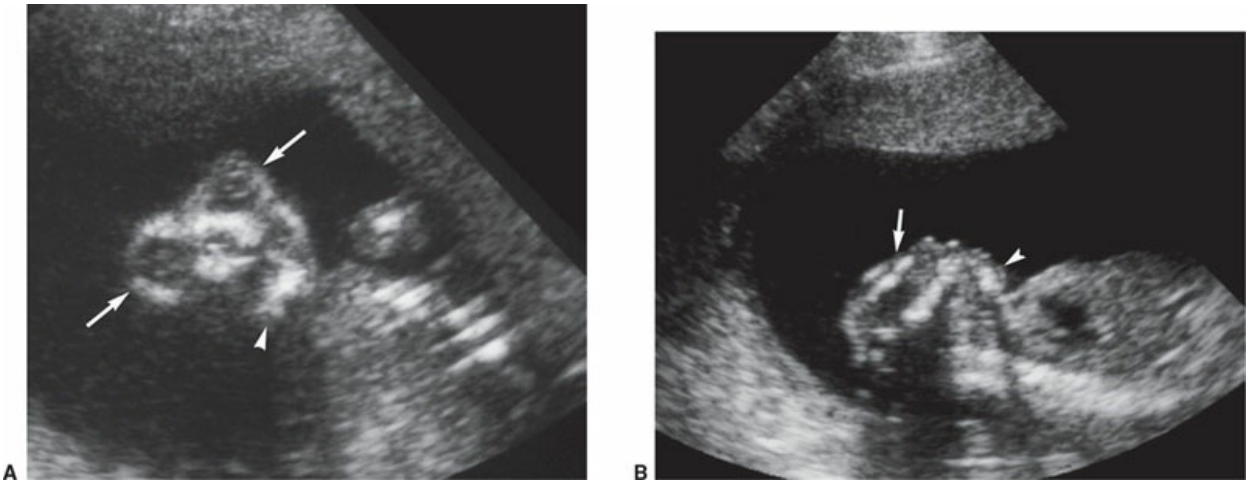


Figure 24-21 Anencephaly. **A.** Coronal image of the fetal face demonstrating absence of the forehead and cranium with the typical "froglike" facies (*arrows*) of anencephaly. The mandible is normally formed (*arrowhead*). **B.** Sagittal image of the same fetus demonstrating absence of the forehead and cranium (*arrow*). The mandible (*arrowhead*) and lower face appears normal.

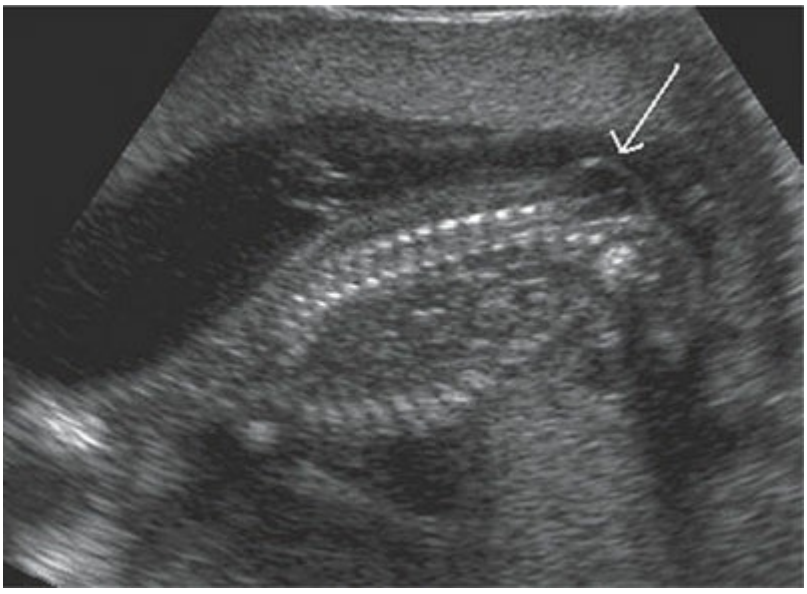


Figure 24-22 Myelomeningocele. Sagittal image of the fetal spine demonstrating a myelomeningocele (*arrow*) located in the distal spine.

SOUND OFF

The cerebellum will become displaced inferiorly and posteriorly and appear curved in the presence of spina bifida, which is referred to as the "banana" sign.



Figure 24-23 Lemon sign. Axial view of the fetal cranium demonstrating the lemon sign found in most cases of spina bifida.

Clinical Findings of Arnold–Chiari II Malformation

1. Elevated MSAFP

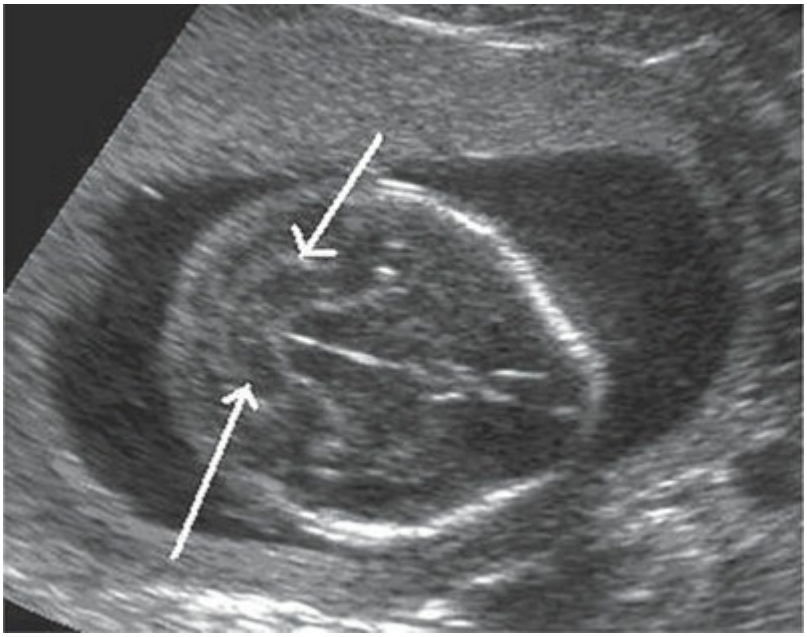


Figure 24-24 Banana sign. Axial view of the cerebellum demonstrating the abnormal banana shape that the cerebellum (*arrows*) takes in the presence of spina bifida.

Sonographic Findings of Arnold–Chiari II Malformation

1. Lemon sign—lemon-shaped cranium with flattened frontal bones
2. Banana sign—banana-shaped cerebellum
3. Obliterated cisterna magna

4. Colpocephaly
5. Enlarged massa intermedia
6. Hydrocephalus
7. Open spinal defect

Cephaloceles

Cephaloceles are protrusions of intracranial contents through a defect in the skull. Table 24-8 provides a description of the different types of cephaloceles based on their content. Cephaloceles can also be distinguished by their location. The most common location for a cephalocele is in the occipital region (Fig. 24-25). However, cephaloceles may also have frontal and parietal positions. Encephaloceles, which include brain tissue, are common findings in Meckel–Gruber syndrome and have varying sonographic appearances based on their content.

TABLE 24-7 Posterior fossa abnormalities and their sonographic findings

Posterior Fossa Abnormality	Sonographic Findings
Mega cisterna magna	Enlargement of the cisterna magna >10 mm in the anteroposterior dimension Normal cerebellum
Dandy—Walker malformation	Enlargement of the cisterna magna >10 mm in the anteroposterior dimension Absent cerebellar vermis Enlarged fourth ventricle
Arnold–Chiari II malformation	Obliterated cisterna magna Banana-shaped cerebellum Lemon-shaped skull

CLINICAL FINDINGS OF CEPHALOCELES

1. Possible elevation of MSAFP

SONOGRAPHIC FINDINGS OF CEPHALOCELES

1. Open cranial defect (typically posterior in location)
2. Small or obliterated cisterna magna
3. Complex or simple appearing mass protruding from the cranium

SOUND OFF
The most common location for a cephalocele is in the occipital region.

TABLE 24-8 Different types of cephaloceles and their contents

Type of Cephalocele	Content of the Mass
Meningocele	Meninges only
Encephalocele	Brain tissue only
Encephalomeningocele	Both meninges and brain tissue
Encephalomeningocystocele	Meninges, brain tissue, and lateral ventricle



Figure 24-25 Occipital cephalocele. Axial image of the fetal skull revealing a cystic mass protruding from the occipital region representing a cephalocele.

THE EFFECTS OF FETAL INFECTIONS ON THE BRAIN

Maternal serum screening for intrauterine infections resulting from toxoplasmosis, other agents, rubella, cytomegalovirus, and Herpes simplex virus (TORCH) can be performed. Although cytomegalovirus has been listed

as the most common in utero infection, other infections, such as toxoplasmosis, rubella, parvovirus, varicella zoster, and Herpes simplex, occur less often but may have devastating effects on the fetus. The sonographic intracranial findings consistent with intrauterine infections are the calcifications around the ventricles and ventriculomegaly. TORCH will be further discussed in Chapter 32.



SOUND OFF

The sonographic intracranial findings consistent with intrauterine infections are the calcifications around the ventricles and ventriculomegaly.

FETAL INTRACRANIAL TUMORS

The most common intracranial tumor found in utero is the teratoma. Teratomas contain tissues such as hair, sebum, and fat and most often appear as complex masses that distort the normal architecture of the brain. Choroid plexus papillomas are found within the choroid plexus and produce an increase in the production of CSF, which in turn leads to ventriculomegaly. Other sonographic findings associated with brain tumors are macrocephaly and intracranial calcifications. Corpus callosum lipomas may also be present with agenesis of the corpus callosum. A lipoma will appear as a solid echogenic mass.



SOUND OFF

The most common intracranial tumor found in utero is the teratoma.

FETAL INTRACRANIAL HEMORRHAGE (INTRAVENTRICULAR HEMORRHAGE)

Although intracranial hemorrhage is a common worry for premature infants weighing less than 1,500 g and those born before 32 weeks gestation, it occurs less often in utero. Maternal use of cocaine, trauma, and a history of amniocentesis are all listed as predisposing condition of fetal intracranial hemorrhage; however, the most common risk factor for fetal intrauterine intracranial hemorrhage has been listed as maternal platelet disorders. Most often, the origin of intracranial hemorrhage, also referred to as intraventricular hemorrhage, is within the germinal matrix.

The germinal matrix is a group of thin-walled, pressure-sensitive vessels located in the subependymal layer of the ventricles. These vessels are prone

to rupture secondary to their thin walls. The hemorrhage can spread into the lateral ventricle, often leading to noncommunicating hydrocephalus, because the clot obstructs the flow of CSF within the narrowed regions of the ventricular system. Hemorrhage can also occur within the parenchyma of the brain. Localized areas of hemorrhage within the cerebral hemispheres will eventually lead to the formation of cystic cavities that communicate with the ventricular system, a condition known as porencephaly.

DOPPLER INTERROGATION OF THE FETAL BRAIN

Doppler of the Middle Cerebral Artery

The normal cerebral circulation typically yields a high-impedance Doppler pattern, with continuous forward flow throughout the cardiac cycle. Doppler assessment of the middle cerebral artery (MCA) has been shown effective at evaluating for potential hypoxia in fetuses that are small for dates (Fig. 24-26). When the fetus is starved for oxygen, redistribution of the blood to the vital organs—such as the brain—occurs in order to spare it from damage. This is referred to as the brain-sparing effect. The pulsatility index of the MCA varies with gestational age, but normally decreases as the pregnancy progresses toward term. The resistance pattern of the MCA should be greater than that of the umbilical artery, and thus should be compared when fetal shunting is suspected. The MCA/umbilical artery resistive index is normally above 1.0, whereas an index lower than 1.0 is considered abnormal.

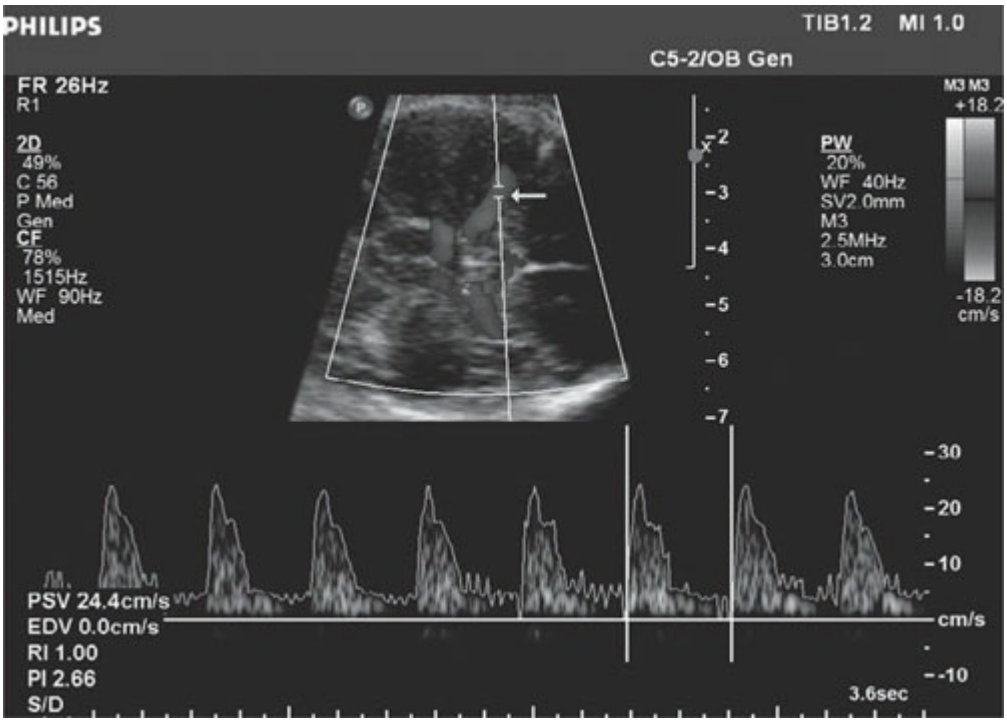


Figure 24-26 Middle cerebral artery (MCA) Doppler. MCA Doppler can be

performed to evaluate the fetus for signs of hypoxia. Color Doppler with spectral tracing of the MCA. The sample gate has been placed in the MCA coursing toward the transducer (*arrow*). To optimize the color signal, the circle of Willis has magnified and the color region of interest reduced. Color image provided online.

SOUND OFF
The resistance pattern of the MCA should be greater than that of the umbilical artery, and thus should be compared when fetal shunting is suspected.

Fetal Intracranial Vascular Anomalies

The vein of Galen aneurysm is an arteriovenous malformation that occurs within the fetal brain. The sonographic findings of a vein of Galen aneurysm is that of a large, anechoic mass within the midline of the cranium that, when interrogated with color and pulsed Doppler, fills with turbulent venous and arterial flow (Fig. 24-27). The fetus will also have signs hydrops and cardiomegaly. Newborns with this condition are prone to suffer from high-cardiac output and congestive heart failure in the postnatal period.

CLINICAL FINDINGS OF VEIN OF GALEN ANEURYSM (NEONATAL)

1. Congestive heart failure

SONOGRAPHIC FINDINGS OF VEIN OF GALEN ANEURYSM

1. Anechoic mass within the midline of the brain that contains turbulent arterial and venous flow when interrogated with pulsed and color Doppler
2. Fetal hydrops
3. Cardiomegaly (caused by cardiac overload)

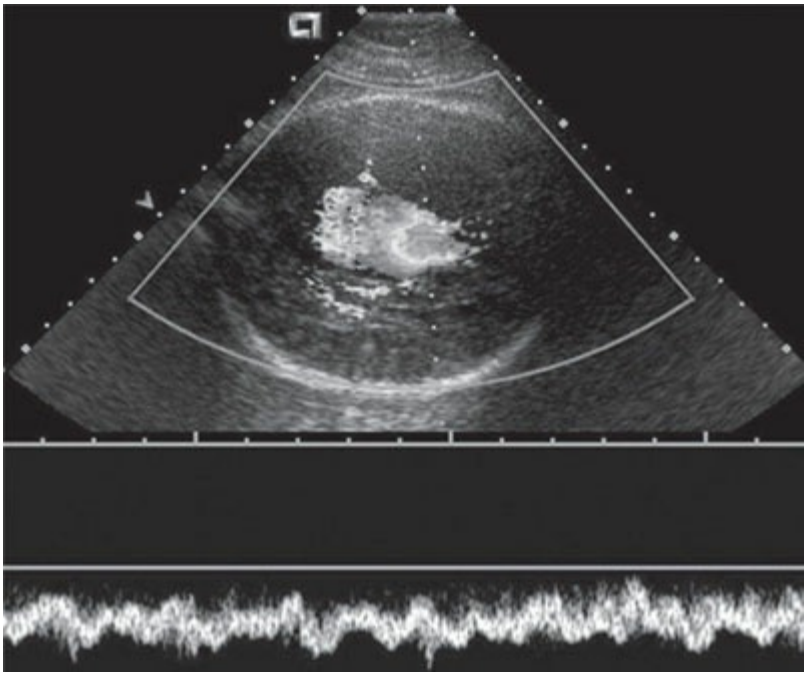


Figure 24-27 Vein of galen aneurysm. Color and spectral Doppler image of a vein of Galen aneurysm demonstrating a large amount of turbulent flow in this vascular abnormality. Color image provided online.

SOUND OFF
The vein of Galen aneurysm is associated with congestive heart failure in the newborn.

REVIEW QUESTIONS

1. With what structure does the posterior fossa cyst associated with DWM communicate?
   a. Fourth ventricle
   b. Third ventricle
   c. Cerebellar vermis
   d. Cerebral aqueduct

2. The choroid plexus cyst could be associated with an increase risk of:
   a. Trisomy 13
   b. Trisomy 4
   c. Arnold–Chiari II malformation
   d. Trisomy 18

3. All of the following are sonographic findings of Arnold–Chiari II malformation except:
   a. Enlarged massa intermedia

b. Hydrocephalus
c. Obliteration of the cisterna magna
d. Strawberry sign

4. Which of the following is located on both sides of the midline?
a. Interhemispheric fissures
b. Third and fourth ventricles
c. Lateral ventricles
d. Third ventricle and cerebral aqueduct

5. Which of the following will also typically be absent with agenesis of the corpus callosum?
a. Cerebellar vermis
b. CSP
c. Third ventricle
d. Fourth ventricle

6. The double fold of dura mater that divides the cerebral hemispheres is the:
a. Cerebellum
b. CSP
c. Corpus callosum
d. Falx cerebri

7. The development of fluid-filled cleft within the cerebrum is consistent with:
a. Holoprosencephaly
b. Lissencephaly
c. Schizencephaly
d. Hydranencephaly

8. The anechoic midline brain structure located between the frontal horns of the lateral ventricles is the:
a. CSP
b. Cavum vergae
c. Corpus callosum
d. Fourth ventricle

9. The “sunburst” of the cerebral sulci is a sonographic finding of:
a. DWM
b. Agenesis of the corpus callosum
c. Colpocephaly
d. Hydranencephaly

10. Enlargement of the frontal horns and narrowing of the occipital horns is termed:
    a. Holoprosencephaly
    b. DWM
    c. Colpocephaly
    d. Apert syndrome

11. The interthalamic adhesion (massa intermedia) passes through the:
    a. Third ventricle
    b. Fourth ventricle
    c. Cisterna magna
    d. CSP

12. The most severe form of holoprosencephaly is:
    a. Lobar
    b. Alobar
    c. Semilobar
    d. Lobular

13. Which of the following is a genetic disorder that includes craniosynostosis, midline facial hypoplasia, and syndactyly?
    a. Lobar holoprosencephaly
    b. Beckwith–Wiedemann syndrome
    c. Arnold–Chiari II malformation
    d. Apert syndrome

14. The third ventricle is located:
    a. Anterior to the thalamus
    b. Anterior to the cerebellar vermis
    c. Between the two lobes of the thalamus
    d. Superior to the corpus callosum

15. What chromosomal aberration is most often associated with holoprosencephaly?
    a. Anophthalmia
    b. Trisomy 21
    c. Trisomy 13
    d. Trisomy 18

16. Dangling choroid sign is associated with:
    a. Ventriculomegaly
    b. Hydranencaphaly

c. Lissencephaly
d. Meckel–Gruber syndrome

17. The third ventricle communicates with the fourth ventricle at the:
    a. Foramen of Magendie
    b. Foramen of Luschka
    c. Foramen of Monro
    d. Aqueduct of Sylvius

18. The fourth ventricle is located:
    a. Posterior to the CSP
    b. Between the frontal horns of the lateral ventricles
    c. Anterior to the cerebellar vermis
    d. Medial to the third ventricle

19. The structure located between the two lobes of the cerebellum is the:
    a. Cerebellar vermis
    b. Cerebellar tonsils
    c. Falx cerebri
    d. Corpus callosum

20. A normal shaped skull is termed:
    a. Dolichocephaly
    b. Brachycephaly
    c. Mesocephaly
    d. Scaphocephaly

21. The most accurate measurement for estimating gestational age is:
    a. BPD
    b. HC
    c. Transcerebellar measurement
    d. Lateral ventricle

22. The cisterna magna should not exceed ____ in the transcerebellar plane.
    a. 4 mm
    b. 2 mm
    c. 8 mm
    d. 10 mm

23. A strawberry-shaped skull is commonly associated with:
    a. Trisomy 21
    b. Trisomy 15
    c. Trisomy 18

d. Trisomy 13

24. Which of the following would be the most likely fetal cranial findings with TORCH infections?
    a. Intracranial calcifications
    b. Cerebral atrophy
    c. Porencephaly
    d. Scaphocephaly

25. The band of tissue that allows communication between the right and left cerebral hemispheres is the:
    a. Falx cerebri
    b. Corpus callosum
    c. Cerebellar vermis
    d. CSP

26. A cloverleaf-shaped skull is related to:
    a. Trisomy 18
    b. Meckel–Gruber syndrome
    c. Trisomy 13
    d. Thanatophoric dysplasia

27. A lemon-shaped skull is related to:
    a. Trisomy 2
    b. Arnold–Chiari II malformation
    c. Thanatophoric dysplasia
    d. Beckwith–Wiedemann syndrome

28. All of the following are sonographic features of alobar holoprosencephaly except:
    a. Cyclopia
    b. Monoventricle
    c. Dorsal cyst
    d. Fused thalamus

29. What cerebral abnormality are atypical facial features most commonly associated with?
    a. DWM
    b. Schizencephaly
    c. Lissencephaly
    d. Holoprosencephaly

30. Absence of the skull is:

a. Hydranencephaly
b. Schizencephaly
c. Acrania
d. Ventriculomegaly

31. What fetal suture is located within the frontal bone along the midline of the forehead?
a. Squamosal suture
b. Sagittal suture
c. Lambdoidal suture
d. Metopic suture

32. The most common cause of hydrocephalus in utero is:
a. Cerebral hemorrhage
b. Holoprosencephaly
c. Brain tumors
d. Aqueductal stenosis

33. The sonographic finding of a fluid-filled cranium with absence of cerebral tissue is consistent with:
a. Hydrocephalus
b. Hydranencephaly
c. Holoprosencephaly
d. Schizencephaly

34. The lack of sulci within the fetal cerebrum is a reliable indicator of:
a. Agenesis of the corpus callosum
b. Lissencephaly
c. Schizencephaly
d. Porencephaly

35. A cisterna magna that measure 15 mm and a normal appearing cerebellum is most likely:
a. Arnold–Chiari II malformation
b. Schizencephaly
c. Mega cisterna magna
d. DWM

36. What cerebral malformation is as a result of agenesis or hypoplasia of the cerebellar vermis?
a. Arnold–Chiari II malformation
b. Schizencephaly
c. Mega cisterna magna

d. DWM

37. Which of the following would not be normally located within the midline of the fetal brain?
    a. CSP
    b. Lobes of the thalamus
    c. Third ventricle
    d. Falx cerebri

38. The condition in which the frontal horns are small and the occipital horns are enlarged is referred to as:
    a. Ethmocephaly
    b. Hydrocephalus
    c. Colpocephaly
    d. Encephalitis

39. Following an intracranial hemorrhage, a cyst is noted within the cerebrum that communicates with the lateral ventricle. This is referred to as:
    a. Schizencephaly
    b. Lissencephaly
    c. Holoprosencephaly
    d. Porencephaly

40. Which of the following should not be included in the correct level for an HC measurement?
    a. Falx cerebri
    b. Fourth ventricle
    c. Thalamus
    d. CSP

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25

The Fetal Face and Neck

Introduction

The astounding resolution and clarity provided by modern sonography equipment has afforded us the opportunity to study in detail the structures of the fetal face and neck. The fetal face may be evaluated using sagittal, axial, and coronal scan planes. Three-dimensional sonographic imaging of the face has also made an impact on the sonography profession, providing additional imaging configurations and a better understanding of cleft lip and cleft palate. This chapter discusses several significant facial and neck abnormalities that may be discovered during a sonographic examination.

Key Terms

amniotic band syndrome—group of abnormalities associated with the entrapment of fetal parts in the amnion, often resulting in fetal amputations or clefting

aneuploidy—a condition of having an abnormal number of chromosomes

anophthalmia—absence of the eye(s)

Beckwith–Wiedemann syndrome—a growth disorder syndrome synonymous with enlargement of several organs, including the skull, tongue, and liver

binocular diameter—measurement from the lateral margin of one orbit to the lateral margin of the other orbit

branchial cleft cyst—benign congenital neck cysts found most often near

the angle of the mandible

cebocephaly—close-set eyes (hypotelorism) and a nose with a single nostril

cleft lip—the abnormal division in the lip

cleft palate—the abnormal development of the soft and/or hard palate of the mouth where there is a division in palate

cyclopia—fusion of the orbits

cystic hygroma—a mass, typically found in the neck region, that is the result of an abnormal accumulation of lymphatic fluid within the soft tissue

edema—abnormal swelling of a structure as a result of a fluid collection

epignathus—an oral teratoma

ethmocephaly—a condition in which there is no nose and a proboscis separating two close-set orbits; associated with holoprosencephaly

fetal goiter—diffuse enlargement of the fetal thyroid gland

fetal hydrops—an abnormal accumulation of fluid in at least two fetal body cavities

holoprosencephaly—a group of brain abnormalities consisting of varying degrees of fusion of the lateral ventricles, absence of the midline structures, and associated facial anomalies

hypertelorism—increased distance between the orbits; widely spaced orbits

hypotelorism—reduced distance between the orbits

interocular diameter—the length between the orbits; measured from the medial margin of one orbit to the medial margin of the other orbit

macroglossia—an unusual protuberance of the tongue

micrognathia—a small mandible and recessed chin

microphthalmia—a decrease in the size of the eye

microtia—small ear(s)

nuchal—the posterior part or nape of the neck

nuchal fold—a collection of solid tissue on the posterior aspect of the fetal neck

nuchal fold thickness—a measurement taken in the second trimester of the skin on the posterior aspect of the fetal neck

nuchal translucency—the anechoic space along the posterior aspect of the fetal neck

ocular diameter—the measurement from the lateral margin of the orbit to the medial margin of the same orbit

teratoma—a tumor that typically consists of several germ cell layers

thyroglossal duct cyst—benign congenital cysts located within the midline

of the neck superior to the thyroid gland and near the hyoid bone

Turner syndrome—a chromosomal aberration where one sex chromosome is absent; may also be referred to as monosomy X

FETAL FACIAL ABNORMALITIES

Holoprosencephaly and Fetal Facial Abnormalities

Whenever any form of holoprosencephaly is suspected, a thorough facial evaluation should be performed to assess for the associated facial abnormalities that often accompany this unfortunate brain malformation. Among the list of facial abnormalities that have been linked with holoprosencephaly are hypotelorism, cebocephaly, ethmocephaly, cyclopia, and cleft lip with or without cleft palate. These abnormalities are further discussed in this chapter, and several are demonstrated in Figure 25-1.



SOUND OFF

Whenever any form of holoprosencephaly is suspected, a thorough facial evaluation should be performed to assess for the associated facial abnormalities that often accompany this unfortunate brain malformation.

Fetal Orbital Abnormalities

There are three measurements that can be obtained in the transverse plane of the fetal face at the level of the eyes (Fig. 25-2). The ocular diameter is a measurement that is obtained from the lateral wall of the orbit to the medial wall of the same orbit. This measurement should only be slightly smaller than the interocular diameter, which is the length between the orbits. The binocular diameter can also be obtained at the same level, and it includes both of the orbits. The binocular diameter is made from the lateral margin of one orbit to the lateral margin of the other orbit.

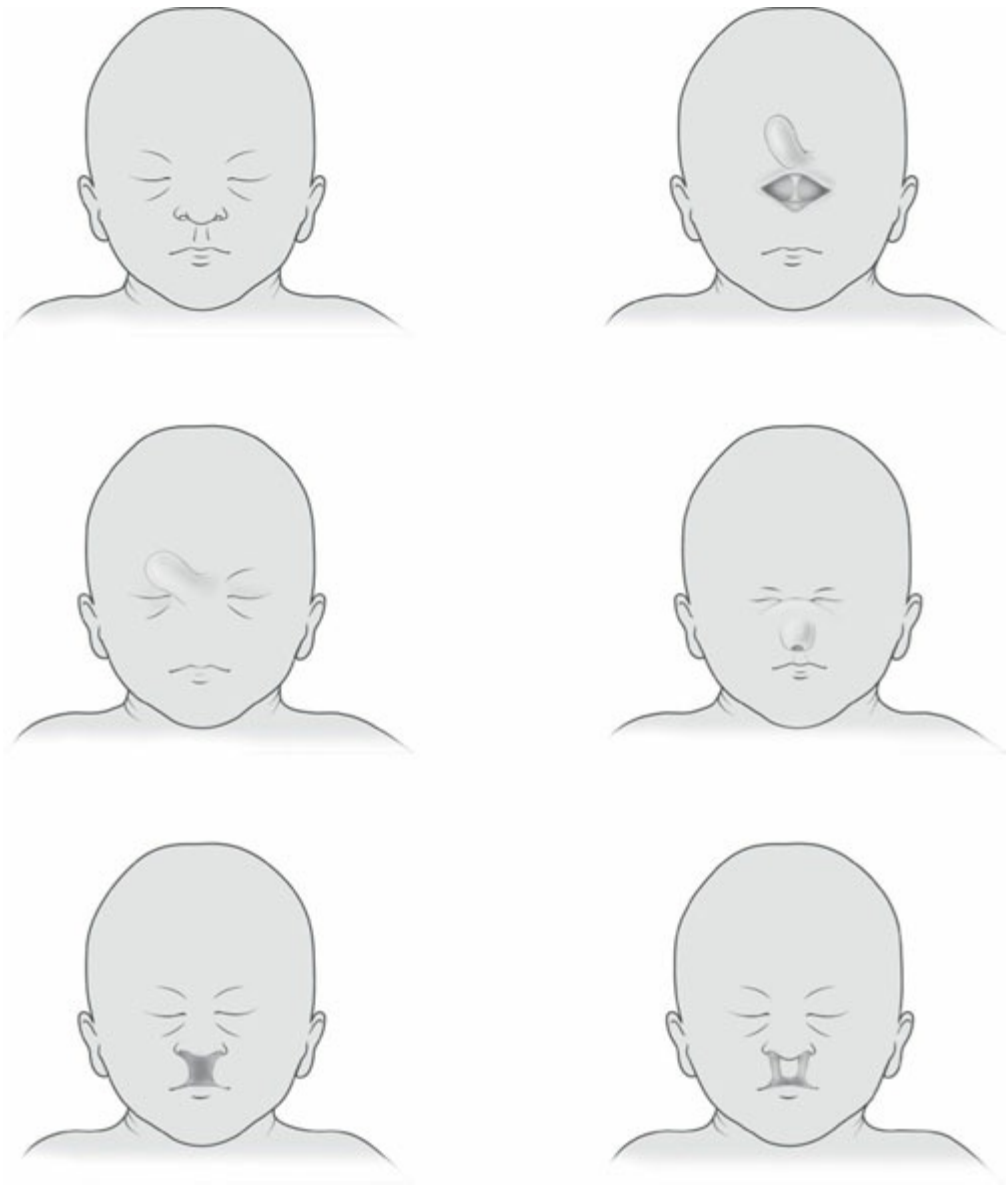


Figure 25-1 Faces of holoprosencephaly. From the top, left to right. Normal, cyclopia, ethmocephaly, cebocephaly, median cleft lip and palate, and bilateral cleft lip and cleft palate.

Microphthalmia is a decrease in the size of the eye. Anophthalmia is the absence of the eye(s). It results from the failure of the optic vesicle to form and has been linked with multiple abnormalities and chromosomal aberrations, including trisomy 13 and trisomy 18. An increased distance between the orbits is referred to as hypertelorism, a disorder more accurately diagnosed utilizing the interocular diameter (Fig. 25-3). An anterior cephalocele, which displaces the orbits laterally, has been cited as the most common cause of hypertelorism. Hypertelorism is also associated with craniosynostosis and many chromosomal abnormalities.

A reduction in the distance between the orbits is referred to as hypotelorism (Fig. 25-4). The most common cause of hypotelorism has been cited to be holoprosencephaly, with trisomy 13 being the most frequently

associated chromosomal abnormality.

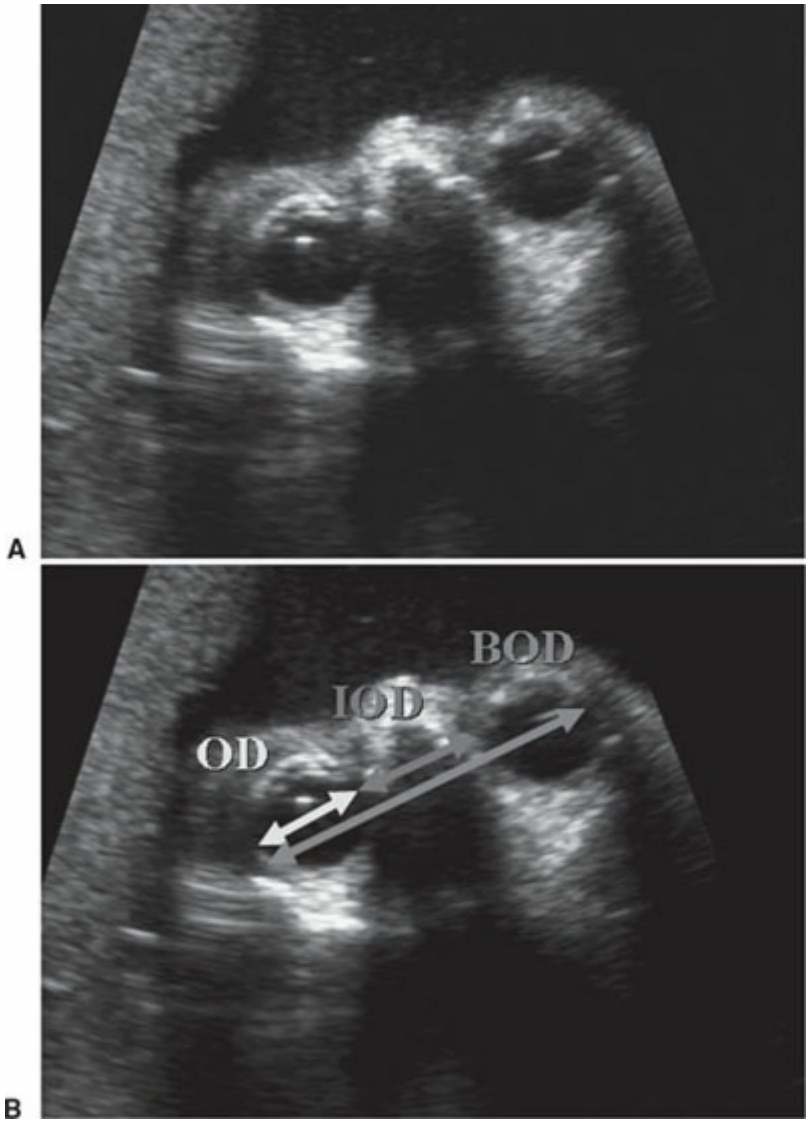


Figure 25-2 Normal orbits. **A.** Transverse view showing normal orbits. **B.** Normal orbital measurements of the ocular diameter (*OD*), interocular diameter (*IOD*), and binocular diameter (*BOD*).



Figure 25-3 Hypertelorism. Coronal image of the fetal face showing hypertelorism. (Image reprinted with permission from Nyberg D, McGaham J, Pretorius D, et al. Diagnostic Imaging of Fetal Anomalies. Philadelphia: Lippincott Williams & Wilkins, 2003:343.)

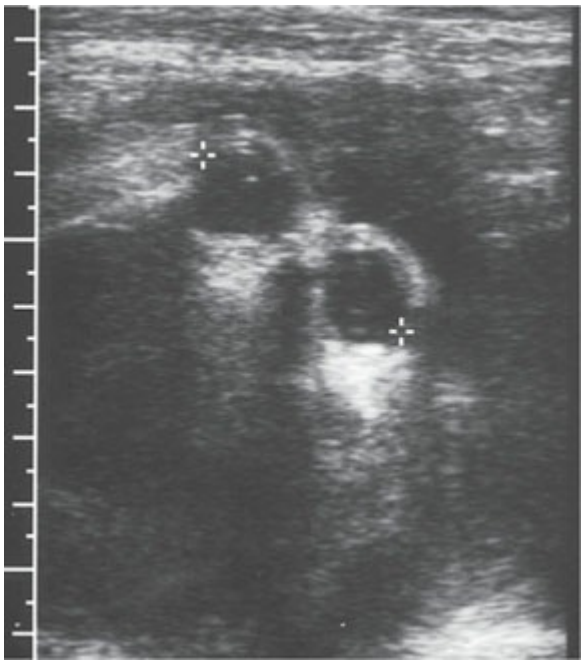


Figure 25-4 Hypotelorism. Transverse view showing hypotelorism.

SOUND OFF

An anterior cephalocele, which displaces the orbits laterally, has been cited as the most common cause of hypertelorism. Holoprosencehaly has been cited as the most common cause of hypotelorism.

Fetal Nasal Bone and Ears

As described in Chapter 23, the fetal nasal bone can be analyzed with sonography. There is a notable link between the absence of the fetal nasal bone and Down syndrome. The nasal bone can also be measured for signs of hypoplasia. For this reason, some institutions incorporate nasal bone imaging as part of the fetal screening protocol.

The ears can be easily imaged with sonography, and measurements can be taken as well. Anomalies of the ears, including low-set ears, have been noted with trisomies 13, 18, and 21. Small ears, referred to as microtia, have a strong link with Down syndrome (trisomy 21). In addition, abnormally shaped ears may be a sign of a more worrisome underlying conditions or syndromes.

Fetal Mouth, Lip, and Mandible

The fetal lip typically closes between 7 and 8 weeks, whereas the palate closes by 12 weeks. An abnormal closure or incomplete closure of lip and palate results in cleft lip and cleft palate, respectively. These two abnormalities may exist together or as isolated findings. Cleft lip and cleft palate are among the most common congenital abnormalities and have been associated with many syndromes and congenital anomalies, such as holoprosencephaly, trisomy 13, and amniotic band syndrome, although most of the cases are not associated with any other abnormalities. Cleft lip can be unilateral, bilateral, or midline in location (Figs. 25-5 and 25-6). Three-dimensional sonography (3-D) can be used to confirm the diagnosis of facial clefts (Fig. 25-7). Isolated cleft palate is more difficult to diagnose sonographically and may be missed altogether. Nonetheless, coronal and axial imaging of the face have been shown exceedingly effective in discovering these defects.

Macroglossia is defined as an unusual protuberance of the tongue. It is most commonly associated with Beckwith–Wiedemann syndrome and Down syndrome (Fig. 25-8). Macroglossia can be difficult to differentiate from epignathus, which is a mostly solid-appearing oral teratoma. Teratomas most often contain complex tissue, whereas the enlarged tongue of macroglossia is completely solid.



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Macroglossia is defined as an unusual protuberance of the tongue. It is most commonly associated with Beckwith–Wiedemann syndrome and Down syndrome.

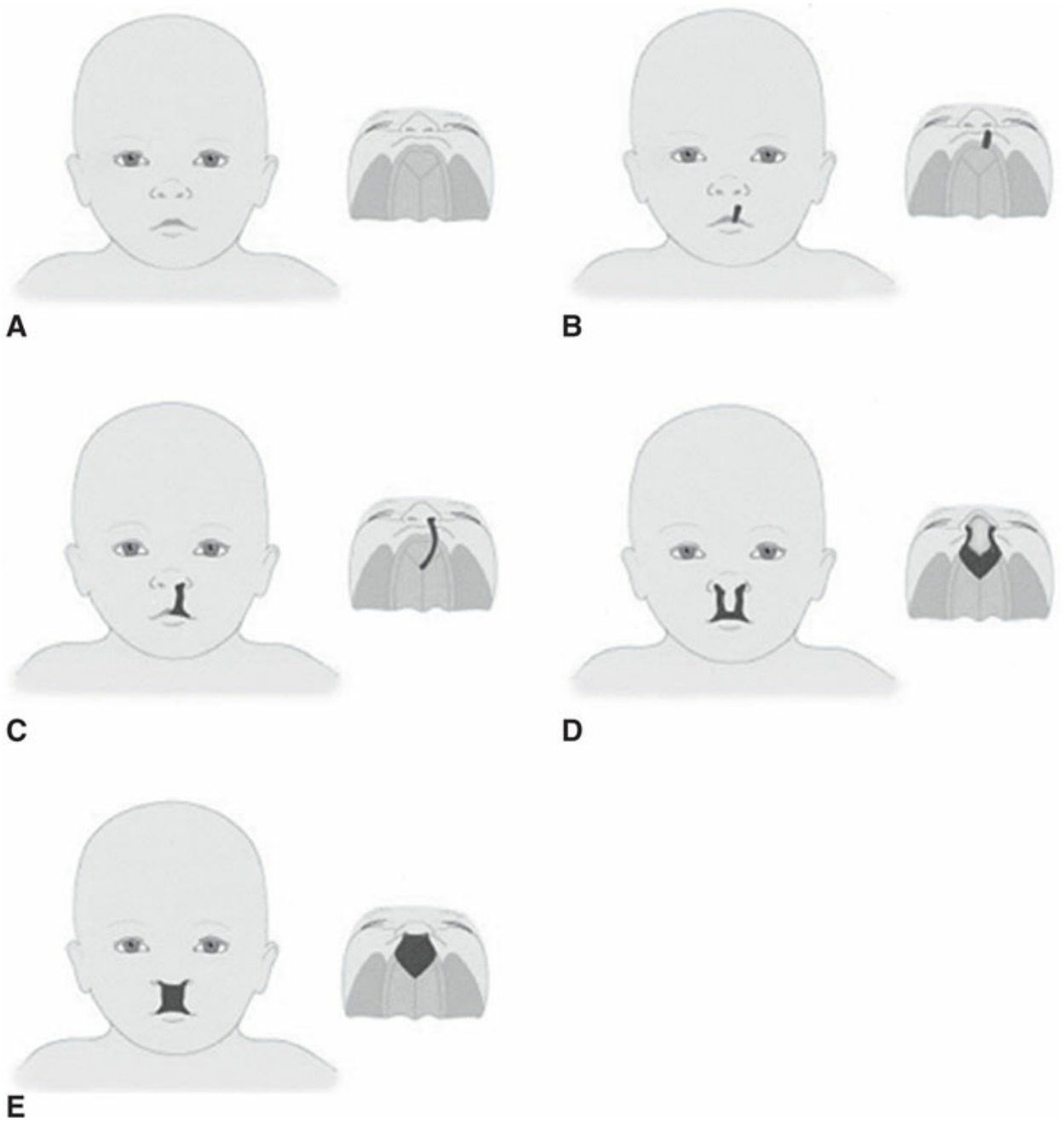


Figure 25-5 Classification of common types of facial clefts. **A.** Normal. **B.** Unilateral cleft lip. **C.** Unilateral cleft lip and palate. **D.** Bilateral cleft lip and cleft palate. **E.** Median cleft lip and cleft palate.

An additional abnormal presentation of the facial bones takes place in the mandible. Micrognathia, a small mandible and recessed chin, is associated with trisomy 13 and trisomy 18 and has been found in several other syndromes and chromosomal aberrations. Micrognathia is best visualized in the sagittal view of the fetal face (Fig. 25-9).

FETAL NECK ABNORMALITIES

Cystic Hygroma

A cystic hygroma results in an abnormal accumulation of lymphatic fluid within the soft tissue. The most common location of a cystic hygroma is within the neck, although it may be found within the axilla. Although they are often related, a cystic hygroma should not be confused with increased nuchal translucency, as discussed in Chapter 23, or nuchal fold thickening, discussed in the next section of this chapter. The sonographic appearance of a cystic hygroma is that of a cystic neck mass divided in the midline by a thick fibrous band of tissue (Fig. 25-10). The mass may contain smaller cystic areas with internal septations. Cystic hygromas have been found in many syndromes and chromosomal abnormalities, such as Turner syndrome, fetal hydrops, aneuploidy, trisomy 21, trisomy 18, and trisomy 13.

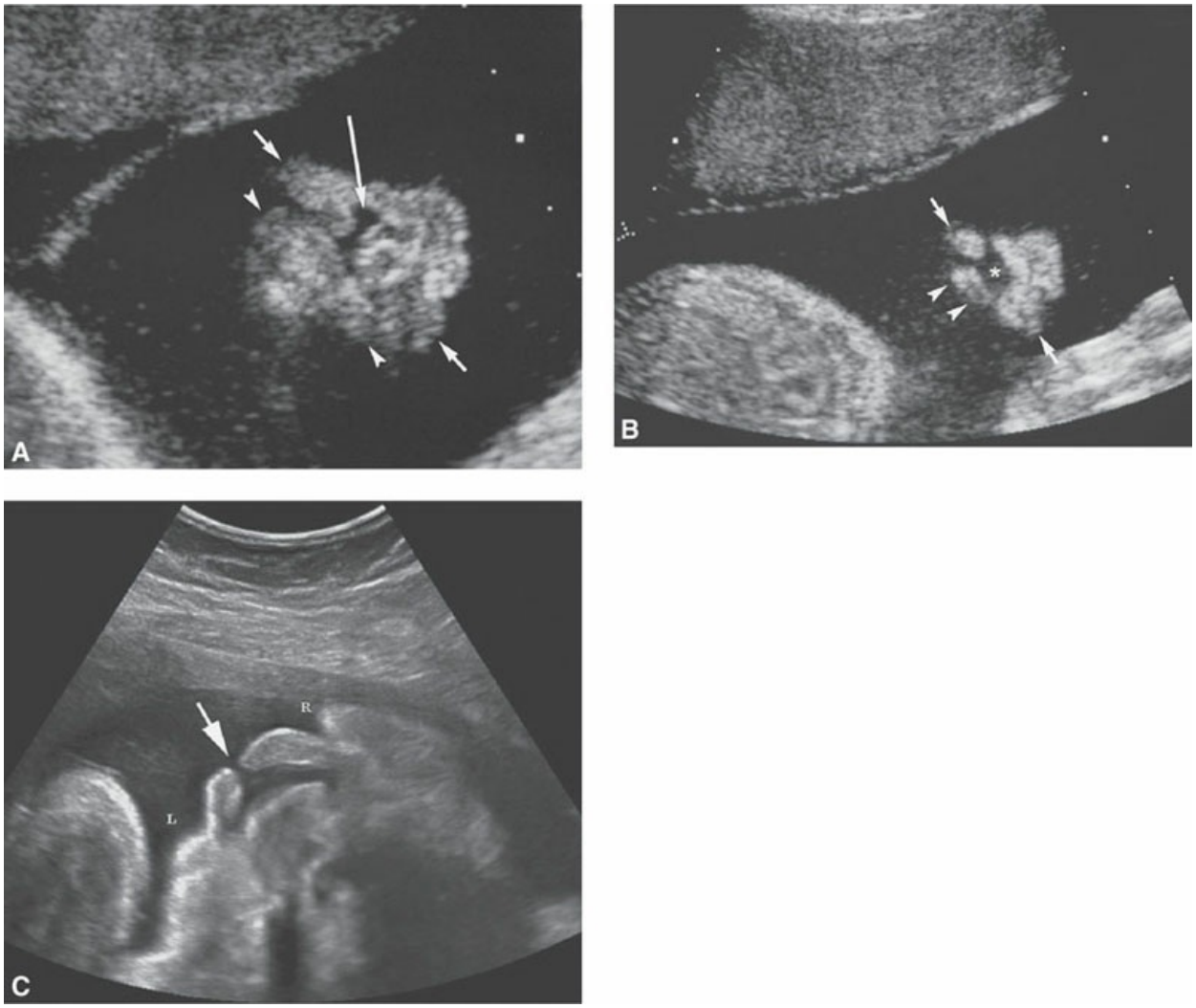


Figure 25-6 Cleft lip. **A.** Coronal image of lower face demonstrating large unilateral defect (*long arrow*) in the upper lip (*short arrows*) extending into the ipsilateral nostril. The lower lip (*arrowheads*) is seen inferior to the cleft. **B.** Coronal image of the same fetus slightly more anterior demonstrating large fluid-filled cleft (*) in the upper lip (*arrows*) above the lower lip (*arrowheads*). **C.** Axial image of the upper lip showing defect (*arrow*) on the left. L, left; R, right.

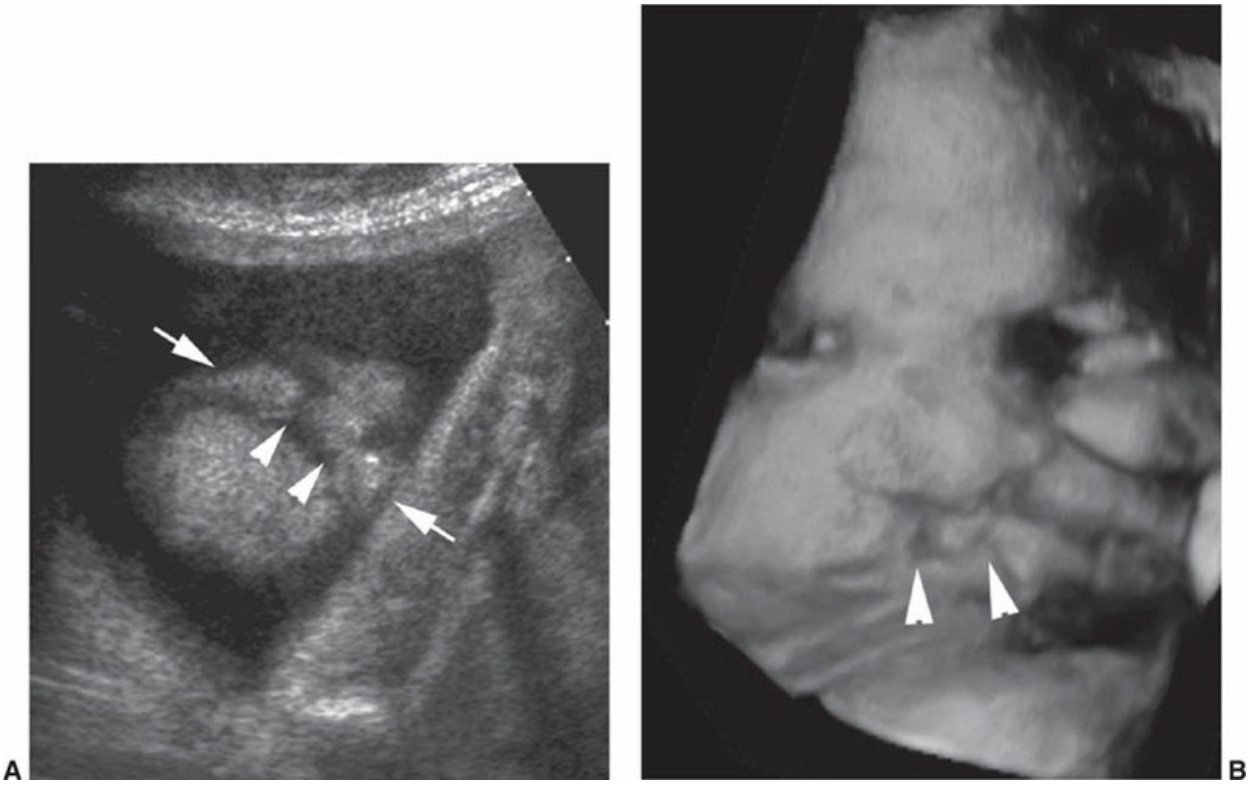


Figure 25-7 Bilateral cleft lip. **A.** Bilateral cleft lip (*arrowheads*) is noted in this image of the upper lip (*between arrows*). **B.** Image of three dimensional of the same fetus demonstrating the clefts (*arrowheads*).

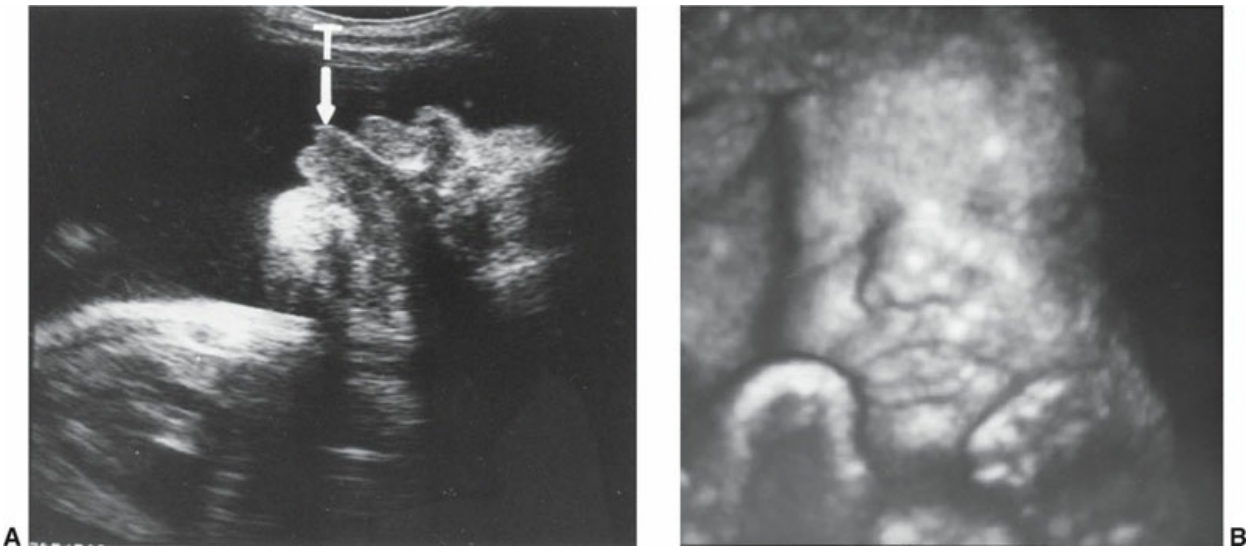


Figure 25-8 Macroglossia. **A.** Profile image of the fetal tongue (*arrow*) protruding from the mouth in a fetus with Beckwith–Wiedemann syndrome. **B.** Three-dimensional image of macroglossia.

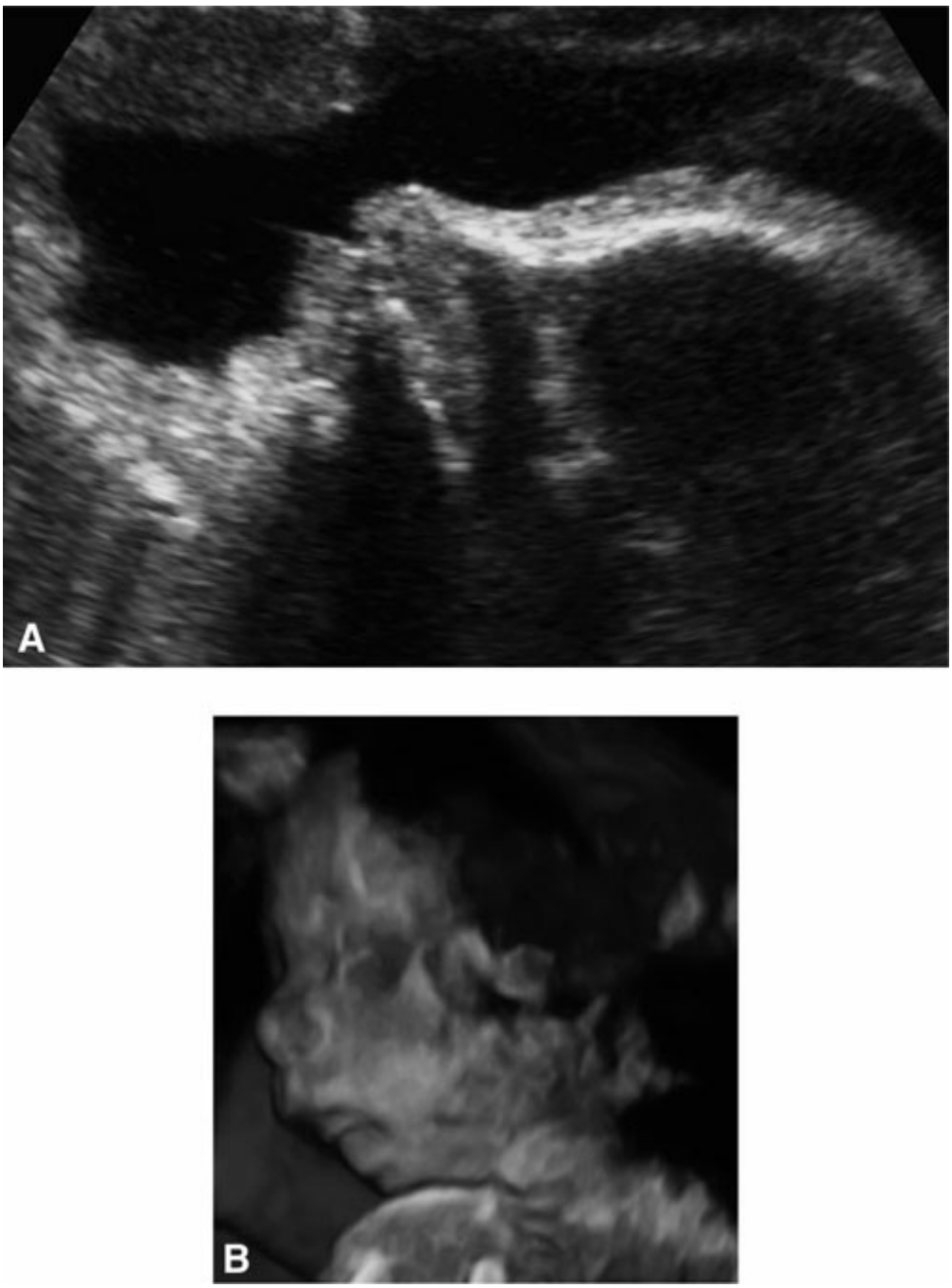


Figure 25-9 Micrognathia. **A.** Profile image of a fetus with a recessed chin, termed micrognathia. **B.** Three-dimensional image of a fetus with micrognathia.



Figure 25-10 Transverse image of the fetal neck revealing a large, septated cystic mass. This is a large cystic hygroma, and the fetus was diagnosed with Turner syndrome.

SONOGRAPHIC FINDINGS OF A CYSTIC HYGROMA

1. Cystic neck mass divided in the midline by a thick fibrous band of tissue
2. The mass may contain smaller cystic areas with internal septations

SOUND OFF

The sonographic appearance of a cystic hygroma is that of a cystic neck mass divided in the midline by a thick fibrous band of tissue.

Nuchal Fold Measurement and Nuchal Translucency Measurement

Regardless of the gestational age, the fetal neck should be analyzed for abnormalities. Nuchal thickening, edema, or redundant skin in the back of the neck is a common finding during the second trimester in fetuses with Down syndrome. The posterior neck can be evaluated and measured starting in the axial plane at the level of the cavum septum pellucidum and angling coronally to include the cerebellum and occipital bone (Fig. 25-11). The calipers are placed from the outer edge of the occipital bone to the outer edge of the skin. A measurement of 6 mm or larger is considered abnormal. Nuchal fold thickness measurements are taken later in gestation compared to nuchal translucency measurements. Although protocols may vary, the nuchal fold is typically measured anywhere between 15 and 21 weeks, whereas the nuchal translucency measurement can be taken earlier and is most accurately measured between 11 and 13 weeks 6 days (Fig. 25-12). Nuchal translucency

is discussed in Chapter 23. It is important to note that nuchal thickening may completely resolve as the pregnancy progresses.



Figure 25-11 Abnormal nuchal fold. Image demonstrating a thickened nuchal fold (*between calipers*) measuring 9.1 mm.

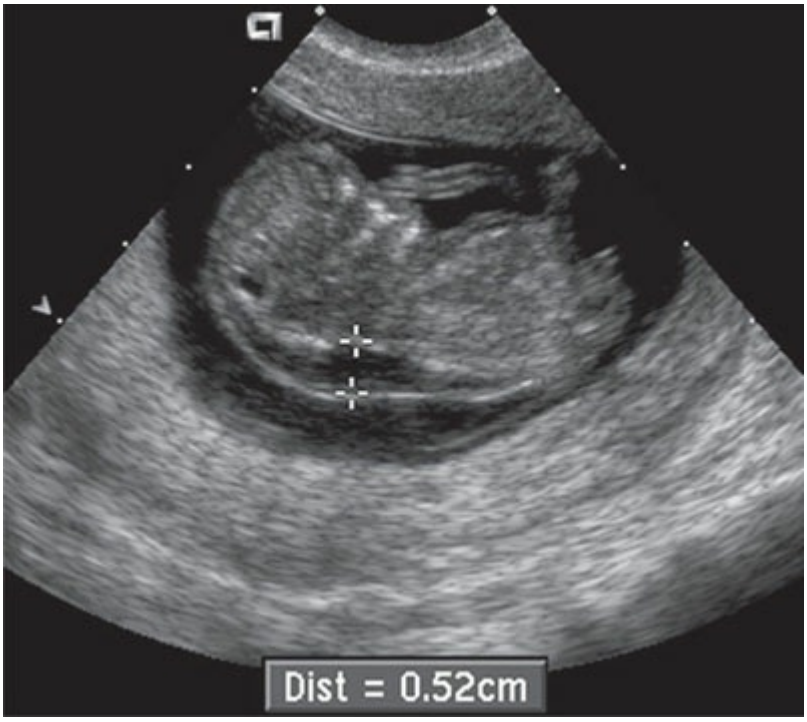


Figure 25-12 Thickened nuchal translucency. This abnormal nuchal translucency measured 5.2 mm.

SOUND OFF
A nuchal fold measurement of 6 mm or larger is considered abnormal.

Fetal Goiter and Other Neck Masses

A fetal goiter can be the cause of overtreatment of maternal Grave disease, iodine deficiency, or hypothyroidism. Sonographically, a fetal goiter will appear as an anterior fetal neck mass. Other possible solid or complex-appearing neck masses include the lymphangioma, hemangioma, cervical teratoma, branchial cleft cyst, or thyroglossal duct cyst. Fetal neck masses can cause compression of the trachea or esophagus and should be noted during a sonographic examination because complication at birth could ensue. Furthermore, fetal swallowing may be inhibited by a neck or oral mass, thus resulting in polyhydramnios.

REVIEW QUESTIONS

1. The isolated enlargement of the fetal thyroid is referred to as:
   a. Fetal goiter
   b. Cystic hygroma
   c. Lymphangioma
   d. Cervical teratoma

2. The absence of the eyes is termed:
   a. Agyria
   b. Epignathus
   c. Hypotelorism
   d. Anophthalmia

3. A reduction in the distance between the orbits is referred to as:
   a. Anophthalmia
   b. Micrognathia
   c. Hypertelorism
   d. Hypotelorism

4. An increased nuchal fold is most likely associated with:
   a. Dandy–Walker syndrome

b. Trisomy 21
c. Trisomy 3
d. Nuchal cord

5. The most frequently encountered chromosomal abnormality associated with holoprosencephaly is:
   a. Triploidy
   b. Trisomy 21
   c. Trisomy 18
   d. Trisomy 13

6. What is the term for a smaller than normal ear?
   a. Microphthalmia
   b. Micronatia
   c. Microtia
   d. Micrognathia

7. The fetal lip typically closes by:
   a. 18 weeks
   b. 8 weeks
   c. 13 weeks
   d. 6 weeks

8. The most common cause of hypertelorism is:
   a. Dandy–Walker malformation
   b. Anencephaly
   c. Anterior cephalocele
   d. Holoprosencephaly

9. Macroglossia is most commonly found with:
   a. Anencephaly
   b. Holoprosencephaly
   c. Beckwith–Wiedemann syndrome
   d. Cystic hygroma

10. An oral teratoma is referred to as:
    a. Macroglossia
    b. Epignathus
    c. Micrognathia
    d. Ethmocephaly

11. There is a definite link between microtia and what syndrome?
    a. Rays syndrome

b. VACTERL syndrome
c. Down syndrome
d. Fitz-Hugh–Curtis syndrome

12. Which of the following would be most difficult to detect sonographically?
a. Cleft lip and cleft palate
b. Isolated cleft lip
c. Isolated cleft palate
d. Isolated median cleft

13. An increase distance between the orbits is referred to as:
a. Hypotelorism
b. Hypertelorism
c. Anophthalmia
d. Micrognathia

14. The optimal scan plane to visualize micrognathia is:
a. Transverse
b. Axial
c. Sagittal
d. Coronal

15. A cystic hygroma is the result of:
a. Alcohol consumption in the first trimester
b. An abnormal development of the roof of the fourth ventricle
c. Occlusion of the internal carotid arteries
d. An abnormal accumulation of lymphatic fluid within the soft tissue

16. Which of following would most likely involve the development of a cystic hygroma?
a. Beckwith–Weidemann syndrome
b. Hydranencephaly
c. Turner syndrome
d. Klinefelter syndrome

17. Which of the following may also be referred to as Turner syndrome?
a. Down syndrome
b. Trisomy 15
c. Trisomy 13
d. Monosomy X

18. Nuchal thickening is most commonly associated with:

a. Patau syndrome
b. Hydranencephaly
c. Down syndrome
d. Cebocephaly

19. Micrognathia is a condition found in:
a. Dandy-Walker complex
b. Hydranencephaly
c. Beckwith–Wiedemann syndrome
d. Trisomy 18

20. The most common location of a cystic hygroma is within the:
a. Axilla
b. Neck
c. Chest
d. Groin

21. An absent or hypoplastic nasal bone is most likely associated with:
a. Trisomy 21
b. Trisomy 15
c. Trisomy 18
d. Turner syndrome

22. An unusual protuberance of the tongue is termed:
a. Epignathus
b. Macrognathia
c. Pharyngoglossia
d. Macroglossia

23. Facial anomalies, when discovered, should prompt the sonographer to analyze the brain closely for signs of:
a. Holoprosencephaly
b. Dandy–Walker malformation
c. Schizencephaly
d. Hydranencephaly

24. The measurement obtained between the lateral walls of the orbits is referred to as the:
a. Interocular diameter
b. Binocular diameter
c. Ocular diameter
d. Biparietal diameter

25. Which of the following is a benign congenital neck cysts found most often near the angle of the mandible?
    a. Epignathus
    b. Branchial cleft cyst
    c. Thyroglossal duct cyst
    d. Fetal goiter

26. A large, mostly cystic mass containing a thick, midline septation is noted in the cervical spine region of a fetus. This most likely represents a(n):
    a. Sacrococcygeal teratoma
    b. Cystic hygroma
    c. Cephalocele
    d. Anophthalmia

27. A group of abnormalities associated with the entrapment of fetal parts and fetal amputations is:
    a. Cystic hygroma
    b. Edwards syndrome
    c. Ethmocephaly
    d. Amniotic band syndrome

28. The growth disorder syndrome synonymous with organ, skull, and tongue enlargement is:
    a. Klinefelter syndrome
    b. Apert syndrome
    c. Meckel–Gruber syndrome
    d. Beckwith–Wiedemann syndrome

29. Which of the following is also referred to as Patau syndrome?
    a. Trisomy 18
    b. Trisomy 21
    c. Trisomy 12
    d. Trisomy 13

30. Close-set eyes and a nose with a single nostril is termed:
    a. Cebocephaly
    b. Cyclopia
    c. Ethmocephaly
    d. Epignathus

31. Which of the following conditions does not affect the orbits?
    a. Cebocephaly
    b. Cyclopia

c. Ethmocephaly
d. Epignathus

32. An abnormal division in the lip is referred to as:
a. Micrognathia
b. Cleft lip
c. Anophthalmia
d. Cebocephaly

33. At what level is the nuchal fold measurement obtained?
a. Cavum septum pellucidum
b. Occipital horns of the lateral ventricle
c. Brain stem
d. Foramen magna

34. Fusion of the orbits is termed:
a. Microglossia
b. Cebocephaly
c. Cyclopia
d. Ethmocephaly

35. Which of the following is also referred to as trisomy 21?
a. Edwards syndrome
b. Patau syndrome
c. Meckel–Gruber syndrome
d. Down syndrome

36. The thickness of the nuchal fold in the second trimester should not exceed:
a. 3 mm
b. 6 mm
c. 10 mm
d. 12 mm

37. A small mandible is termed:
a. Macroglossia
b. Epignathus
c. Micrognathia
d. Ethmocephaly

38. The condition in which there is no nose and a proboscis separating two close-set orbits is:
a. Ethmocephaly

b. Epignathus
c. Micrognathia
d. Cebocephaly

39. All of the following are sonographic features of holoprosencephaly except:
    a. Cystic hygroma
    b. Proboscis with cyclopia
    c. Fused thalamus
    d. Monoventricle

40. The nuchal fold measurement is typically obtained:
    a. Before 12 weeks 6 days
    b. Between 11 weeks and 13 weeks 6 days
    c. Between 15 weeks and 21 weeks
    d. After 24 weeks

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26

The Fetal Spine and Musculoskeletal System

Introduction

This chapter provides a review of both the fetal skeleton and fetal spine. The embryologic development and associated abnormalities of the fetal axial and appendicular skeleton are also discussed.

Key Terms

achondrogenesis—rare, lethal condition resulting in abnormal development of the bones and cartilage

achondroplasia—a disorder that results in abnormal bone growth and dwarfism

acoustic shadowing—an area where sound has been prohibited to propagate resulting in a dark shadow projecting posterior to a structure

alpha-Fetoprotein—a protein produced by the fetal yolk sac, fetal gastrointestinal tract, and the fetal liver; may also be produced by some malignant tumors

amniotic band syndrome—group of abnormalities associated with the entrapment of fetal parts in the amnion, often resulting in fetal amputations or clefting

anencephaly—neural tube defect that is described as the absence of the cranium and cerebral hemispheres

anhydramnios—no amniotic fluid

appendicular skeleton—includes the bones of the upper extremities, lower

extremities, and pelvic girdle

autosomal dominant disorder—a way in which a disorder or trait can be inherited by a fetus; at least one of the parents has to be the carrier of the gene for the disease

axial skeleton—includes the bones of cranium and spine

banana sign—the sonographic sign of the cerebellum being curved in the presence of spina bifida

bilateral renal agenesis—the failure of both kidneys to develop in the fetus

biparietal diameter—a fetal head measurement obtained in the transverse plane at the level of the third ventricle and thalamus; this measurement is obtained from the outer table of the proximal parietal bone to inner table of the distal parietal bone

caudal regression syndrome—syndrome associated with the absence of the sacrum and coccyx; also referred to as sacral agenesis

cephalocele(s)—protrusions of intracranial contents through a defect in the skull

cerebellum—the portion of the brain located in the inferior posterior part of the skull that is responsible for motor output, sensory perception, and equilibrium

closed spina bifida—see key term spina bifida occulta

cloverleaf skull—the abnormal shape of the cranium caused by premature fusion of the sutures in which there is frontal bossing and a cloverleaf shape to the skull

clubfoot—a malformation of the bones of the foot in which the foot is most often inverted and rotated medially, and the metatarsals and toes lie in the same plane as the tibia and fibula

colpocephaly—the abnormal lateral ventricle shape in which there is a small frontal horn and enlarged occipital horn

dwarfism—abnormal short stature

dysplasia—denotes the abnormal development of a structure

encephalocele—protrusion of brain tissue through a defect in the skull

estriol—an estrogenic hormone produced by the placenta

exencephaly—form of acrania in which the entire cerebrum is located outside of the skull

femur length—a sonographic measurement of the femoral diaphysis that provides an estimated gestational age

folate—a vitamin that has been shown to significantly reduce the likelihood of a fetus suffering from a neural tube defect; also referred to as folic acid

frontal bossing—the angling of the frontal bones that produces an unusually prominent forehead

gastroschisis—herniation of abdominal contents through a right-sided, periumbilical abdominal wall defect

germ cell tumor—a type of neoplasm derived from germ cells of the gonads; may also be found outside of the reproductive tract

hemangioma—a benign tumor composed of blood vessels

hemivertebra—the anomaly of the spine in which there is absence of all or part of a vertebral body and posterior element

heterozygous achondroplasia—most common nonlethal skeletal dysplasia that is characterized by rhizomelia

homozygous achondroplasia—the fatal form of achondroplasia

human chorionic gonadotropin—hormone produced by the trophoblastic cells of the early placenta; may also be used as a tumor marker in nongravid patients and males

hydronephrosis—the dilation of the renal collecting system resulting from the obstruction of the flow of urine from the kidney(s) to the bladder; also referred to as pelvocaliectasis or pelvicaliectasis

kyphoscoliosis—the combination of both scoliosis and kyphosis in the fetus

kyphosis—an abnormal posterior curvature of the spine

lemon sign—the sonographic sign associated with a lemon-shaped cranium; most often found in the fetus with spina bifida

limb-body wall complex—a group of disorders with sonographic findings including a short or absent umbilical cord, ventral wall defects, limb defects, craniofacial defects, and scoliosis

lipoma—a benign fatty tumor

maternal serum alpha-fetoprotein—a screening test that detects the amount of alpha-fetoprotein in the maternal blood stream

maternal serum screening—blood screening test that evaluates maternal levels of alpha-fetoprotein, estriol, and human chorionic gonadotropin (as well as other labs) during a pregnancy for neural tube defects and chromosomal abnormalities

meninges—the coverings of the brain and spinal cord

meningocele—herniation of the cranial or spinal meninges because of an open cranial or spinal defect; contains cerebrospinal fluid but no nerve tissue

meningomyelocele—mass that results from open spina bifida that contains the spinal cord and the meninges; also referred to as a myelomeningocele

mermaid syndrome—see key term sirenomelia

myelocele—mass that results from open spina bifida that contains spinal cord only

neural tube—embryologic formation that results from fusion of the two folded ends of the neural plate

oligohydramnios—a lower-than-normal amount of amniotic fluid for the gestational age

omphalocele—an anterior abdominal wall defect where there is herniation of the fetal bowel and other abdominal organs into the base of the umbilical cord

open spina bifida—see key term spina bifida aperta

osteogenesis imperfecta—a group of disorders that result in multiple fractures in utero; caused by decreased mineralization and poor ossification of the bones

polyhydramnios—an excessive amount of amniotic fluid for the gestational age

posterior fossa—posterior portion of the cranium located near the cerebellum and containing the cisterna magna

pregestational diabetes—maternal diabetes that existed before pregnancy; includes both type 1 and 2 diabetes mellitus

radial ray defect—absence or underdevelopment of the radius

rhizomelia—shortening of the proximal segment of a limb

sacral agenesis—the nondevelopment of the sacrum; see key term caudal regression syndrome

sacral dimple—an opening in the skin over the distal spine

scoliosis—an abnormal lateral curvature of the spine

sirenomelia—a fetal abnormality characterized by fusion of the lower extremities, renal agenesis, and oligohydramnios; may also be referred to as mermaid syndrome

spina bifida aperta—most common form of spina bifida; results in open lesions that are typically not covered by skin and a mass that protrudes from the spine; also referred to as open spina bifida

spina bifida occulta—closed spinal lesions that are completely covered by skin and can be difficult to identify sonographically; also referred to as closed spina bifida

spinal dysraphism—a group of neural tube defects that describe some manifestation of incomplete closure of the spine

splay—turned outward

synechiae—adhesions

talipes equinovarus—see key term clubfoot

thanatophoric dysplasia—most common lethal skeletal dysplasia characterized by a cloverleaf skull with frontal bossing and hydrocephalus

trident hand—a wide separation between the middle and ring finger

triple screen—a maternal blood test that typically includes an analysis of human chorionic gonadotropin, alpha-fetoprotein, and estriol

VACTERL association—an acronym for a combination of abnormalities that represent vertebral anomalies, anorectal atresia, cardiac anomalies, tracheoesophageal fistula, renal anomalies, and limb anomalies; may also be referred to as VATER association

EMBRYOLOGY OF THE AXIAL SKELETON

The axial skeleton begins to form between the sixth and eighth menstrual week. It consists of the bones of the cranium and spine. As bones grow and accumulate minerals, they are said to ossify. It is this ossification that allows sonographers to readily visualize these structures as echogenic reflections that produce acoustic shadowing. As the pregnancy progresses, the skull and skeletal bones become more echogenic.

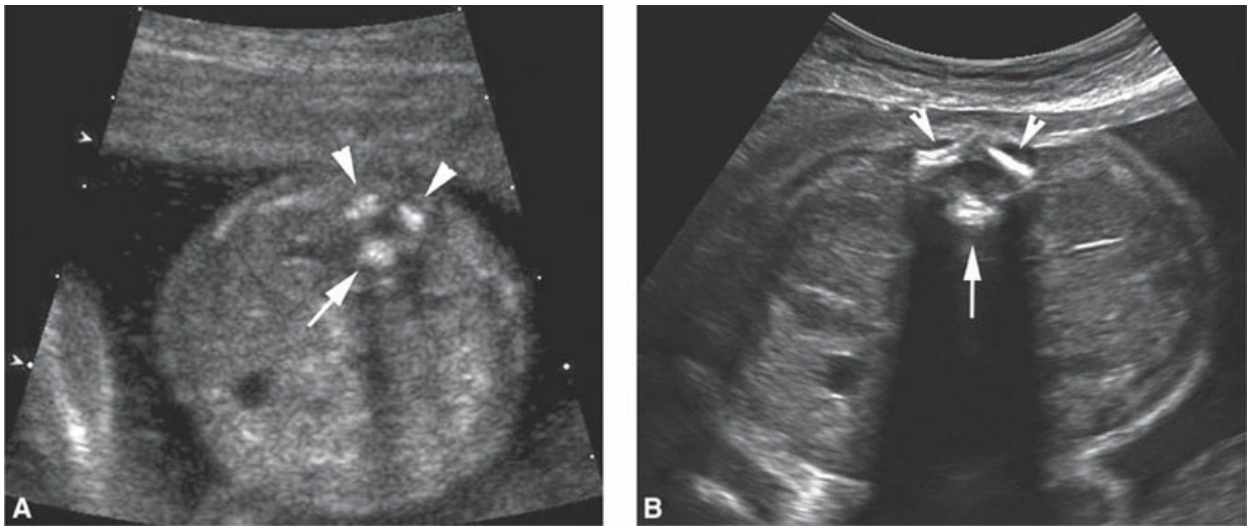


Figure 26-1 Transverse fetal spine. **A.** Transverse fetal spine at 18 weeks demonstrating the three ossification centers: two posterior elements (*arrowheads*) and one anterior element (*arrow*). Skin can be seen clearly covering the spine posteriorly. **B.** Transverse fetal spine at 30 weeks demonstrating more clearly the posterior (*arrowheads*) and anterior (*arrow*) ossification centers.

The spine consists of five sections: cervical, thoracic, lumbar, sacrum, and coccyx. The spine is typically imaged in three scan planes: sagittal, transverse, and coronal (Figs. 26-1 to 26-3). Each fetal vertebra consists of

three echogenic ossification centers: one centrum and two neural processes. The centrum will eventually form the vertebral body, whereas the neural process of each vertebra will become the lamina, pedicle, transverse process, spinous process, and articular process. Between the two laminae and posterior to the centrum, lies the vertebral column, the structure that runs the length of the spine and contains the spinal cord. The echogenic laminae are normally angled inward, whereas with spina bifida, the defective laminae will be angled outward or be said to splay. The spinal cord appears as a hypoechoic linear structure that extends from the base of the cranium to the distal spine.

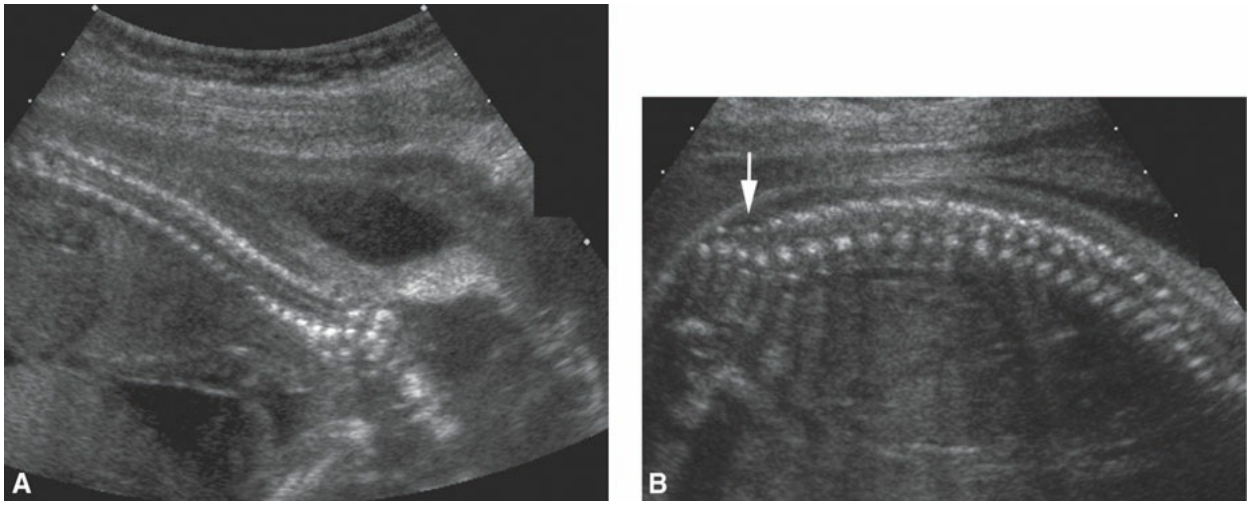


Figure 26-2 Longitudinal fetal spine. **A.** Longitudinal image of the cervical and thoracic spine. **B.** Longitudinal image of the thoracic, lumbar, and sacral spine (*arrow*).

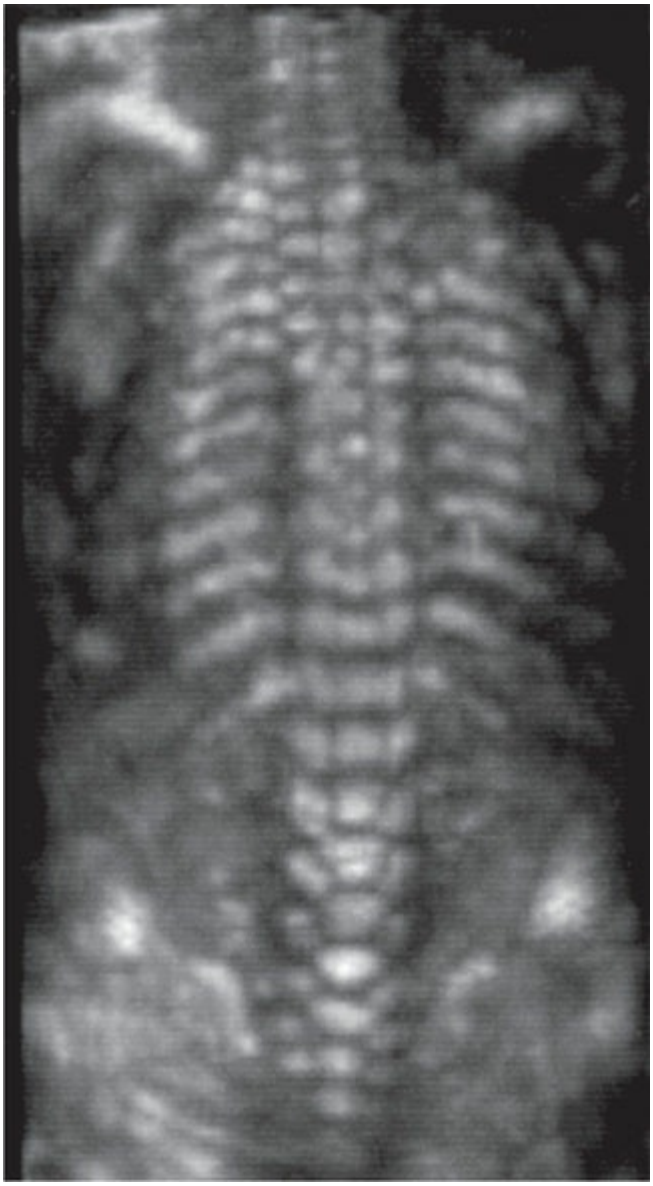


Figure 26-3 Three-dimensional fetal spine. This three-dimensional image revealing the cervical, thoracic, and lumbar spine.

SOUND OFF
Each fetal vertebra consists of three echogenic ossification centers: one centrum and two neural processes.

SPINA BIFIDA, ALPHA-FETOPROTEIN, AND FOLIC ACID SUPPLEMENTS

Among the list of neural tube defects are cephaloceles, anencephaly, and spina bifida. Anencephaly and spina bifida are the most common neural defects, occurring in 1 in every 1,000 pregnancies. Recall, maternal serum screening, also referred to as the triple screen, combines the laboratory values of human chorionic gonadotropin, estriol, and maternal serum alpha-

fetoprotein (MSAFP). The MSAFP component of this test is particularly helpful for detecting neural tube defects. Reportedly, as many as 80% of spina bifida cases can be detected with alpha-fetoprotein (AFP) screening in combination with sonography. AFP is initially produced by the yolk sac, fetal gastrointestinal tract, and the fetal liver, respectively. AFP exits the fetus through an opening in the neural tube if one is present, such as with open spina bifida and anencephaly, thus allowing a greater amount to pass into the maternal circulation. It is important to note that an elevation in AFP does not necessarily mean that spina bifida is present. Elevated MSAFP is also associated with omphalocele, gastroschisis, multiple gestations, and fetal death. Moreover, closed spina bifida is not associated with elevated MSAFP because of the skin covering. Fortunately, studies have shown that a supplement of just 0.4 mg a day of folate (folic acid) in a woman's diet significantly reduces the likelihood of her fetus developing spina bifida and other neural tube defects. In high-risk patients, as much as 4 mg a day may be prescribed.



SOUND OFF

AFP exits the fetus through an opening in the neural tube if one is present, such as with open spina bifida or gastroschisis, thus allowing a greater amount to pass into the maternal circulation.

SPINA BIFIDA

Spina bifida is a neural tube defect that occurs when the embryonic neural tube fails to close. Spina bifida may also be referred to as spinal dysraphism, meningocele, and meningomyelocele (myelomeningocele). There are several ways to classify spina bifida. Essentially, this disorder can be subdivided into two types: spina bifida occulta (hidden) and spina bifida aperta (open) (Table 26-1). Occult lesions are closed lesions, meaning that they are typically covered by skin, and thus can be difficult to identify sonographically in utero. Therefore, with spina bifida occulta, although the vertebrae fail to close, there is no herniation of the spinal contents outside of the spinal column. In the postnatal period, spina bifida occulta is suspected when a sacral dimple, hemangioma, lipoma, or a tuft of hair is identified in the midline of the newborn, directly over the distal spine. Sonography can be highly effective at determining whether the spinal cord is tethered in neonates who present with these clinical findings.

Spina bifida aperta, which is an open lesion, is the most common form of spina bifida and the type more frequently recognized in utero. Open lesions are not covered by skin and will often result in a mass that protrudes beyond

the bony defect, making them more readily identifiable with sonography. If the mass only contains spinal cord, it is referred to as a myelocele. Meningoceles contain meninges only, whereas meningomyeloceles (spina bifida cystic) contain meninges and nerve roots (Fig. 26-4). The most common location of spina bifida is the lumbosacral region, although it can occur anywhere along the spine. It is also important to note that the higher the location of spina bifida, the greater the neurologic impairment.

TABLE 26-1 Type of spinal defect and description

Type of Spinal Defect	Description
Spina bifida occulta	Closed defect Skin surface abnormality noted on postnatal physical examination can be a sacral dimple, tuft of hair, hemangioma, or lipoma
Spina bifida aperta	Typically an open defect May also be referred to as spina bifida cystica Mass is referred to as a meningocele or meningomyelocele (myelomeningocele) depending upon contents



SOUND OFF
The most common location of spina bifida is the lumbosacral region.

Spina bifida is often initially recognized by its associated cranial findings, a group of abnormalities referred to as Arnold–Chiari II malformation. The pressure of a large mass in the distal spine pulling on the spinal cord causes malformations of the cranium and intracranial contents. The frontal bones become flattened and will yield a lemon-shaped cranium (Fig. 26-5). This "lemon sign," often described as scalloping of the frontal bones, presents a distinct finding on sonography.

It is most helpful to analyze the posterior fossa of the cranium for abnormalities when a lemon sign is suspected. The cerebellum will become displaced inferiorly and posteriorly and appear curved in the presence of spina bifida (Fig. 26-6). This is referred to as the "banana sign." As a result of the cerebellum being displaced inferiorly, the cisterna magna is completely obliterated or nonexistent. The lateral ventricles will also be enlarged and distorted in shape. The frontal horns will be small and slitlike, whereas the occipital horns will be enlarged, a condition known as colpocephaly. The sensitivity of these cranial findings at detecting spina

bifida is said to be greater than 99%. It is important to note that the fetus with closed spina bifida will lack these intracranial findings. Arnold–Chiari II malformation has also been discussed in Chapter 24.

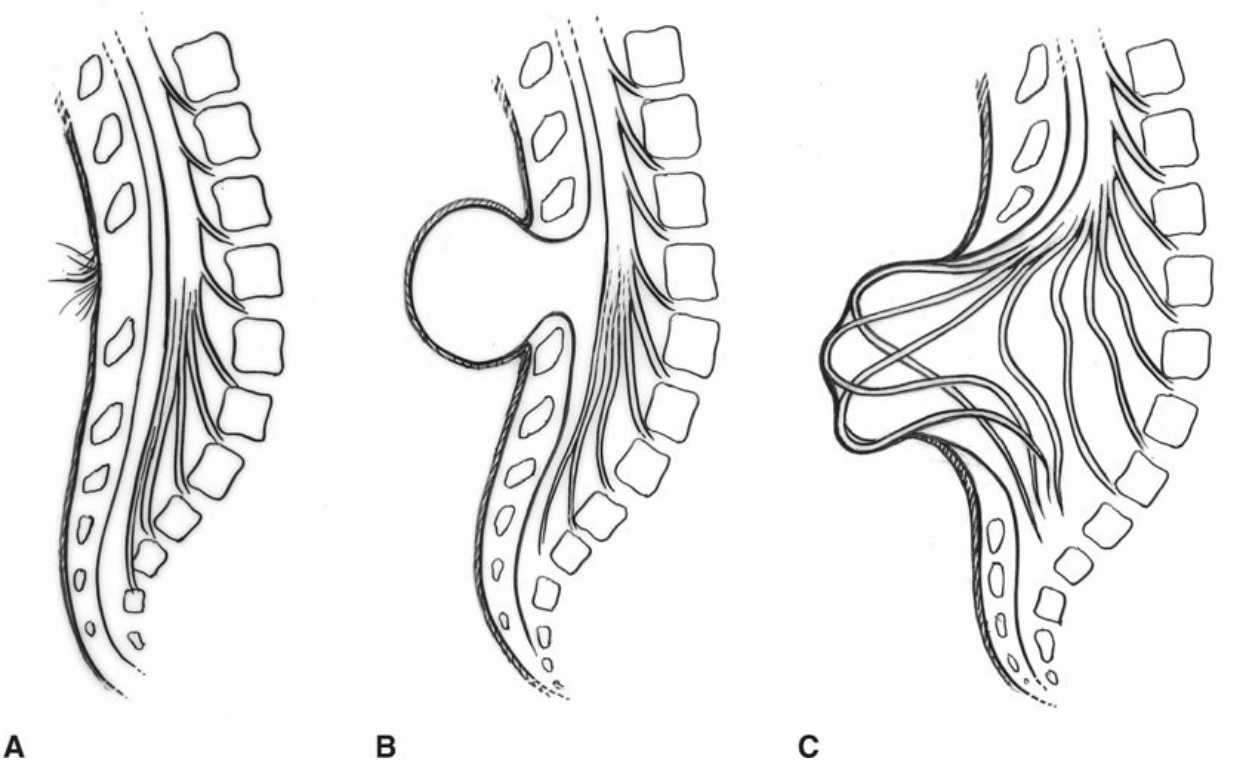


Figure 26-4 Classifications of spina bifida. **A.** Spina bifida occulta is characterized by a defect in one or more vertebrae, but intact skin and no alteration in the spinal cord. **B.** Meningocele is characterized by a protrusion of the meninges and cerebrospinal fluid through the defect in the spine. **C.** Myelomeningocele is characterized by the protrusion of the neural elements as well as the meninges through the spinal defect.

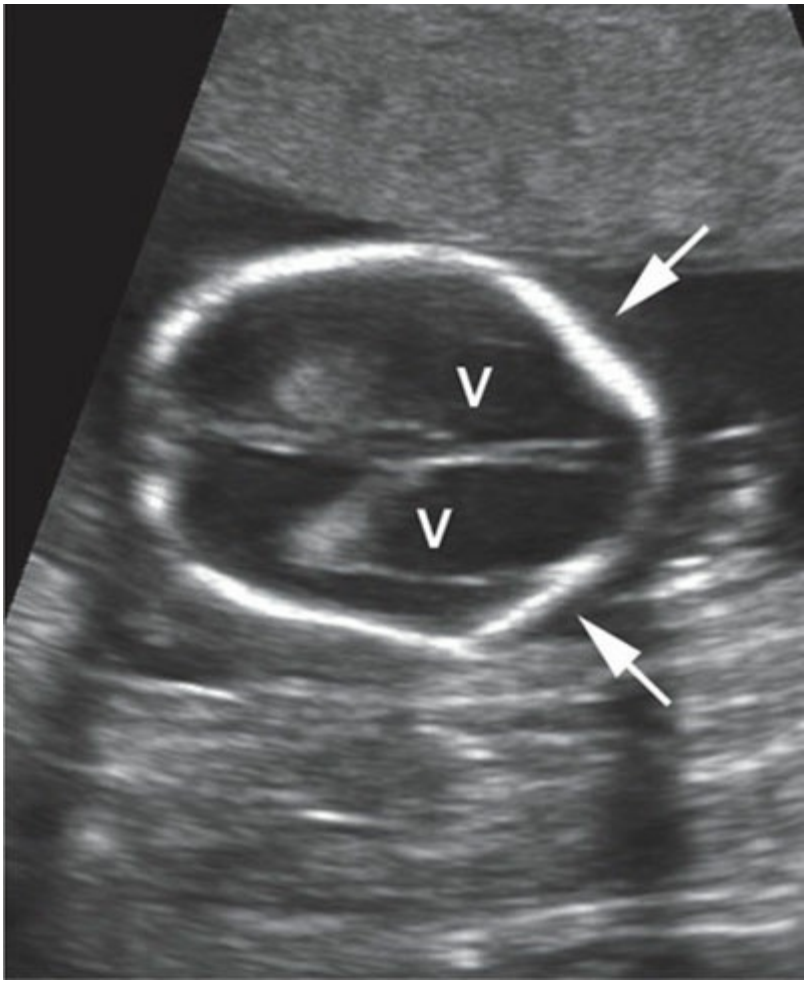


Figure 26-5 Lemon sign. Axial image of the cranium in a fetus with a myelomeningocele demonstrating a concavity in the frontal bones (*arrows*), causing the head to have a lemon shape. This is consistent with Arnold–Chiari II malformation. Ventriculomegaly (*V*) is also noted.

SOUND OFF
Keep in mind that spina bifida is associated with two yellow fruits—the banana and the lemon.

Once cranial findings are suggestive of spina bifida, a thorough analysis of the spine should be performed. In the presence of spina bifida, the posterior ossification elements or laminae will often appear splayed in the transverse plane (Fig. 26-7). A meningocele will appear as a simple cystic mass protruding from the spine, whereas a myelomeningocele tends to appear more complex (Fig. 26-8). One differential diagnosis of these masses is the sacrococcygeal teratoma (SCT) mentioned later in the chapter. However, it is important to note that the fetus with an SCT will most likely have normal skull and intracranial anatomy, whereas the intracranial anatomy of a fetus with open spina bifida is often altered as described above.

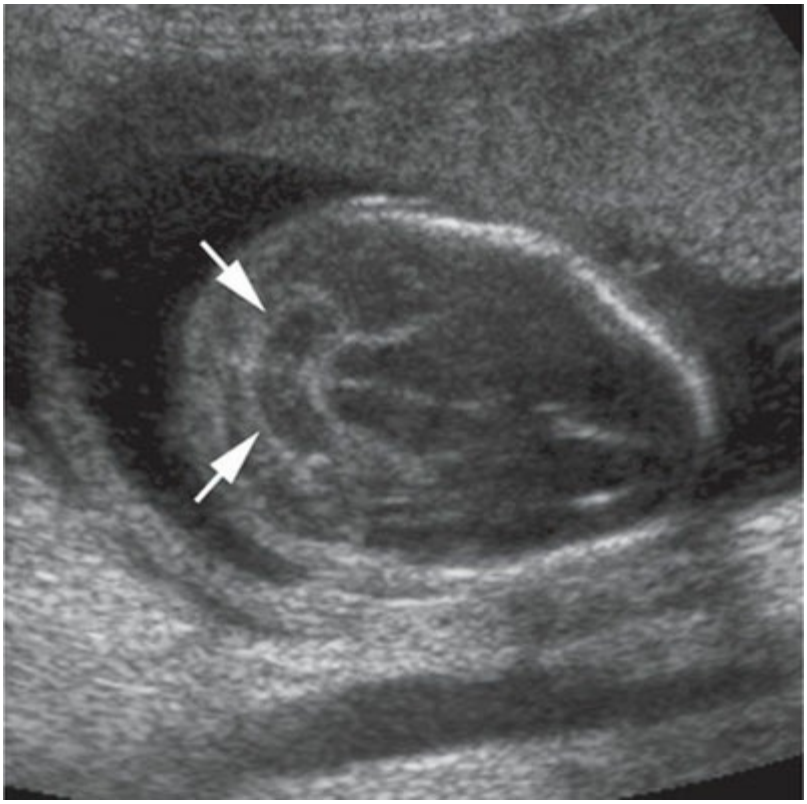


Figure 26-6 Banana sign. Axial image of the posterior fossa revealing a banana-shaped cerebellum (*arrows*) associated with a myelomeningocele. This is consistent with Arnold–Chiari II malformation.

With open spina bifida, the exposure of the delicate spinal nerves to the amniotic fluid during fetal life is thought to be one of the causes of neurologic impairment. Open fetal surgery can be performed on the fetus with spina bifida when a mass is identified on the spine, even as early as 16 weeks. The ultimate goal of this procedure is to prevent, or at least minimize, the neurologic deficits associated with spina bifida. During the operation, the uterus, amniotic sac, and fetus are accessed, and the open defect is surgically repaired. After the spinal repair is made, the fetus is placed back into the uterus for continued growth and maturation. In recent years, fetoscopic surgery has presented some promise as a novel approach to fetal spina bifida repair as well. Ultimately, sonography can aid in the detection of spina bifida, the assessment of the level of the defect, and offer postoperative follow-up examinations after fetal surgery.

CLINICAL FINDINGS OF OPEN SPINA BIFIDA APERTA (OPEN)

1. Elevated MSAFP

SONOGRAPHIC FINDINGS OF SPINA BIFIDA APERTA (OPEN)

1. Splaying of the laminae in the area of the defect

2. Cystic mass (meningocele) or complex mass (myelomeningocele) protruding from the spine
3. Lemon sign—lemon-shaped cranium with flattened frontal bones
4. Banana sign—banana-shaped cerebellum
5. Obliterated cisterna magna
6. Colpocephaly
7. Hydrocephalus

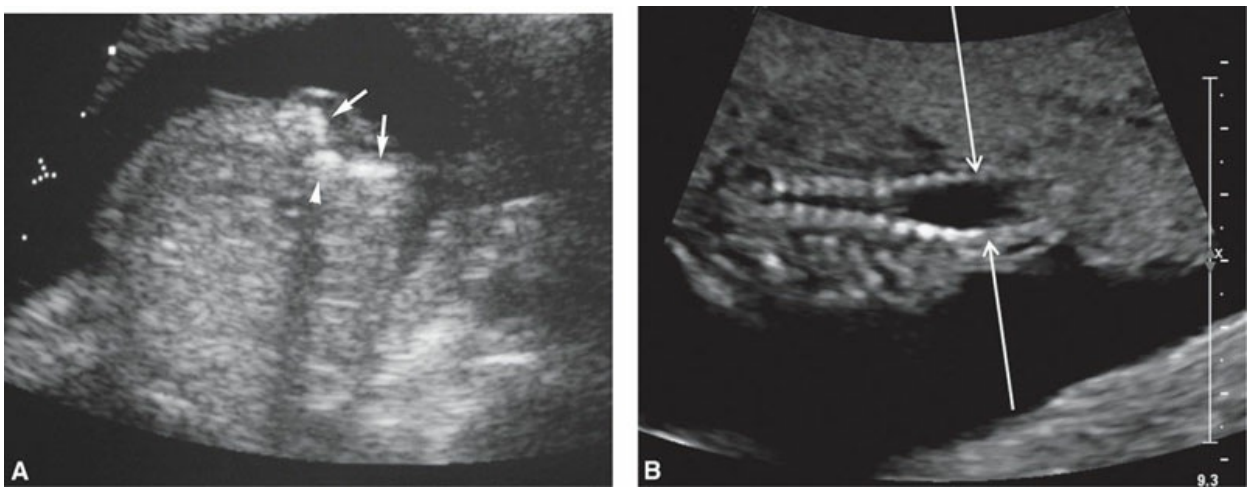


Figure 26-7 Splaying of the posterior ossification centers. **A.** Transverse image of the fetal spine revealing splaying of the two posterior ossification centers (*arrows*). The third ossification (*arrowhead*) represents the vertebral body. **B.** Coronal scan of the fetal lumbosacral spine shows fusiform widening of the spinal canal (*between arrows*).

CLINICAL FINDINGS OF SPINA BIFIDA OCCULTA

1. In utero—normal laboratory values
2. Postnatal—sacral dimple, hemangioma, lipoma, or excessive hair is identified directly over the distal spine

SCOLIOSIS AND KYPHOSIS

Scoliosis is a deformity of the spine in which there is an abnormal lateral curvature. The spine will appear S shaped in the affected region of scoliosis (Fig. 26-9). Scoliosis typically involves the thoracic and upper lumbar spine. Kyphosis is an abnormal posterior curvature of the spine. Both of these abnormalities can exist together, a condition known as kyphoscoliosis. Although these abnormalities may be the only anomaly noted during a fetal sonogram, distortion of the spine can be seen with hemivertebrae, myelomeningoceles, amniotic band syndrome, and limb-body wall complex (LBWC). Scoliosis and kyphosis are also often associated with additional

anomalies in other systems, as seen in VACTERL association.

SONOGRAPHIC APPEARANCE OF SCOLIOSIS

1. Lateral curvature of the spine
2. S-shaped spine

SONOGRAPHIC APPEARANCE OF KYPHOSIS

1. Abnormal posterior curvature of the spine

SOUND OFF

Scoliosis is a deformity of the spine in which there is an abnormal lateral curvature, whereas kyphosis is an abnormal posterior curvature of the spine.

LIMB-BODY WALL COMPLEX

LBWC, also referred to as body stalk anomaly or short umbilical cord syndrome, is a rare group of fetal defects. There are three postulated causes for this fatal condition: vascular occlusion, amnion rupture, or embryonic dysgenesis. The most common sonographic findings of LBWC are a short or absent umbilical cord, ventral wall defects, limb defects, craniofacial defects (exencephaly or encephalocele), and scoliosis. The fetus will appear closely connected with the placenta and will have marked scoliosis (Fig. 26-10). Because of the opening in the ventral wall, elevated levels of MSAFP can be detected in the second trimester. Amniotic band syndrome has very similar sonographic findings and may actually be seen simultaneously with LBWC.

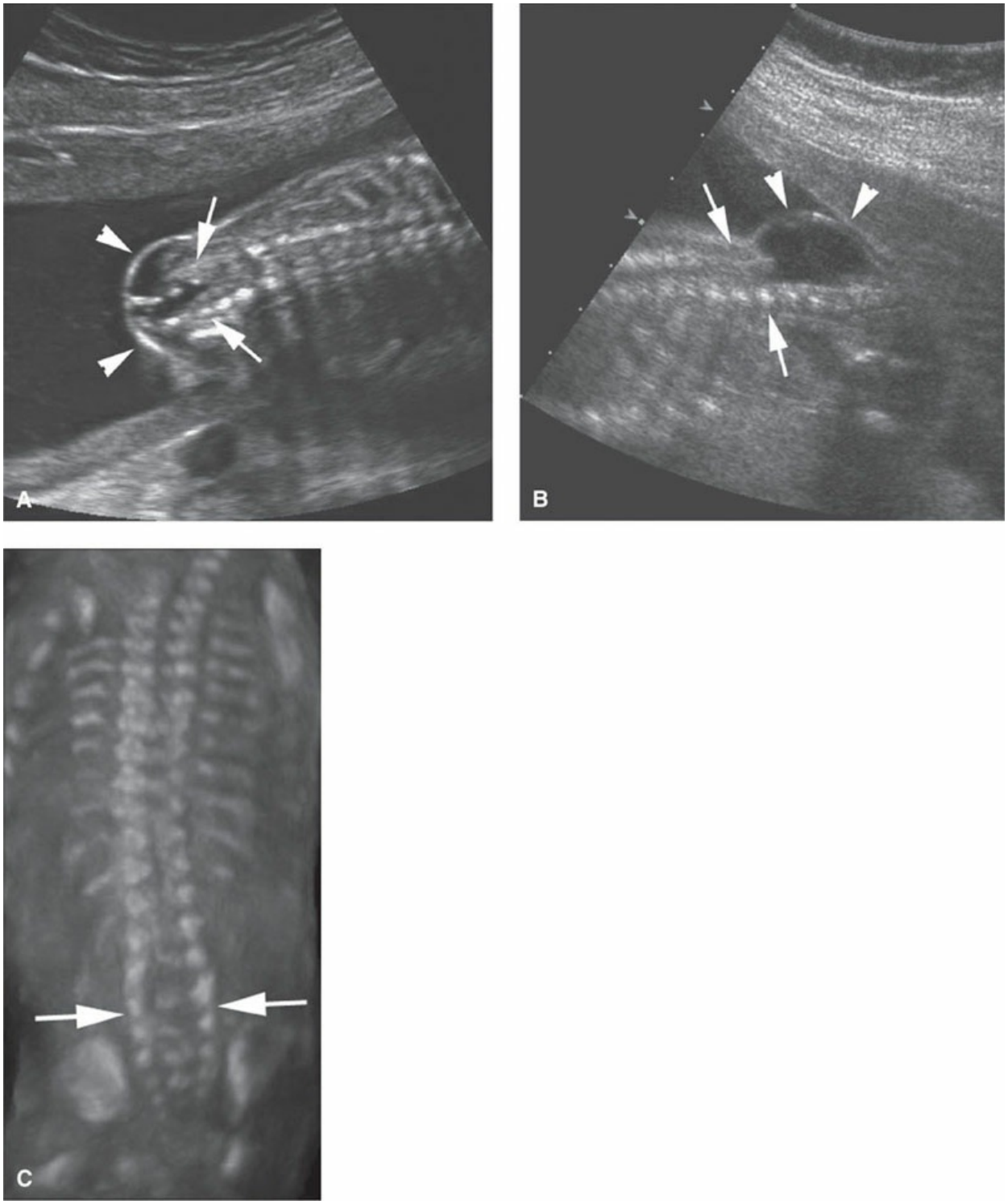


Figure 26-8 Myelomeningocele. **A.** Coronal image of the distal spine (*arrows*) revealing herniation of the spinal cord (*arrowheads*). **B.** A large myelomeningocele (*arrowheads*) is noted protruding from the distal spine (*arrows*) in this image. **C.** Three-dimensional image of the fetal spine demonstrating widening of the distal spine in the area of the defect (*between arrows*).

CLINICAL FINDINGS OF LIMB-BODY WALL COMPLEX

1. Elevated MSAFP

SONOGRAPHIC FINDINGS OF LIMB-BODY WALL COMPLEX

1. Short or absent umbilical cord
2. Marked scoliosis
3. Various other anomalies including craniofacial and limb defects

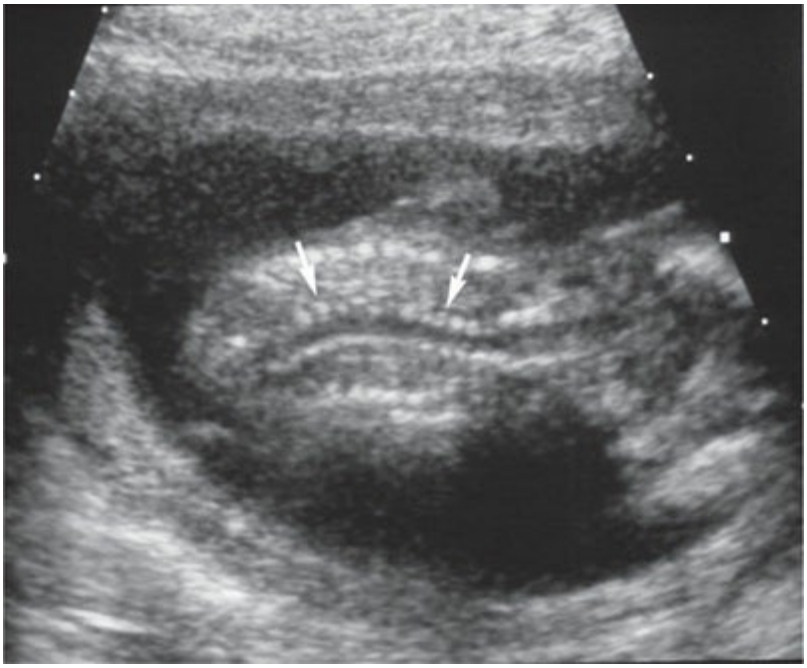


Figure 26-9 Scoliosis. Longitudinal image of the fetal spine (*arrows*) demonstrating scoliosis.



Figure 26-10 Limb-body wall complex (LBWC). This fetus had multiple anomalies including marked scoliosis, neural tube defects, and an anterior abdominal wall defect, and was ultimately diagnosed with LBWC.

SOUND OFF


A common sonographic finding of LBWC is a short or absent umbilical cord.

FETAL SKELETAL ABNORMALITIES

Overview of Skeletal Dysplasia

Dysplasia denotes the abnormal development of a structure. Skeletal dysplasias exist as a large group of abnormalities of the skeletal system. More than 271 skeletal dysplasias have been identified. The four most common skeletal dysplasias are as achondroplasia, achondrogenesis, osteogenesis imperfecta, and thanatophoric dysplasia.

Achondroplasia

Heterozygous achondroplasia is the most common nonlethal skeletal dysplasia. This is a type of dwarfism in which the proximal portions of the limbs, the humeri and femurs, are much shorter than the distal portion of the limbs, a condition known as rhizomelia. Heterozygous achondroplasia is an autosomal dominant disorder, although many times it is the result of a spontaneous genetic mutation.

Rhizomelia is typically detected when a notable difference in the gestational age measurements between the biparietal diameter and femur length is discovered, typically in the mid to late second trimester. The sonographic findings of achondroplasia include micromelia, macrocrania, frontal bossing, flattened nasal bridge, and trident hand (Figs. 26-11 and 26-12). Achondroplasia can also be homozygous. Homozygous achondroplasia, which can occur when both parents are dwarfs, is usually fatal within the first 2 years of life.

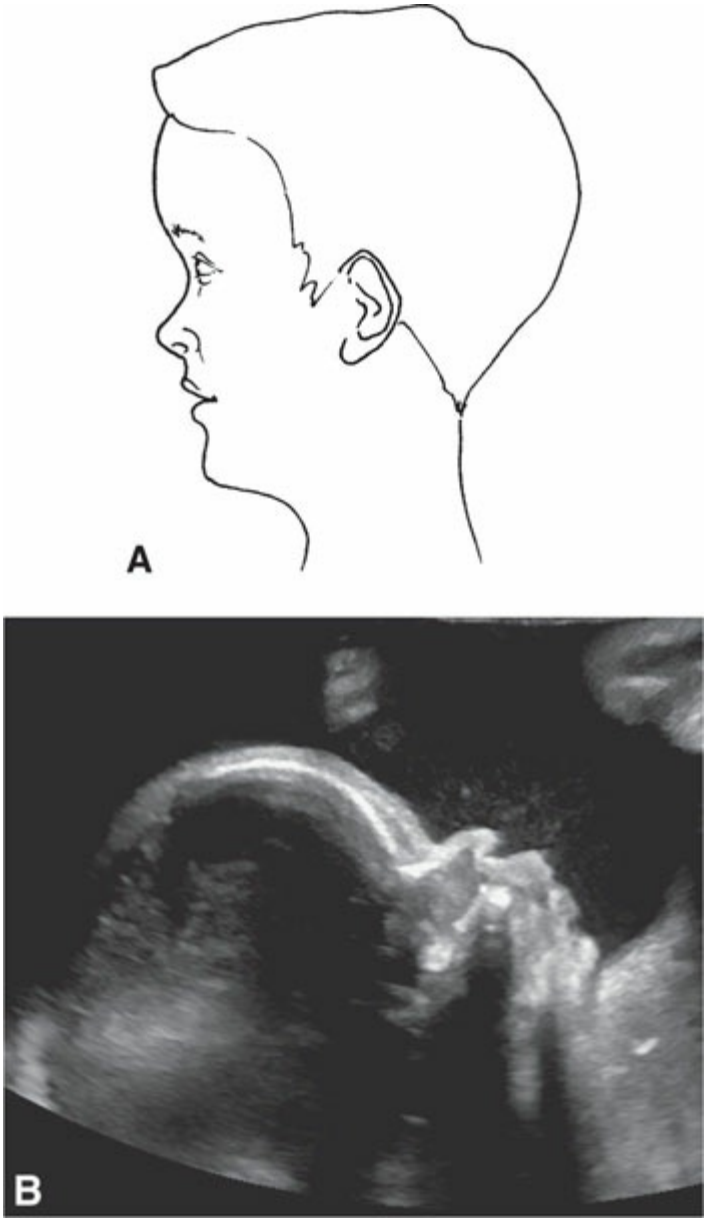


Figure 26-11 Achondroplasia and frontal bossing. **A.** Drawing of a child with achondroplasia and frontal bossing. **B.** Facial profile of a 32-week fetus reveals frontal bossing that produces an unusually prominent forehead.

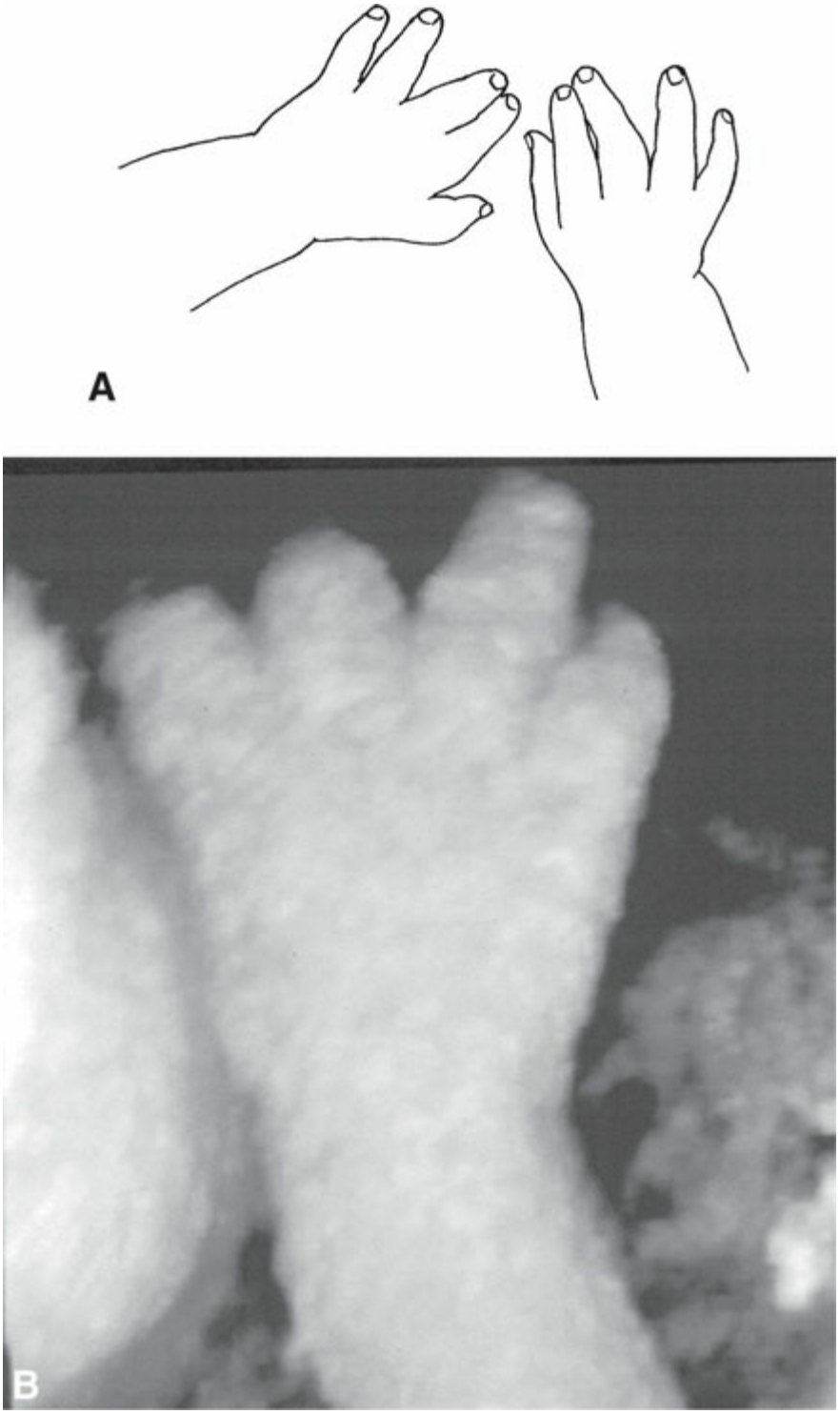


Figure 26-12 Trident hand. **A.** Drawing of trident hands. Note the distinct separation between the third and fourth digits. **B.** Three-dimensional image revealing a widening between the third and fourth digits. This is characteristic of a trident hand, often associated with achondroplasia.

SONOGRAPHIC FINDINGS OF ACHONDROPLASIA

1. Macrocrania
2. Frontal bossing
3. Flattened nasal bridge

4. Micromelia (resulting from rhizomelia)
5. Trident hand

SOUND OFF
Heterozygous achondroplasia is the most common nonlethal skeletal dysplasia.

Achondrogenesis

Achondrogenesis is a rare, lethal condition resulting in absent mineralization of the skeletal bones. It is apparent when there is deficient ossification of the fetal spine, pelvis, and cranium, ultimately leading to stillbirth or early death. The fetus will suffer from severe limb shortening and may have rib fractures. Sonographic findings include a large skull, severely shortened limbs, demineralization of the fetal skull, spine, pelvis, and limbs, distention of the abdomen, and a narrow chest (Fig. 26-13). Polyhydramnios is often present as well.

SONOGRAPHIC FINDINGS OF ACHONDROGENESIS

1. Severely shortened limbs (micromelia)
2. Absent mineralization of the skull, spine, pelvis, and limbs
3. Large skull
4. Narrow chest and distended abdomen
5. Polyhydramnios

Osteogenesis Imperfecta

Osteogenesis imperfecta, commonly known as brittle bone disease, is a group of disorders that results in multiple fractures that can occur in utero. The fractures are a result of decreased mineralization and poor ossification. There are four different types of osteogenesis imperfecta. Type II, a uniformly fatal form of osteogenesis imperfecta, is the most severe type of the disease. Osteogenesis imperfecta type II results in multiple fractures in utero, skull demineralization (recognized by a lack of posterior shadowing), bell-shaped chest, and decreased fetal movement. One distinctive finding is that when transducer pressure is applied to the skull, the shape of the "soft" skull can be distorted (Fig. 26-14). Types I, III, and IV are typically diagnosed after birth.

SONOGRAPHIC FINDINGS OF OSTEOGENESIS IMPERFECTA

1. Demineralization of the skull (transducer pressure can alter the shape of the skull)
2. Multiple fractures

3. Bell-shaped chest

SOUND OFF
Osteogenesis imperfecta, commonly known as brittle bone disease, is a group of disorders that results in multiple fractures that can occur in utero.

Thanatophoric Dysplasia

Thanatophoric ("death-bearing") dysplasia is the most common lethal skeletal dysplasia. The fetus with thanatophoric dysplasia will have a cloverleaf skull with frontal bossing and hydrocephalus (Fig. 26-15). Additionally, the shortened long bones take on a "telephone receiver" shape, because the diaphysis of the long bones will be bowed and have prominent metaphyseal ends (Fig. 26-16). The thoracic and abdominal circumference will be remarkably dissimilar, leading to a bell-shaped chest. Specifically, the thorax will be remarkably narrow, resulting in hypoplasia of the lungs, whereas the abdomen will appear prominent. This disparity can be best recognized with a sagittal image of the fetus. To document that the chest is much smaller than the abdomen, a thoracic circumference measurement can be obtained. With advancing gestation, redundant soft tissue, especially on the limbs, can also be noted. Fetuses with thanatophoric dysplasia typically die shortly after birth, succumbing most often to respiratory distress as a result of pulmonary hypoplasia.

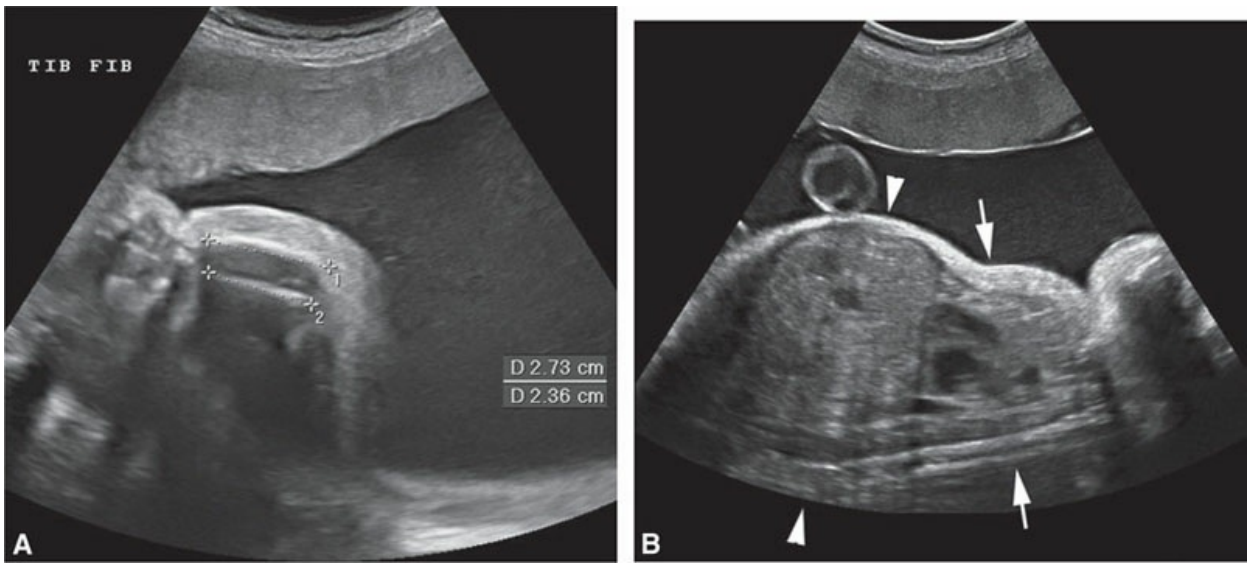


Figure 26-13 Achondrogenesis. **A.** Demineralized lower leg bones are noted in this fetus with achondrogenesis. **B.** A narrow thorax (*between arrows*) and distended abdomen (*between arrowheads*) is noted in this sagittal image of the chest and abdomen.

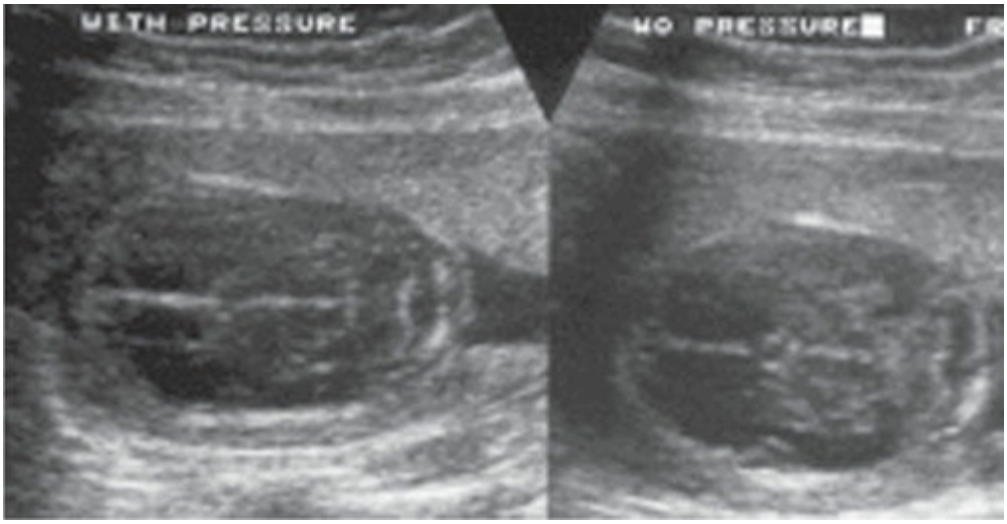


Figure 26-14 Osteogenesis imperfecta. The skull demonstrates markedly decreased echogenicity and is readily compressible even with moderate transducer pressure **(left)**.

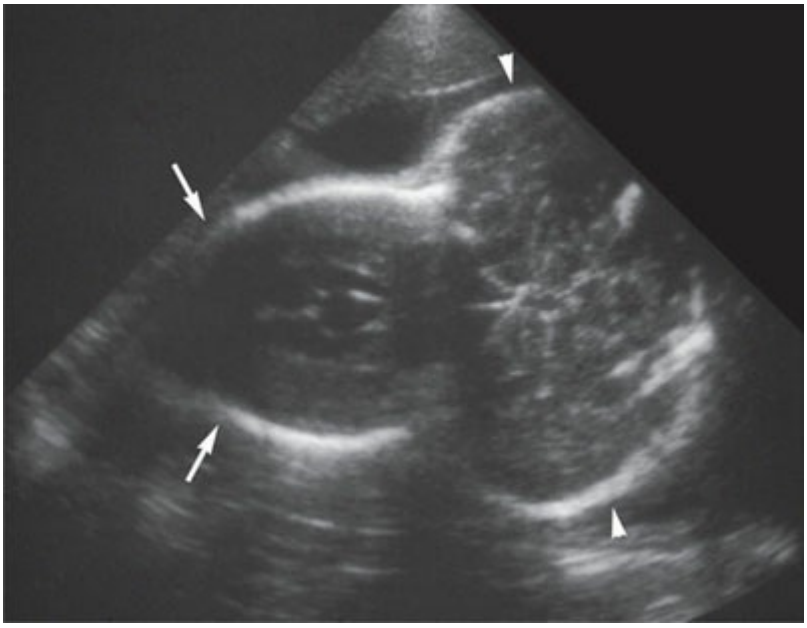


Figure 26-15 Cloverleaf head. This fetus with thanatophoric dysplasia has a cloverleaf head with frontal bossing (*arrows*) and lateral protrusion in the region of the temporal bones (*arrowheads*). (Image reprinted with permission from Doubilet P, Benson C. Atlas of Ultrasound in Obstetrics and Gynecology. Philadelphia: Lippincott Williams &Wilkins, 2003:167.)

SONOGRAPHIC FINDINGS OF THANATOPHORIC DYSPLASIA

1. Cloverleaf skull
2. Hydrocephalus
3. Depressed nasal bridge
4. Bell-shaped chest (narrow thorax)
5. Polyhydramnios
6. Redundant soft tissue

7. Telephone receiver–shaped long bones

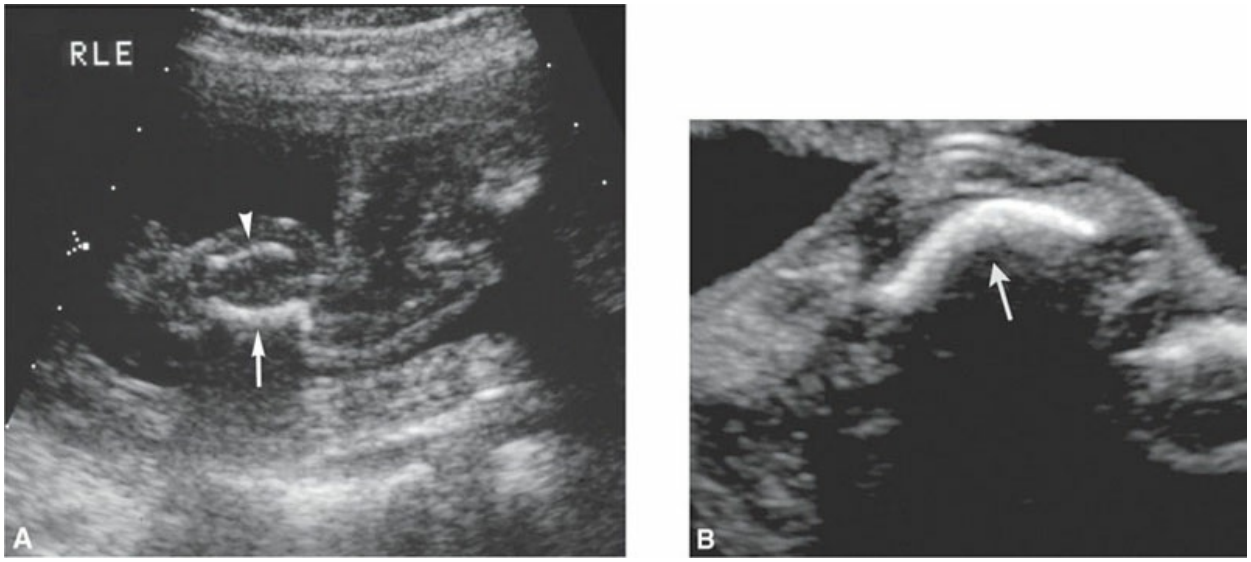


Figure 26-16 Thanatophoric dysplasia. **A.** A shortened and bowed tibia (*arrow*) and fibula (*arrowhead*) are noted in this fetus with thanatophroric dysplasia. **B.** Severe shortening and bowing of the tibia *(arrow)* is noted in this fetus.

SOUND OFF
The fetus with thanatophoric dysplasia will have a cloverleaf skull with frontal bossing and hydrocephalus.

CAUDAL REGRESSION SYNDROME

Caudal regression syndrome may also be referred to as sacral agenesis. The sonographic findings of caudal regression syndrome are absence of the sacrum (sacral agenesis) and coccyx (coccygeal agenesis) (Fig. 26-17). There may also be defects in the lumbar spine and lower extremities. Uncontrolled maternal pregestational diabetes has a strong association with caudal regression syndrome.

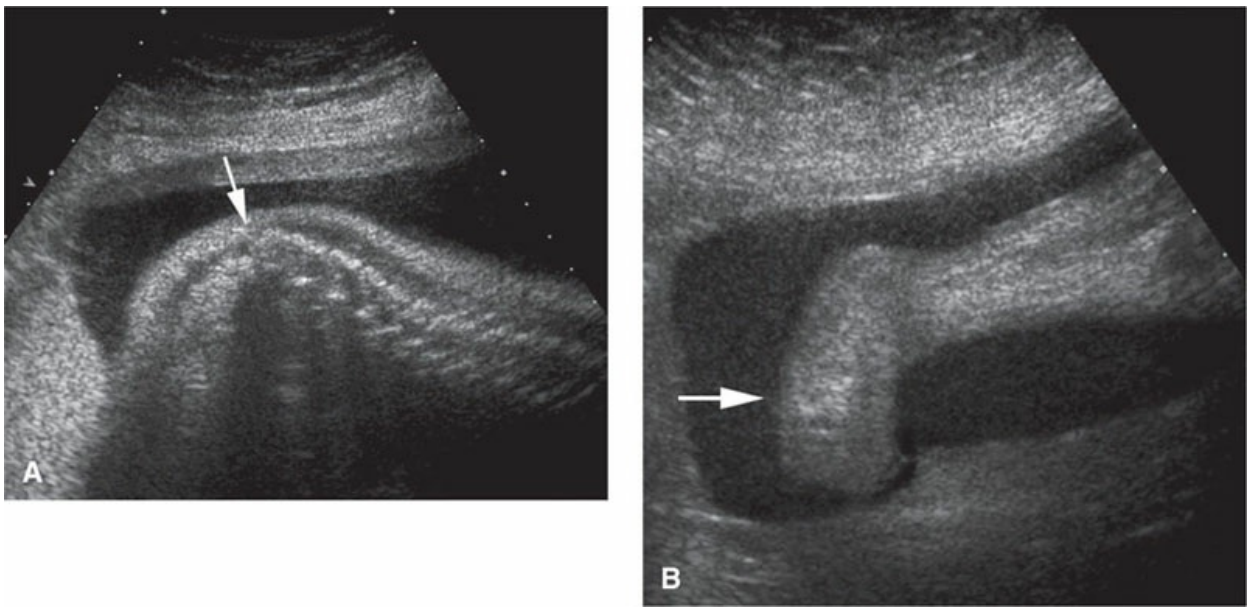


Figure 26-17 Caudal regression syndrome. **A.** Sagittal image of the fetal spine appears to abruptly terminate at the level of the lumbar spine (*arrow*) with absence of the sacrum. **B.** This fetus also had a clubfoot (*arrow*).

CLINICAL FINDINGS OF CAUDAL REGRESSION SYNDROME

1. Uncontrolled maternal pregestational diabetes

SONOGRAPHIC FINDINGS OF CAUDAL REGRESSION SYNDROME

1. Absent sacrum (sacral agenesis) and possibly part of the lumbar vertebra
2. Possible abnormalities in the lower extremities like clubfeet

SIRENOMELIA

Sirenomelia is also referred to as mermaid syndrome because of the fusion of the lower extremities that occurs with this disorder. Because bilateral renal agenesis often accompanies this condition, it is almost always lethal. In turn, oligohydramnios and many other defects, including cardiac anomalies, genital absence, and a two-vessel cord, may be seen. Again, like caudal regression syndrome, uncontrolled maternal pregestational diabetes seems to play a role in the development of this disorder.

CLINICAL FINDINGS OF SIRENOMELIA

1. Uncontrolled pregestational maternal diabetes

SONOGRAPHIC FINDINGS OF SIRENOMELIA

1. Fusion of the lower extremities
2. Bilateral renal agenesis
3. Oligohydramnios (possibly **anhydramnios**)

SOUND OFF
Sirenomelia is also referred to as mermaid syndrome because of the fusion of the lower extremities that occurs in this disorder.

SACROCOCCYGEAL TERATOMA

An SCT is a germ cell tumor. This means that this mass contains elements of the three different germ cell layers: endoderm, mesoderm, and ectoderm. SCT has been cited as the most common congenital neoplasm and is more frequently found in females. This tumor will typically appear as a complex or solid mass extending posteriorly and inferiorly from the distal fetal spine (Fig. 26-18). A SCT has the potential to grow inside of the pelvis and may cause obstruction of the urinary tract and destruction of the sacrum and pelvic bones. Large SCTs have malignant potential. SCTs have been associated with hydrops and may lead to high-output congestive heart failure.

SONOGRAPHIC FINDINGS OF SACROCOCCYGEAL TERATOMA

1. Complex mass extending off the distal fetal spine
2. Mass can be highly vascular
3. **Hydronephrosis** may be present (when mass invades the pelvis)
4. Fetal hydrops may be present
5. Cardiomegaly

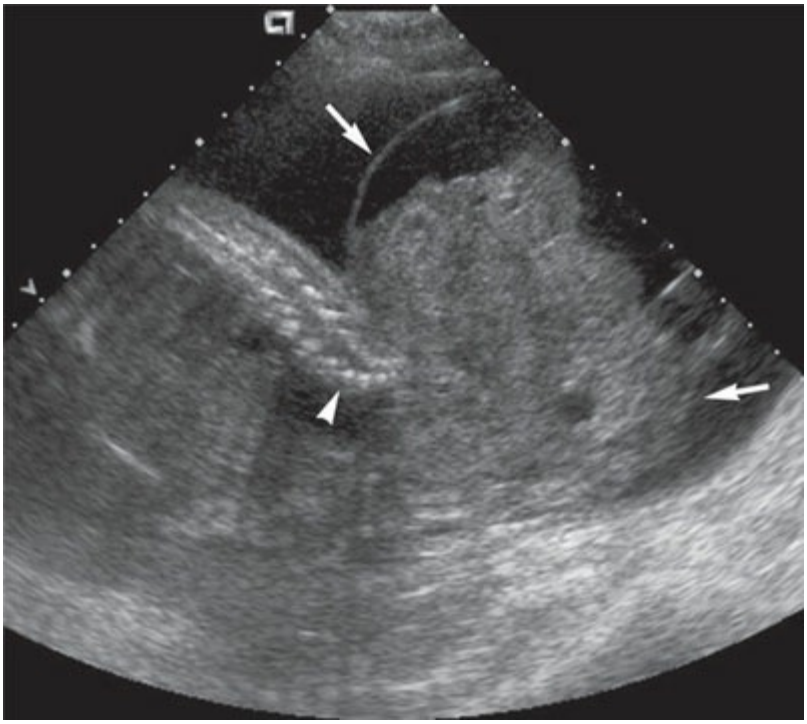


Figure 26-18 Sacrococcygeal teratoma. The large sacrococcygeal teratoma (*arrows*) seen in this image extends posterior and inferior from the fetal sacrum (*arrowhead*).

EMBRYOLOGY OF THE APPENDICULAR SKELETON

Similar to the axial skeleton, the appendicular skeleton begins to form between the sixth and eighth menstrual weeks. The appendicular skeleton includes the bones of the upper extremities, lower extremities, and pelvic girdle. The first sonographic appearances of the fetal limbs are referred to as limb buds. During the second trimester, the fetal limb bones take on more of an adult appearance and appear echogenic and will produce posterior shadowing. The upper extremities include the phalanges (fingers), the metacarpals, carpals, radius, ulna, humerus, clavicle, and scapula. The lower extremities consist of the phalanges (toes), metatarsals, tarsals, tibia, fibula, and femur.

Measurements of the long bones, especially the femur, are included in an obstetric sonogram. The femur, tibia, fibula, humerus, radius, and ulna can be measured as early as 12 weeks' gestation. The measurement of these long bones should include only the diaphysis of the bones and not the hypoechoic cartilaginous ends.

Shortening of a limb or part of limb can be identified sonographically. The sonographic determination of the shortening of a limb is made when the long bones measure more than four standard deviations below the norm for gestational age. Table 26-2 identifies and defines several terms related to shortening of the limbs and other abnormalities of the appendicular skeleton.

TABLE 26-2 Various limb abnormalities and their description

Type of Limb Abnormality	Description
Acromelia	Shortening of the distal segment of a limb
Arthrogryposis	Limitation of fetal limb motion as a result of joint contractures; most often affecting the hands and feet
Clinodactyly	Deviation of a finger (e.g., absence of the middle fifth phalanx)
Clubfoot	An inversion of the soles of one foot toward the other; when the metatarsals and toes lie in the same plane as the tibia and fibula; also referred to as talipes equinovarus
Mesomelia	Shortening of the middle segment of a limb
Micromelia	Shortening of an entire limb
Phocomelia	Absent long bones with the hands and feet arising from the shoulders and hips
Polydactyly	Having more than the normal number of digits
Rhizomelia	Shortening of the proximal segment of a limb
Rockerbottom foot	Abnormal curved shape of the sole of the foot
Sandal gap (Fig. 26-19)	Exaggerated distance between the first toe and second toe
Syndactyly	Fusion of digits (e.g., webbed toes)
Sirenomelia (mermaid syndrome)	Fusion of the legs
Trident hand	Increases space between the third finger and fourth finger

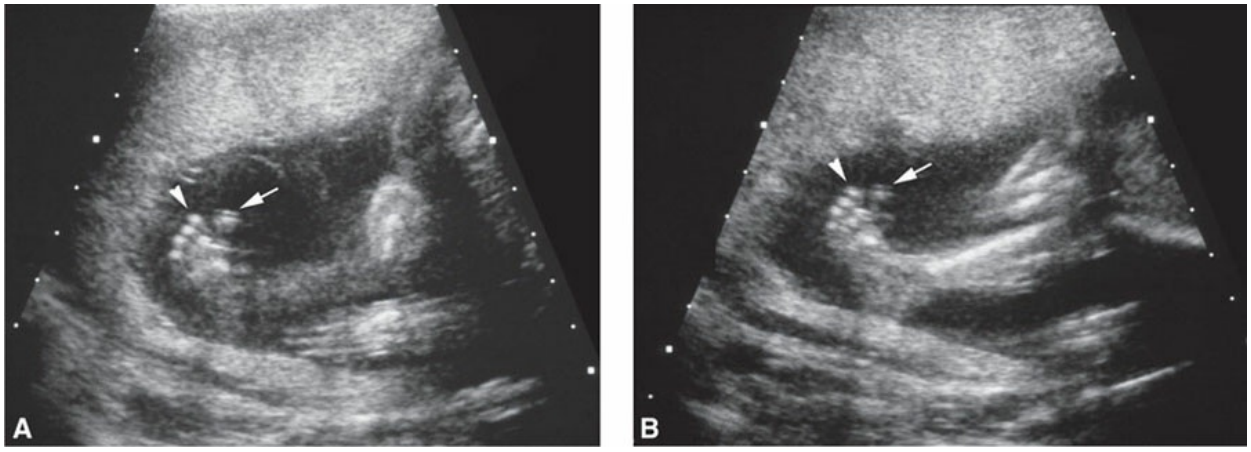


Figure 26-19 Sandal gap. **A** and **B.** Two views of the foot in a fetus with an abnormally large gap between the great toe (*arrow*) and the second toe (*arrowhead*).

RADIAL RAY DEFECT

Radial ray defect is uncommon and described as the absence (aplasia) or underdevelopment (hypoplasia) of the radius. This abnormality can be seen in the presence of trisomy 13, trisomy 18, and several other syndromes. There are often other anomalies present, specifically cardiac abnormalities. There is a link with VACTERL association.

SONOGRAPHIC FINDINGS OF RADIAL RAY DEFECT

1. Absent or hypoplastic radius
2. Various defects in other body systems: cardiac and VACTERL association

CLUBFOOT

Clubfoot, also referred to as talipes or talipes equinovarus, is a malformation of the bones of the foot. The foot is most often inverted and rotated medially. The sonographic diagnosis of clubfoot can be made when the metatarsals and toes lie in the same plane as the tibia and fibula (Fig. 26-20).

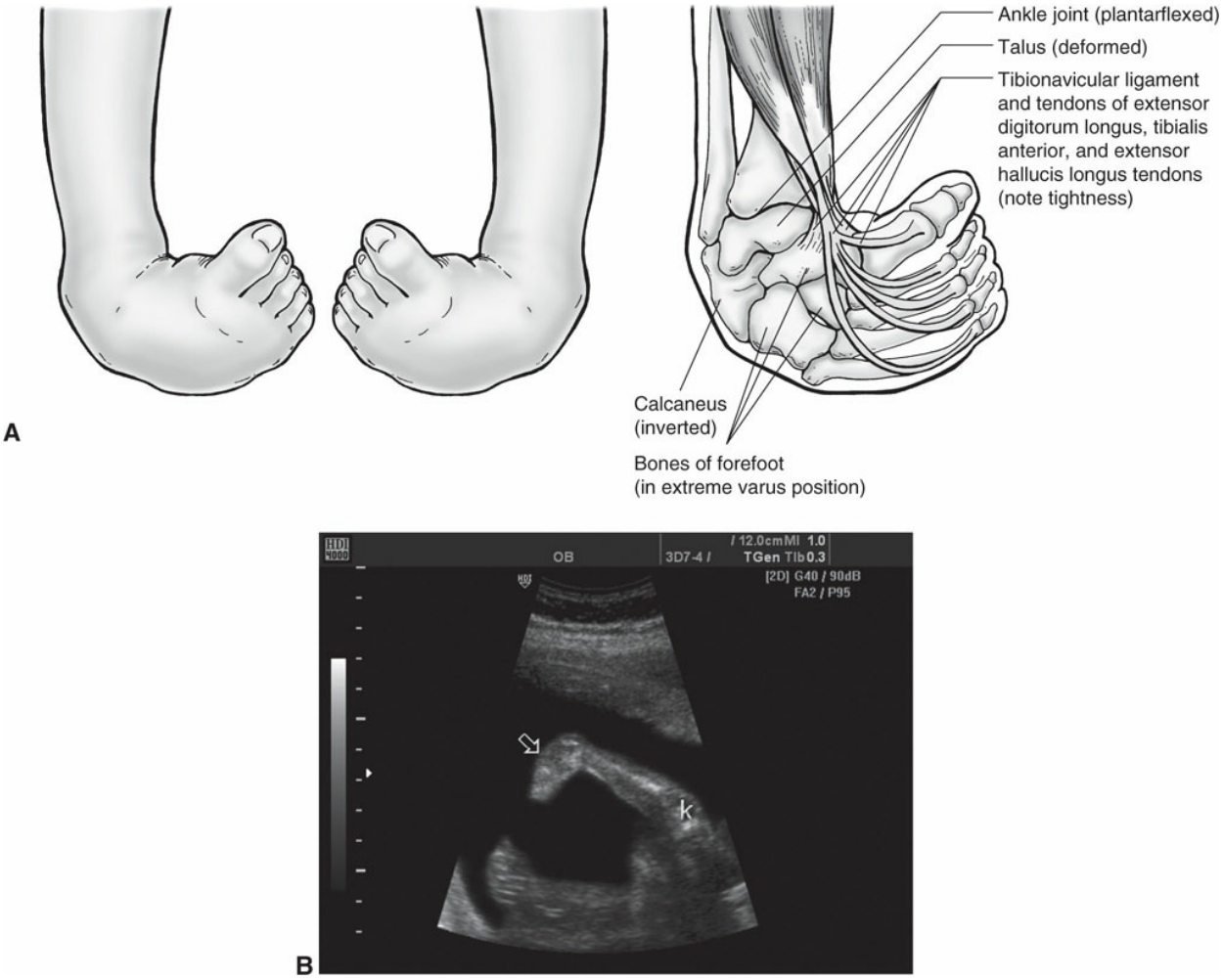


Figure 26-20 Clubfoot. **A.** Drawing of bilateral clubfeet. **B.** Image of the lower leg and knee (*k*) depicting a clubfoot (*arrow*).

SONOGRAPHIC FINDINGS OF CLUBFOOT

1. Metatarsals and toes lie in the same plane as the tibia and fibula

SOUND OFF
Clubfoot results in the metatarsals and toes lying in the same plane as the tibia and fibula.

LIMB REDUCTION AND AMNIOTIC BAND SYNDROME

Limb reduction can be caused by amniotic band syndrome, also referred to as amniotic band sequence. Sticky bands result from the rupture of the amnion. These bands can entrap fetal parts and cause amputation of digits, limbs, and even the skull (Fig. 26-21). Amniotic bands can also lead to peculiar facial clefting. These bands should not be confused with uterine synechiae. Amniotic bands may be seen with sonography, though occasionally only the results of the bands are seen. Uterine synechiae may be recognized as linear, thin membranes with a broad base crossing the amniotic sac (Fig. 26-22).

SONOGRAPHIC FINDINGS OF AMNIOTIC BAND SYNDROME

1. Amputation of fetal parts or severe edema in the affected area
2. Thin, linear bands may be seen
3. Facial clefting

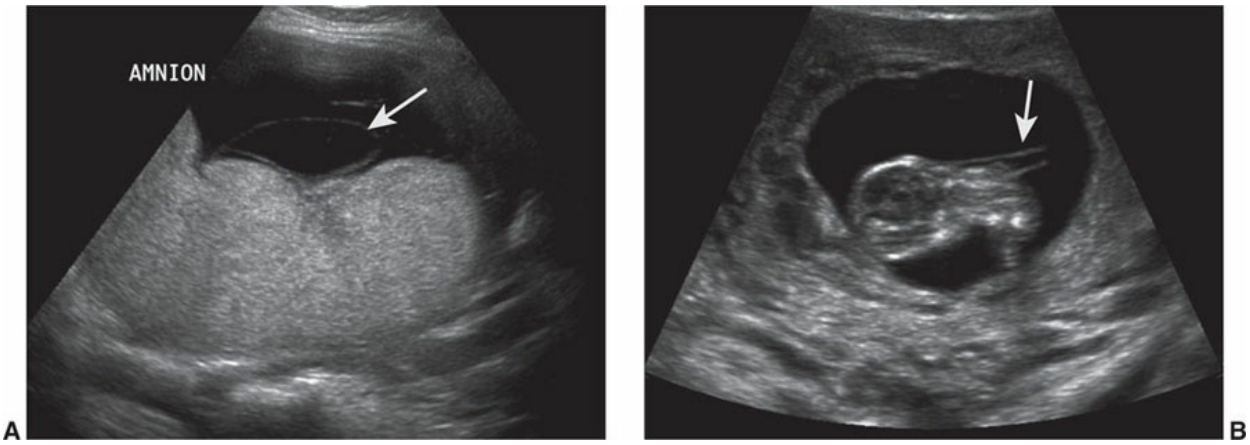


Figure 26-21 Amniotic bands. Images **(A)** and **(B)** demonstrating free-floating amniotic bands (*arrows*). The fetus in **(B)** also had scoliosis, limb deformities, and an anterior abdominal wall defect.

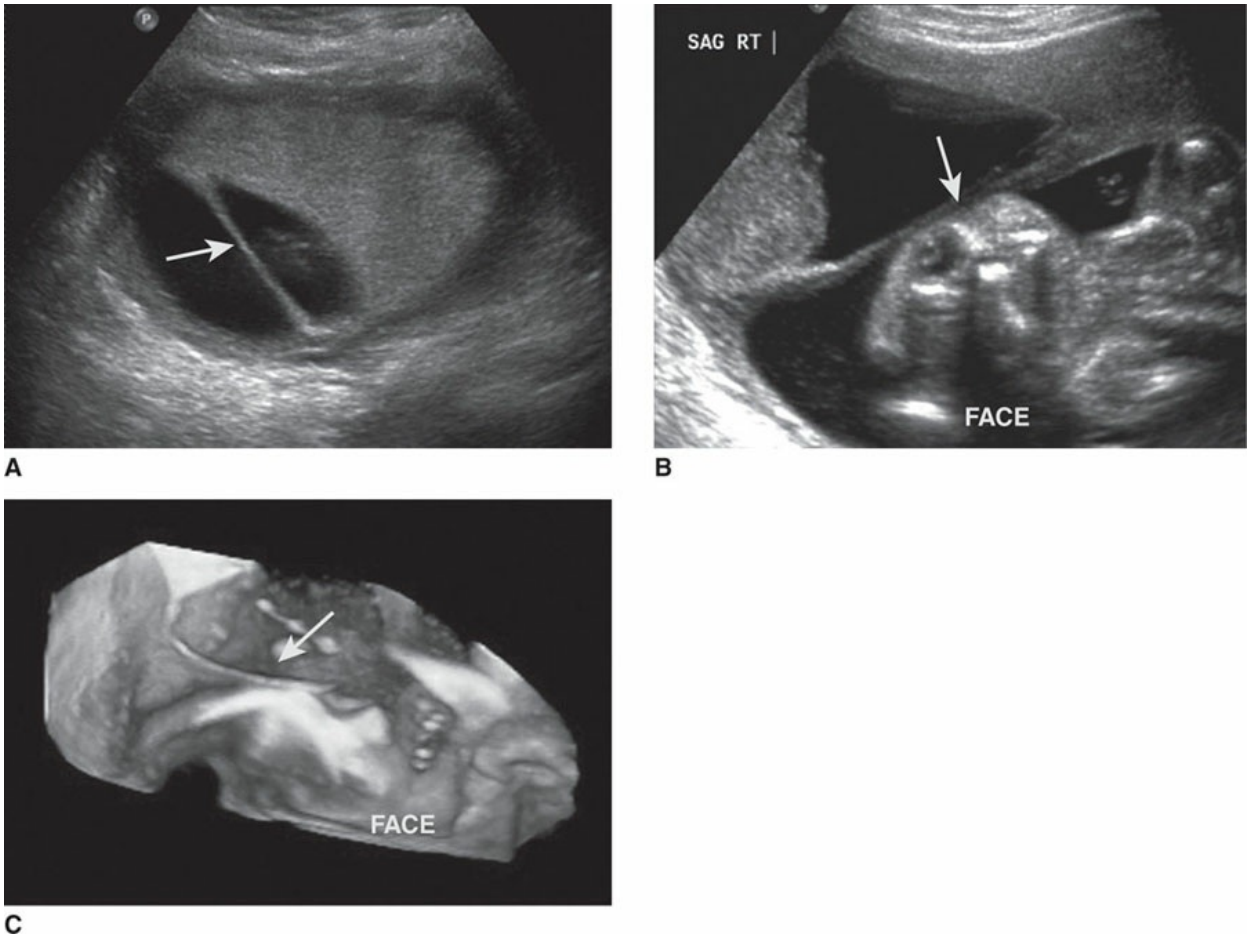


Figure 26-22 Uterine synechia. A, B, & C. Sonographic images demonstrating a thick linear structure continuous with the placenta in a singleton pregnancy, consistent with a uterine synechia (*arrow*).

REVIEW QUESTIONS

1. What is the maternal dietary supplement that has been shown to significantly reduce the likelihood of the fetus suffering from a neural tube defect?
   a. AFP
   b. Estriol
   c. Folate
   d. Pregnancy protein A

2. Talipes equinovarus is associated with:
   a. Clubfoot
   b. Syndactyly
   c. Rhizomelia
   d. Rockerbottom feet

3. The artifact seen posterior to solid structures such as fetal bone is referred

to as:
a. Acoustic shadowing
b. Posterior enhancement
c. Reverberation artifact
d. Edge artifact

4. What is the anomaly of the spine in which there is absence of all or part of a vertebral body and posterior element?
a. Kyphosis
b. Scoliosis
c. Kyphoscoliosis
d. Hemivertebra

5. The disorder associated with fetal amputations is:
a. Achondroplasia
b. Osteogenesis imperfecta
c. Thanatophoric dysplasia
d. Amniotic band syndrome

6. The form of inheritance in which at least one parent has to be a carrier of an abnormal gene for it to be passed to the fetus is:
a. Autosomal recessive
b. Autosomal dominant
c. Inherited dominant
d. Inherited recessive

7. The condition associated with the absence of the sacrum and coccyx:
a. LBWC
b. Caudal regression syndrome
c. Thanatophoric dwarfism
d. Heterozygous achondroplasia

8. All of the following are characteristics of spina bifida occulta except:
a. Closed defect
b. Elevated MSAFP
c. Sacral dimple
d. Hemangioma

9. The abnormal lateral ventricle shape in which there is a small frontal horn and enlarged occipital horn is referred to as:
a. Cebocephaly
b. Banana sign
c. Colpocephaly

d. Cephalocele

10. All of the following are characteristics of spina bifida cystica except:
    a. Banana sign
    b. Lemon sign
    c. Enlarged massa intermedia
    d. Normal MSAFP

11. In VACTERL association, the letter “C” stands for:
    a. Cerebellar
    b. C-spine
    c. Cranial
    d. Cardiac

12. All of the following are associated with spina bifida except:
    a. Splaying of the laminae
    b. Enlarged posterior fossa
    c. Lemon sign
    d. Banana sign

13. The abnormal lateral curvature of the spine is referred to as:
    a. Kyphosis
    b. Scoliosis
    c. Splaying
    d. Achondroplasia

14. The lemon sign denotes
    a. An abnormal shape of the fetal skull
    b. A normal shape of the cerebellum
    c. An abnormal shape of the cerebellum
    d. A normal shape of the fetal skull

15. All of the following are clinical or sonographic findings consistent with LBWC except:
    a. Ventral wall defects
    b. Decreased MSAFP
    c. Marked scoliosis
    d. Shortened umbilical cord

16. A disorder that results in abnormal bone growth and dwarfism is:
    a. Osteogenesis imperfecta
    b. Achondroplasia
    c. Radial ray defect

d. Caudal regression syndrome

17. Which of the following would increase the likelihood of a fetus developing sirenomelia and caudal regression syndrome?
    a. Previous cesarean section
    b. Preexisting maternal diabetes
    c. Previous ectopic pregnancy
    d. Elevated human chorionic gonadotropin

18. The group of fetal head and brain abnormalities that often coexists with spina bifida is referred to as:
    a. Dandy–Walker malformation
    b. Budd–Chiari syndrome
    c. Arnold–Chiari II malformation
    d. Amniotic band syndrome

19. In VACTERL association, the letter "L" stands for:
    a. Limb
    b. Lung
    c. Liver
    d. Larynx

20. The most common nonlethal skeletal dysplasia is:
    a. Achondrogenesis
    b. Achondroplasia
    c. Thanatophoric dysplasia
    d. Osteogenesis imperfecta

21. Achondroplasia is associated with all of the following except:
    a. Frontal bossing
    b. Flattened nasal bridge
    c. Trident hand
    d. Absent mineralization of the skull

22. What abnormality results in limitation of the fetal limbs as a result of joint contractures?
    a. Acromegaly
    b. Radial ray defect
    c. Achondrogenesis
    d. Arthrogryposis

23. The thalamic tissue located within the third ventricle of the brain that can become enlarged with Arnold–Chiari II malformation is the:

a. Corpus callosum
b. Cerebellar vermis
c. Cavum septum pellucidum
d. Massa intermedia

24. Rhizomelia denotes:
a. Long upper extremities
b. Shortening of an entire limb
c. Shortening of the proximal segment of a limb
d. Shortening of the distal segment of a limb

25. An absent sacrum and coccyx is referred to as:
a. Sirenomelia
b. Caudal regression syndrome
c. Achondroplasia
d. Radial ray defect

26. Absent long bones with the hands and feet arising from the shoulders and hips describes:
a. Micromelia
b. Mesomelia
c. Phocomelia
d. Arthrogryposis

27. All of the following are characteristic sonographic findings of achondrogenesis except:
a. Micromelia
b. Absent mineralization of the pelvis
c. Multiple dislocated joints
d. Polyhydramnios

28. Upon sonographic interrogation of a 28-week pregnancy, you note that when pressure is applied to the fetal skull, the skull can be easily distorted. This is sonographic evidence of:
a. Arnold–Chiari II malformation
b. Achondroplasia
c. Thanatophoric dysplasia
d. Osteogenesis imperfecta

29. A bell-shaped chest and multiple fetal fractures are indicative of:
a. Thanatophoric dysplasia
b. Caudal regression syndrome
c. Achondrogenesis

d. Osteogenesis imperfecta

30. All of the following are signs of Arnold–Chiari II malformation except:
    a. S-shaped spine
    b. Banana sign
    c. Lemon sign
    d. Colpocephaly

31. All of the following are associated with amniotic band syndrome except:
    a. Amputation of fetal parts
    b. Anencephaly
    c. Facial clefting
    d. Synechiae

32. The exaggerated distance between the first toe and the second toe is:
    a. Trident toes
    b. Sandal gap
    c. Phocomelia
    d. Mesomelia

33. Sirenomelia is commonly referred to as:
    a. Radial ray defect
    b. Rhizomelia
    c. Mermaid syndrome
    d. Rockerbottom feet

34. Absence of the radius is referred to as:
    a. Talipes equinovarus
    b. Clubfoot
    c. Radial ray defect
    d. Phocomelia

35. Sonographically, you visualize a mass extending from the distal spine of a fetus. This mass could be all of the following except:
    a. SCT
    b. Meningocele
    c. Meningomyelocele
    d. Phocomeningocele

36. A cloverleaf skull and hydrocephalus is seen with:
    a. Achondrogenesis
    b. Osteogenesis imperfecta
    c. Sirenomelia

d. Thanatophoric dysplasia

37. What term is defined as fusion of the digits?
    a. Clinodactyly
    b. Polydactyly
    c. Syndactyly
    d. Rhizodactyly

38. A protein produced by the yolk sac and fetal liver that is found in excess in the maternal circulation in the presence of a neural tube defect is:
    a. Folate
    b. hCG
    c. Estriol
    d. AFP

39. What condition is associated with bilateral renal agenesis, oligohydramnios, and fusion of the lower extremities?
    a. SCT
    b. Caudal displacement syndrome
    c. Sirenomelia
    d. Osteogenesis imperfect

40. Which of the following is true for the diagnosis of clubfoot?
    a. The metatarsals and toes lie in the same plane as the tibia and fibula.
    b. The metatarsals are perpendicular to the tibia and fibula.
    c. The carpals and metacarpals lie in the same plane as the tibia and fibula.
    d. The tibia, fibula, and patella are perpendicular to the femur.

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27

The Fetal Heart and Chest

Introduction

The primary focus of this chapter is on anomalies detectable on a routine sonographic examination of the fetal heart and chest, although additional anomalies will be covered. An overview of embryology of the heart and lungs is also provided. The obstetric sonographer should have a balanced understanding of four-chamber heart anatomy and structural defects that can be detected with this view. With the addition of the outflow tracts, several other anomalies may be distinguished.

Key Terms

aneuploidy—a condition of having an abnormal number of chromosomes

aortic atresia—abnormality in which there is a small or absent opening between the left ventricle and aorta

aortic stenosis—abnormal narrowing of the aortic valve

atrioventricular defect—abnormal development of the central portion of the heart; also referred to as endocardial cushion defect

bat-wing sign—the sonographic appearance of a fetal unilateral pleural effusion

biophysical profile—a method of fetal monitoring with sonography to produce a numeric scoring system that predicts fetal well-being

Bochdalek hernia—the herniation of abdominal contents into the chest cavity because of an opening in the left posterolateral portion of the

diaphragm

chordae tendineae—tendons within the heart that attach the tricuspid valve in the right ventricle and the mitral valve in the left ventricle to their respective papillary muscle

coarctation of the aorta—the narrowing of the aortic arch

cystic adenomatoid malformation—a mass consisting of abnormal bronchial and lung tissue that develops within the fetal chest

diaphragmatic hernia—the herniation of the abdominal contents into the chest cavity through a defect in the diaphragm

DiGeorge syndrome—a genetic disorder characterized by an absent or hypoplastic thymus, which ultimately leads to impairment of the immune system and susceptibility to infection, as well as cognitive disorders, congenital heart defects, palate defects, and hormonal abnormalities

ductus arteriosus—a fetal shunt that connects the pulmonary artery to the aortic arch

ductus venosus—a fetal shunt that connects the umbilical vein to the inferior vena cava

Ebstein anomaly—the malformation or malpositioning of the tricuspid valve that causes multiple heart defects

ectopic cordis—a condition in which the heart is located either partially or completely outside the fetal chest

endocardial cushion defect—see key term atrioventricular defect

eventration of the diaphragm—lack of muscle in the dome of the diaphragm

fetal hydrops—an abnormal accumulation of fluid in at least two fetal body cavities

foramen of Bochdalek—an opening located in the left posterolateral portion of the diaphragm

foramen of Morgagni—an opening located right anteromedially within the diaphragm

foramen ovale—an opening within the fetal heart within the atrial septum that allows blood to flow from the right atrium to the left atrium

hypoplastic left heart syndrome—incomplete development of the left ventricle, resulting in a small or absent left ventricle

hypoplastic right heart syndrome—incomplete development of the right ventricle, resulting in a small or absent right ventricle

lecithin to sphingomyelin ratio—a test of the amniotic fluid that predicts fetal lung maturity

oligohydramnios—a lower-than-normal amount of amniotic fluid for the gestational age

omphalocele—an anterior abdominal wall defect where there is herniation of the fetal bowel and other abdominal organs into the base of the umbilical cord

papillary muscle—paired muscles in both sides of heart that hold in place either the mitral or tricuspid valves

pentalogy of Cantrell—a group of anomalies that includes an omphalocele, along with ectopic cordis, cleft sternum, anterior diaphragmatic defect, and pericardial defects

pericardial effusion—fluid accumulation around the heart in the pericardial cavity

pleural effusion—the abnormal accumulation of fluid in the pleural space

Potter syndrome—syndrome characterized by bilateral renal agenesis, abnormal facies, pulmonary hypoplasia, and limb abnormalities

pulmonary atresia—the absence of the pulmonary valve, which in turn prohibits blood flow from the right ventricle into the pulmonary artery and essentially to the lungs

pulmonary hypoplasia—underdevelopment of the lungs

pulmonary sequestration—a separate mass of nonfunctioning lung tissue with its own blood supply

pulmonary stenosis—the narrowing of the pulmonary valve

rhabdomyoma—a fetal heart tumor found within the myocardium

tetralogy of Fallot—a group of abnormalities consisting of an overriding aortic root, ventricular septal defect, pulmonary stenosis, and right ventricular hypertrophy

thoracentesis—a procedure that uses a needle to drain fluid from the pleural cavity for either diagnostic or therapeutic reasons

transposition of the great vessels—abnormality in which the pulmonary artery arises from the left ventricle and the aorta arises from the right ventricle

tricuspid regurgitation—the leakage of blood back through the tricuspid valve

trisomy 18—chromosomal aberration in which there is a third chromosome 18; also referred to as Edwards syndrome

trisomy 21—chromosomal aberration in which there is a third chromosome 21; also referred to as Down syndrome

tuberous sclerosis—a systemic disorder that leads to the development of tumors within various organs

Turner syndrome—a chromosomal aberration where one sex chromosome is absent; may also be referred to as monosomy X

ventricular septal defect—an opening within the septum that separates the right and the left ventricles

THE FETAL HEART

Embryology and Anatomy of the Heart

The embryonic heart begins as two tubes. These two tubes ultimately fuse and fold to form into four chambers, two atria and two ventricles. The heart begins to contract at 36 to 37 days of gestation. It is initially recognized by its motion, which can be seen adjacent to the secondary yolk sac, often before an embryo is distinguishable. A heart rate using M-mode should be sonographically obtainable with endovaginal imaging when the crown rump length measures 4 to 5 mm.

During a biophysical profile assessment in the third trimester, an average fetal heart rate is 150 beats per minute (bpm), with a range of 110 to 180 bpm considered normal after the first trimester. An elevation in fetal heart rate is termed tachycardia, whereas a decrease is referred to as bradycardia.



SOUND OFF

The embryonic heart begins as two tubes. These two tubes ultimately fuse and fold to form into four chambers, two atria and two ventricles.

Four-Chamber Heart View

The heart, which is fully formed by 10 weeks, is imaged most often in a cross-sectional or axial view of the fetal chest, just above the fetal stomach. This transducer placement will yield the standard four-chamber view of the heart (Figs. 27-1 and 27-2). The apex of the heart will be angled to the left of the midline, with the base closest to the spine. The normal fetal heart will fill approximately one-third of the fetal chest, with its apex forming a 45-degree angle with the fetal spine. The chamber closest to the fetal spine is the left atrium.



SOUND OFF

The normal fetal heart will fill approximately one-third of the fetal chest, with its apex forming a 45-degree angle with the fetal spine. The chamber closest to the fetal spine is the left atrium.

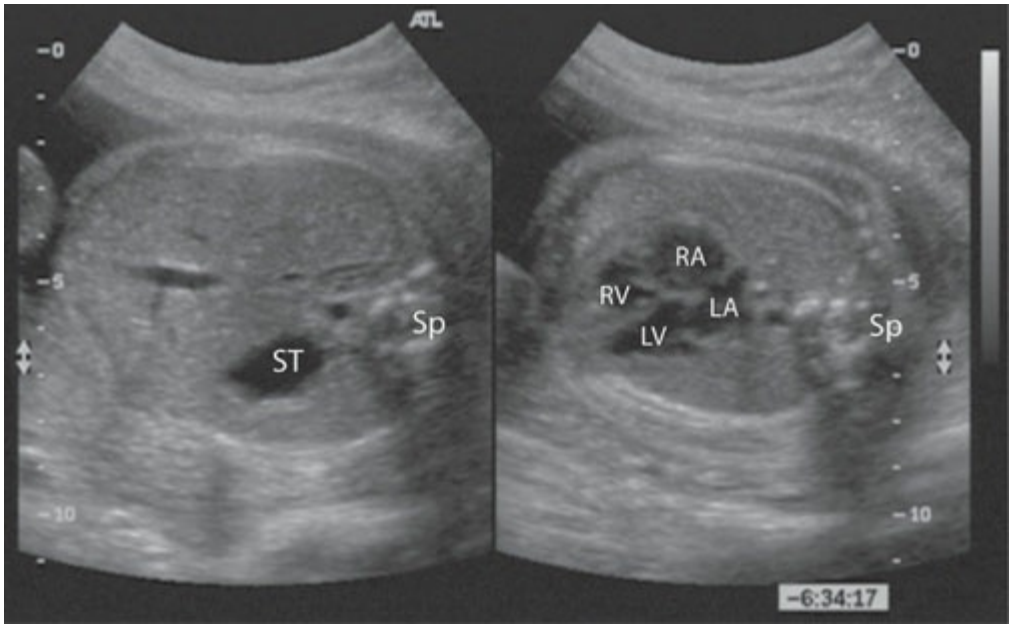


Figure 27-1 Four-chamber heart view. The orientation of the heart within the chest in relationship to the fetal stomach (*ST*) is demonstrated in these two images. The apex of the heart is on the same side of the body as the stomach. The left atrium (*LA*), left ventricle (*LV*), right atrium (*RA*), and right ventricle (*RV*) are clearly identified. Note that the left atrium is the chamber positioned closest to the fetal spine (*Sp*).

The four-chamber view can be used to evaluate the separation of the chambers, structures called septums. The two atria are separated by the atrial septum, and the two ventricles are separated by the ventricular septum. The ventricular septum should be uninterrupted and of equal thickness to the left ventricular wall, whereas the atrial septum is open only at the foramen ovale (Fig. 27-3). Within the right ventricle can be seen the moderator band, a normal structure that appears as an echogenic focus. The left ventricle has much smoother walls compared to the right. Between the right ventricle and right atrium, one should visualize the tricuspid valve, and between the left ventricle and left atrium, the mitral valve should be noted. Normally, the tricuspid valve is positioned closer to the cardiac apex than the mitral valve (Fig. 27-4).

Outflow Tracts

Outflow tracts of the fetal heart can be evaluated during the routine screening examination, and should be when technically feasible according to the American Institute of Ultrasound in Medicine. The right ventricular outflow tract leads to the pulmonary artery and branches, whereas the left ventricular outflow tract leads to the aorta. One important anatomic finding is that the normal pulmonary artery should be positioned anterior to the aorta and should be visualized crossing over it (Figs. 27-5 and 27-6). That means, that the aorta and pulmonary artery normally crisscross each other. There are

several other features that should be assessed while imaging the outflow tracts (Table 27-1; Fig. 27-7).

FETAL CIRCULATION

It is important for sonographers to have a basic appreciation for fetal circulation (Fig. 27-8). The normal umbilical cord contains two arteries and one vein. The vein, entering the umbilicus, brings oxygen-rich blood from the placenta to the fetus. The umbilical vein travels superiorly and connects to the left portal vein. Half of the blood goes to the liver through the left portal vein, whereas the other half is shunted directly into the inferior vena cava (IVC) via a small branch of the umbilical vein called the ductus venosus. The blood that was taken to the liver is used to oxygenate the liver and is then returned back to the IVC by the hepatic veins.

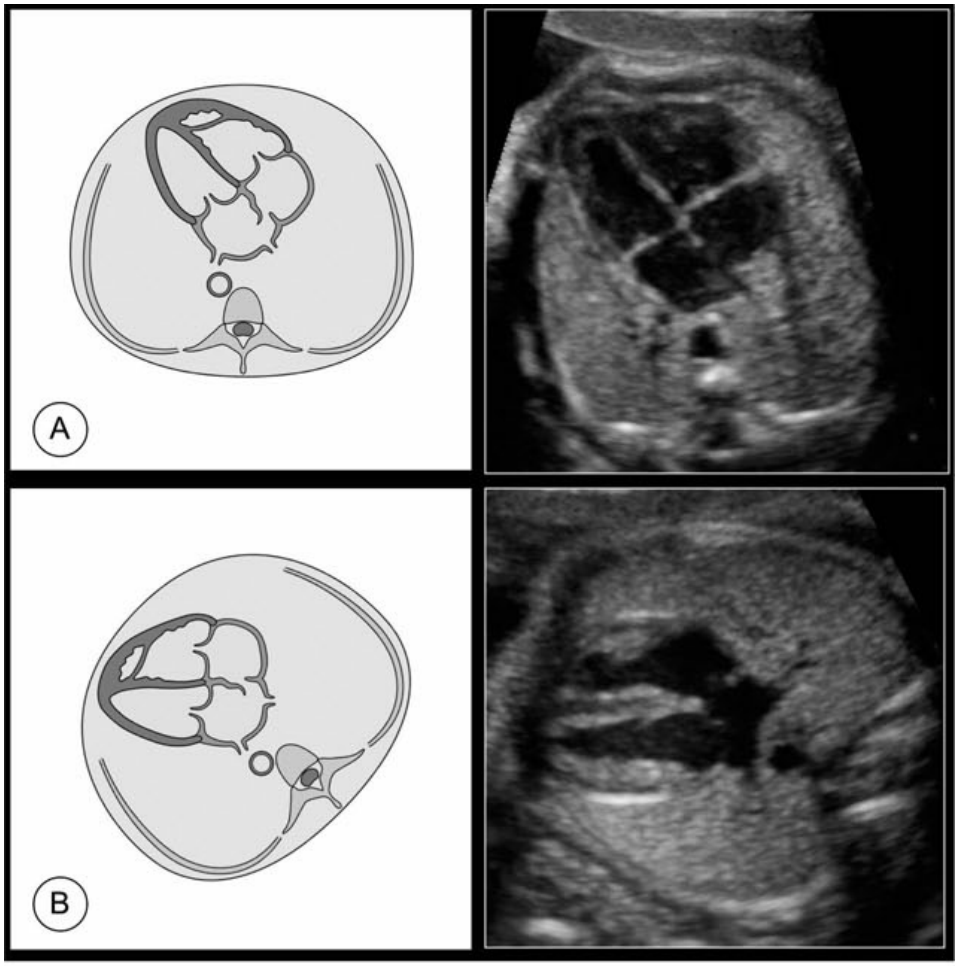
SOUND OFF
Blood from the right ventricle can flow through the ductus arteriosus and into the descending aorta.

The existing oxygen-rich blood in the IVC travels up to the heart and enters the right atrium. Blood can then travel across the foramen ovale, an opening in the lower middle third of the atrial septum and into the left atrium, or it can enter the right ventricle through the tricuspid valve. The blood then leaves the right ventricle through the main pulmonary artery. The main pulmonary artery bifurcates into right and left, thus allowing a small amount of blood to travel to the respective lung. Blood from the right ventricle can also flow through the ductus arteriosus and into the descending aorta (Fig. 27-9).

SOUND OFF
Blood is shunted directly into the IVC via a small branch of the umbilical vein called the ductus venosus.

The blood returning from the lungs through the pulmonary veins enters into the left atrium. Blood then travels from the left atrium into the left ventricle via the mitral valve. From the left ventricle, it travels to the ascending aorta and into the aortic arch, where it exits into the brachiocephalic artery, left common carotid artery, and left subclavian artery on its way to the thorax, upper extremities, and head. The blood will return from the head and upper torso via the superior vena cava to the right atrium.

The blood that flows through the ductus arteriosus and into the descending aorta travels inferiorly to either exit the abdomen via the umbilical arteries or travels to the abdomen and lower extremities to replenish those regions. Therefore, the umbilical arteries return the deoxygenated blood from the fetus back to the placenta.


A
B

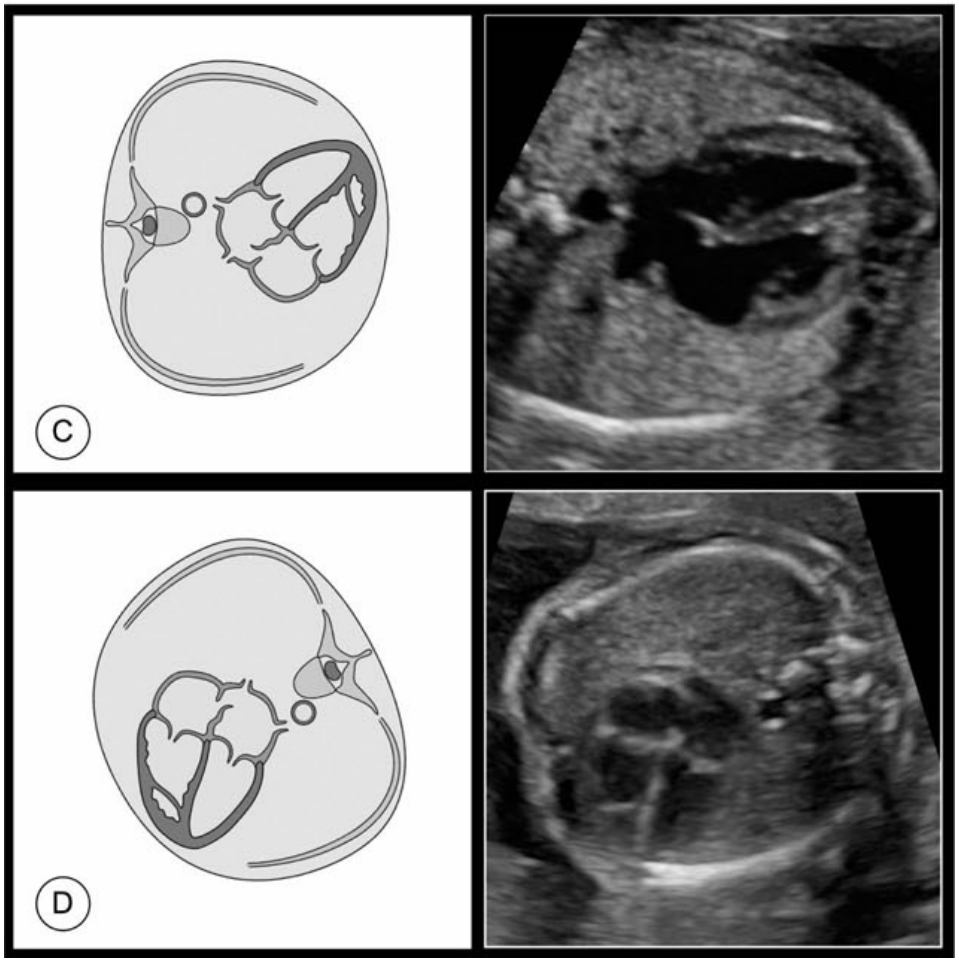

C
D

Figure 27-2 Schematic drawings and the corresponding ultrasound images of four-chamber views in four fetuses: fetus **(A)** with a posterior spine position, fetus **(B)** with a right lateral spine position, fetus **(C)** with a left lateral spine position, and fetus **(D)** with a somewhat anterior spine position.

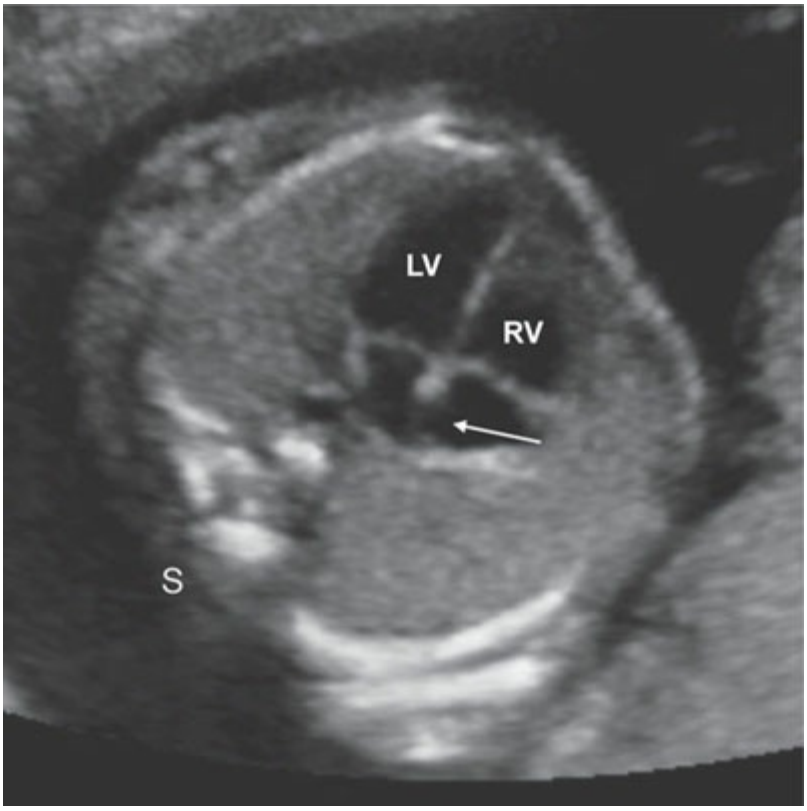


Figure 27-3 Foramen ovale. Normal four-chamber view of the heart in a 21-week fetus. The cardiac apex is directed to the left side of the fetus. The right ventricle (*RV*) is the most anteriorly positioned chamber and is separated from the left ventricle (*LV*) by the interventricular septum. The left atrium is the most posterior chamber, located just anterior to the spine (*S*). The foramen ovale *(arrow)* is seen between the right and the left atria.



Figure 27-4 Valves seen on the four-chamber view. Normally, the tricuspid valve (*tv*) inserts closer to the apex of the heart compared to the mitral valve (*mv*).

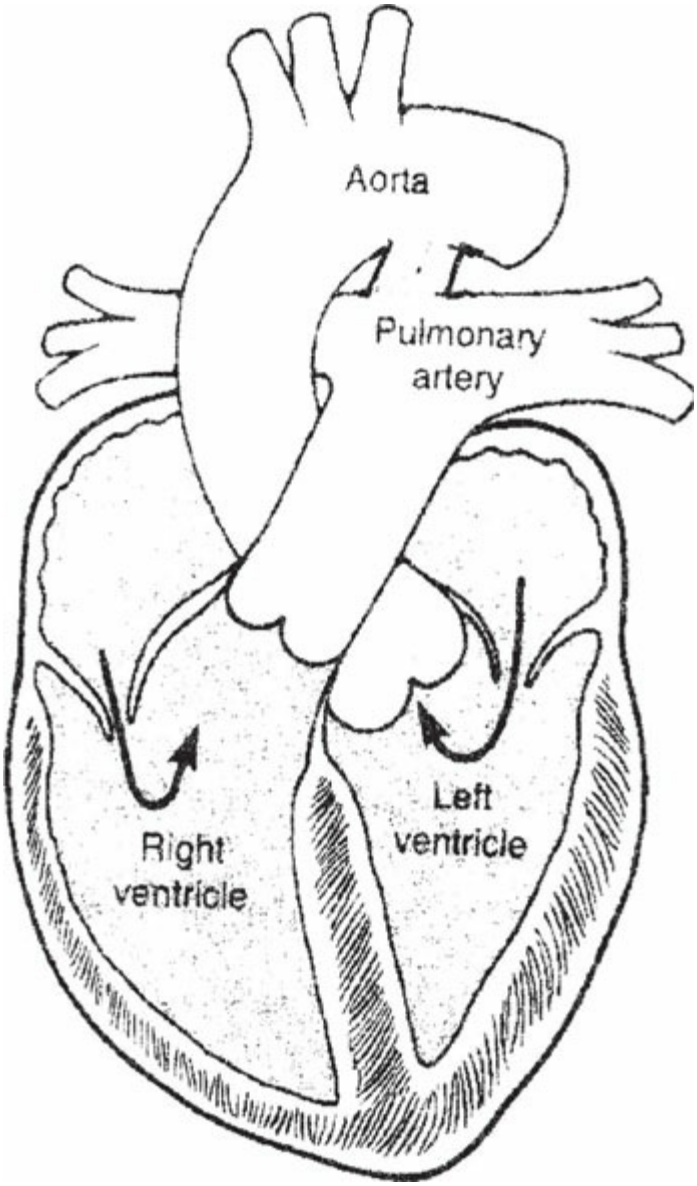


Figure 27-5 Crisscross of the outflow tracts. Diagram of the heart demonstrating the normal crossing of the pulmonary artery and aorta. The pulmonary artery should be located more anterior than the aorta and be noted crossing over the aorta to originate at the right ventricle.

FETAL HEART ABNORMALITIES

Hypoplastic Left Heart Syndrome

Hypoplastic left heart syndrome is a group of anomalies characterized sonographically as a small or absent left ventricle (Fig. 27-10). Hypoplastic left heart syndrome is the leading cause of cardiac death in the neonatal period, with 95% dying within the first month of life if surgery is not performed. This anomaly can be recognized on a four-chamber heart view. To distinguish this anomaly from complete absence of the left side of the heart, a small or normal left atrium must be visualized. When found in girls,

Turner syndrome should be suspected. There is also a connection with trisomy 18.

Sonographic Findings of Hypoplastic Left Heart Syndrome

1. Absent or small left ventricle
2. No communication between the left atrium and the left ventricle
3. **Aortic atresia** (possibly)
4. **Aortic stenosis** (possibly)
5. **Coarctation of the aorta** (possibly)

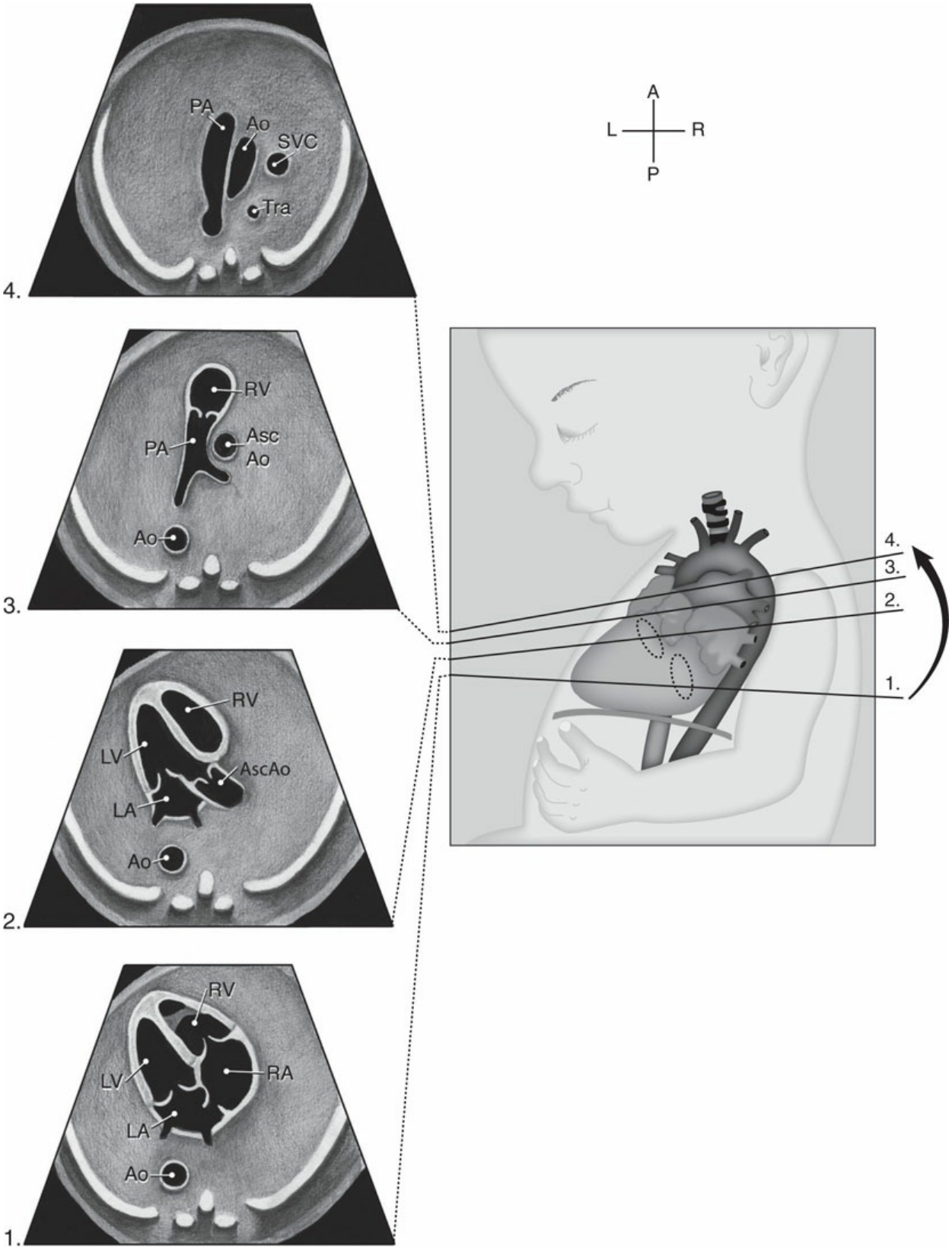


Figure 27-6 Standardized transverse scanning planes for fetal echocardiography as recommended in the Guidelines of the American Institute of Ultrasound in Medicine (AIUM), and include an evaluation of the four-chamber view (*1*); arterial outflow tracts—left ventricular (*2*) and right ventricular (*3*); and the three-vessel-trachea view (*4*). *Ao*, descending aorta; *Asc Ao*, ascending aorta; *LA*, left atrium; *LV*, left ventricle; *PA*, pulmonary artery; *RA*, right atrium; *RV*, right ventricle; *Tra*, trachea; SVC, superior vena cava.

Hypoplastic Right Heart Syndrome

Hypoplastic right heart syndrome is sonographically identified as a small or an absent right ventricle (Fig. 27-11). It, like hypoplastic left heart syndrome, is best visualized with the four-chamber heart view. Hypoplastic heart syndrome most often results from pulmonary stenosis or pulmonary atresia, but it may result from stenosis or atresia of the tricuspid valve.

TABLE 27-1 Basic assessment of the fetal outflow tracts

1. The aortic outflow tract originates from the left ventricle.
2. The pulmonary outflow tract originates from the right ventricle.
3. The outflow tracts should be comparable in size.
4. The ascending aorta and the main pulmonary artery are perpendicular to each other because they exit their respective ventricles. They should be seen crossing and not lying in the same plane.

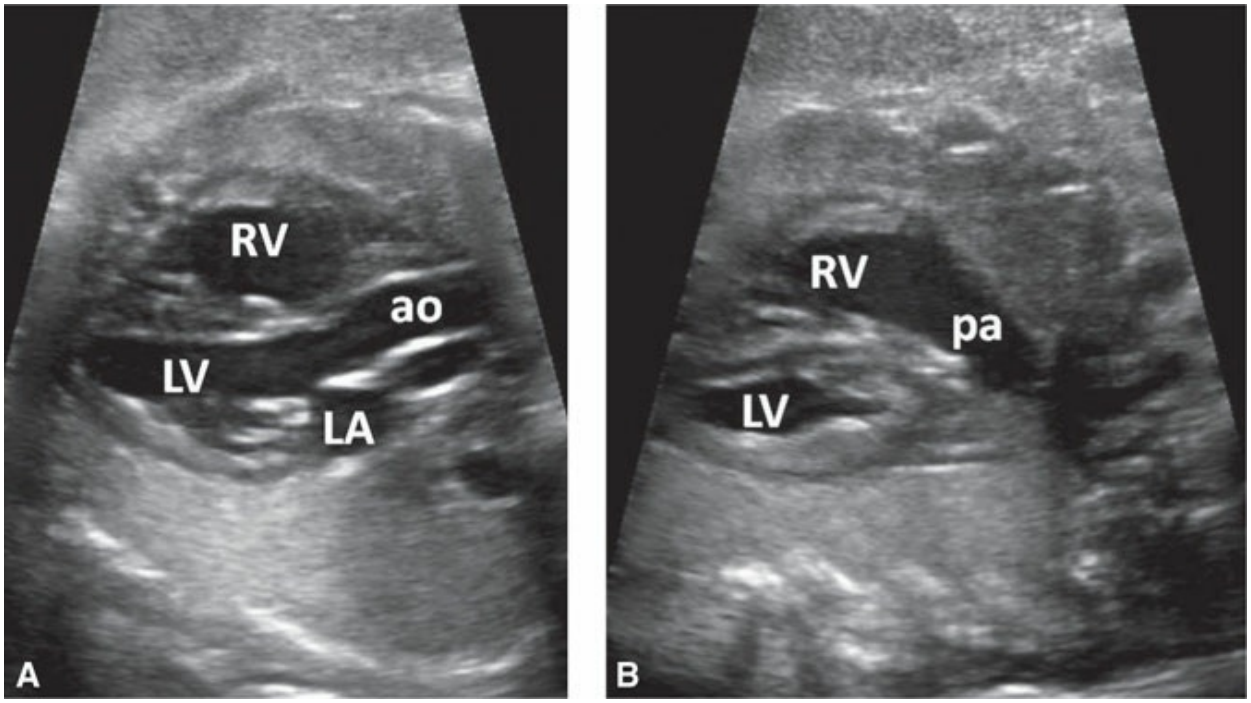


Figure 27-7 Sonogram of outflow tracts. Axial views of the outflow tracts. **A.** Aortic outflow (*ao*) tract exiting from the left ventricle (*LV*). **B.** Pulmonary artery outflow (*pa*) exiting from the right ventricle (*RV*). *LA*, left atrium.

SONOGRAPHIC FINDINGS OF HYPOPLASTIC RIGHT HEART SYNDROME

1. Absent or small right ventricle

2. Enlarged left ventricle
3. **Fetal hydrops** (secondary to cardiac failure)
4. Narrowing of the pulmonary valve

Ventricular Septal Defects

A ventricular septal defect (VSD) is an abnormal opening in the septum between the two ventricles of the heart (Fig. 27-12). The VSD is the most common form of cardiac defect. This defect can be isolated, seen in the presence of chromosomal abnormalities, or associated with other cardiac anomalies, including tetralogy of Fallot, which is mentioned later in this chapter. Color Doppler can be used to identify the flow within and through the defect.

SONOGRAPHIC FINDINGS OF VENTRICULAR SEPTAL DEFECTS

1. Absence of part of the ventricular septum
2. Color Doppler is helpful at detecting small defects



SOUND OFF
The VSD is the most common form of cardiac defect.

Atrial Septal Defects

An atrial septal defect (ASD) is an abnormal opening in the septum between the two atria of the heart. An ASD can be isolated but may be found in the presence of various syndromes.

SONOGRAPHIC FINDINGS OF ATRIAL SEPTAL DEFECTS

1. Absence of part of the atrial septum
2. Color Doppler is helpful at detecting small defects

Atrioventricular Septal Defects or Atrioventricular Canal

The combination of both atrial and VSDs is termed atrioventricular defect (AVSD) or atrioventricular canal. An AVSD results from the abnormal development of the central portion of the heart. The central portion of the heart is referred to as the “endocardial cushion”; this is the reason why the AVSD may be referred to as an endocardial cushion defect. AVSDs are commonly associated with aneuploidy, trisomy 21, and trisomy 18.

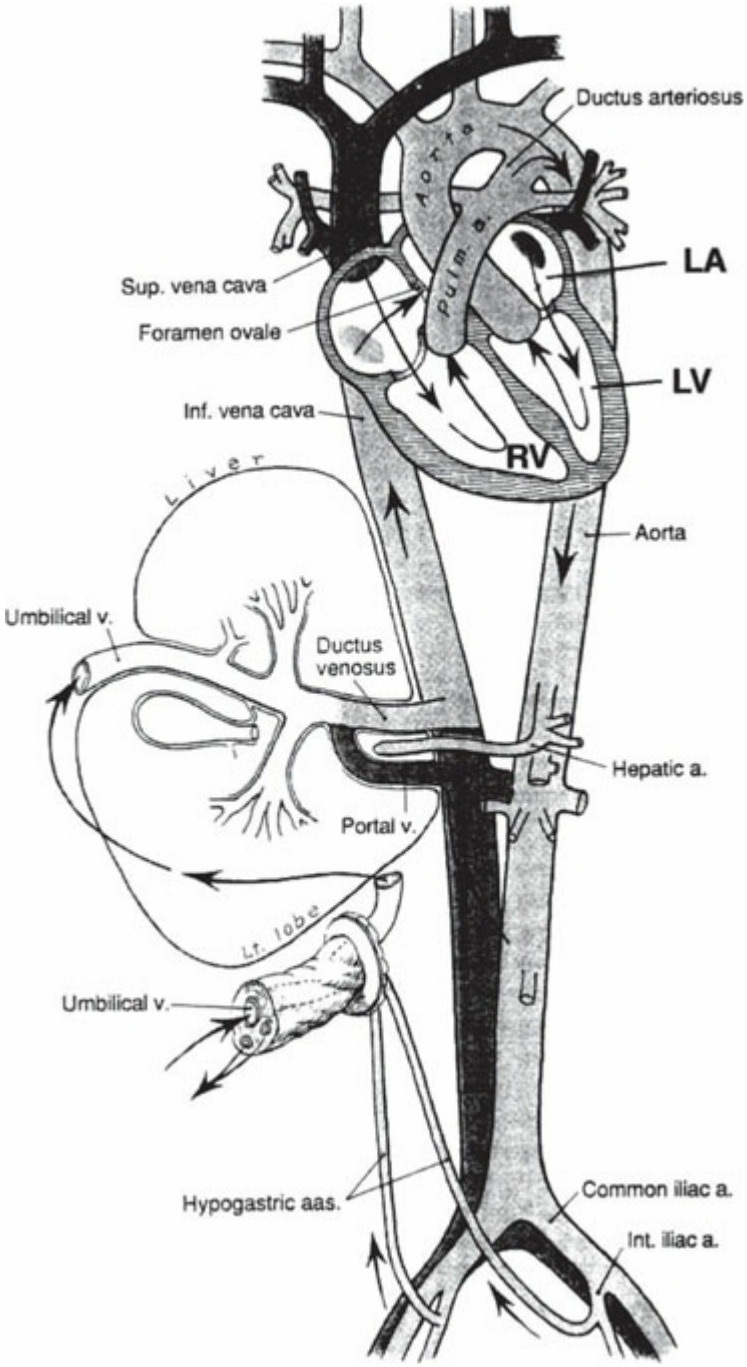


Figure 27-8 Fetal circulation. (Image reprinted with permission from Sanders R, Winters T. Clinical Sonography: A Practical Guide. 4th Ed. Philadelphia: Lippincott Williams & Wilkins, 2007:514.)

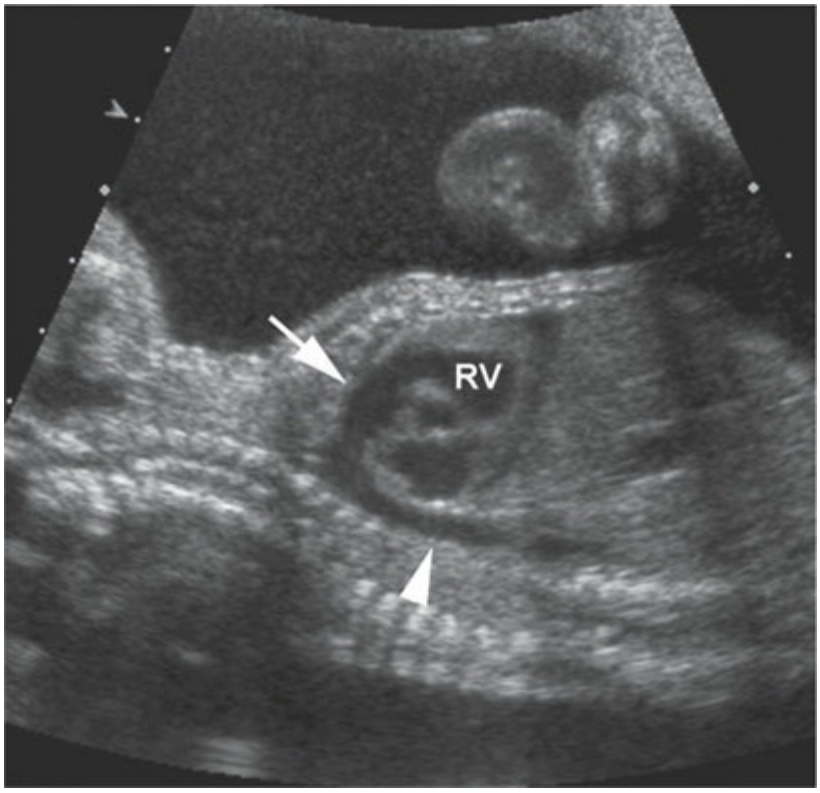


Figure 27-9 Right ventricular outflow tract and ductal arch. Right ventricular outflow tract and ductal arch to the descending aorta. Sagittal image demonstrating the right ventricular (*RV*) outflow tract and ductal arch *(arrow)*, representing the connection of the ductus arteriosus to the descending thoracic aorta *(arrowhead)*.

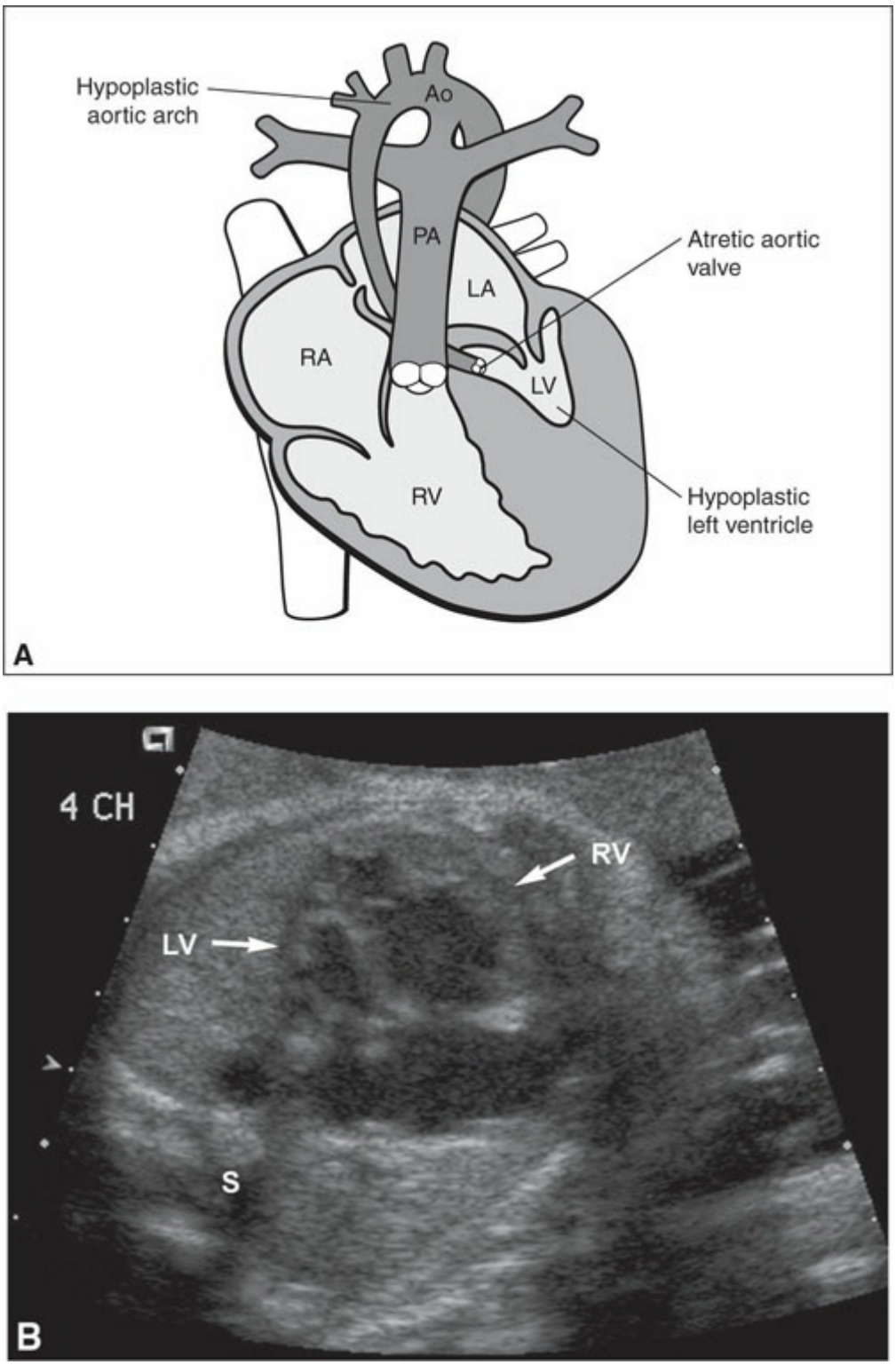


Figure 27-10 Hypoplastic left heart. **A.** Schematic drawing of hypoplastic left heart syndrome demonstrating the typical features of hypoplastic hypokinetic left ventricle (*LV*), dysplastic mitral valve, atretic aortic valve, and hypoplastic aorta (*Ao*). **B.** Transverse image of the fetal spine (*S*) and thorax at the level of the four-chamber view demonstrating a hypoplastic left ventricle (*LV arrow*) and larger right ventricle (*RV arrow*). ***LA***, left atrium; **PA**, pulmonary artery; **RA**, right atrium; **RV**, right ventricle.

SONOGRAPHIC FINDINGS OF ATRIOVENTRICULAR SEPTAL DEFECTS

1. Absence of the atrial and ventricular septum
2. Color Doppler findings are helpful at showing mixture of flow patterns

Ebstein Anomaly

Malformation or malpositioning of the tricuspid valve results in Ebstein anomaly (Fig. 27-13). With this abnormality, the right ventricle is contiguous with the right atrium, a finding referred to as an "atrialized" right ventricle. This anomaly is associated with tricuspid regurgitation, ASDs, tetralogy of Fallot, transposition of the great vessels, and coarctation of the aorta. Prognosis is poor, with 80% of infants dying in the perinatal period.

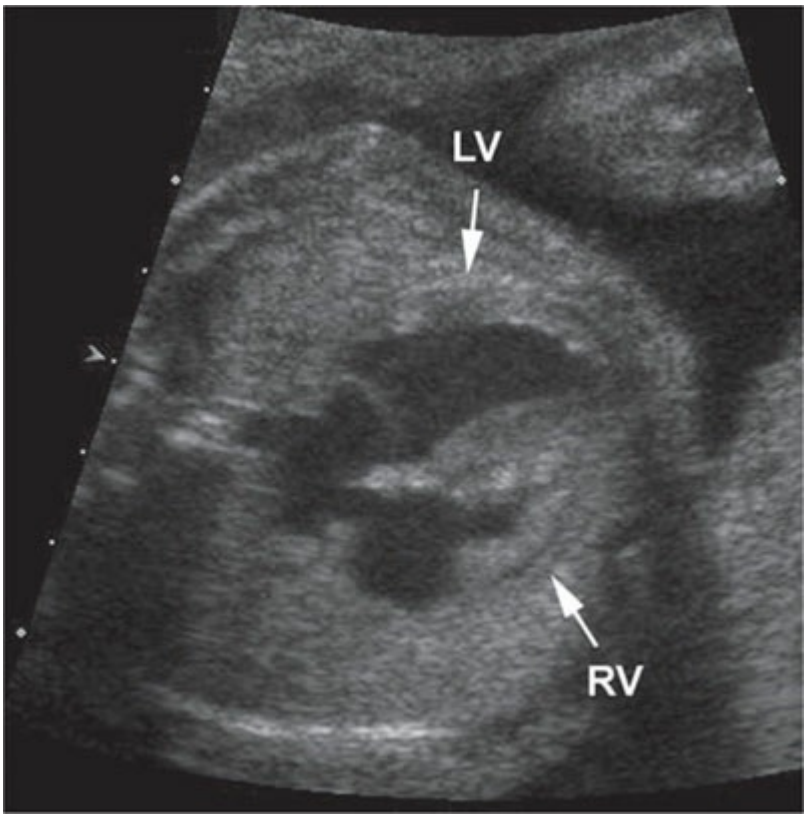


Figure 27-11 Hypoplastic right heart. Transverse image of the fetal thorax at the level of the four-chamber view of the heart demonstrating the left ventricle (*LV*) and a small right ventricle (*RV*) with a thickened wall.

SONOGRAPHIC FINDINGS OF EBSTEIN ANOMALY

1. Malpositioned tricuspid valve
2. Right and left atrial shunting
3. Tricuspid regurgitation
4. Enlarged right atrium

5. Deviation of the atrial septum to the left
6. Fetal hydrops (secondary to cardiac failure)

SOUND OFF
Malformation or malpositioning of the tricuspid valve results in Ebstein anomaly.

Coarctation of the Aorta

Coarctation of the aorta is the narrowing of the aortic arch. The most common location is between the left subclavian artery and the ductus arteriosis. Associated findings consist of right ventricle and pulmonary artery enlargement. This anomaly can be difficult to diagnose in utero during a routine sonographic examination. However, the aforementioned associated findings are most often recognized first, and consequently further evaluation with fetal echocardiography is typically warranted for official diagnosis. Other common findings include patent ductus arteriosus and VSDs.

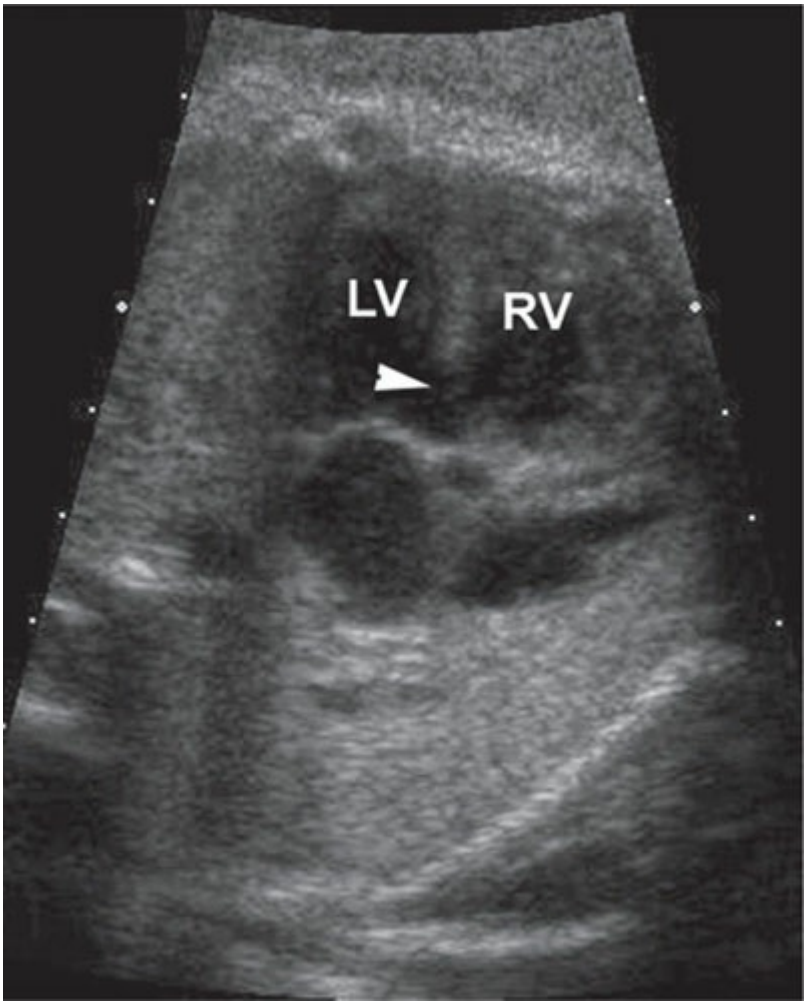


Figure 27-12 Ventricular septal defect. **A.** Four-chamber view of the heart demonstrating a defect *(arrow)* in the muscular ventricular septum between the right

ventricle (*RV*) and left ventricle (*LV*).

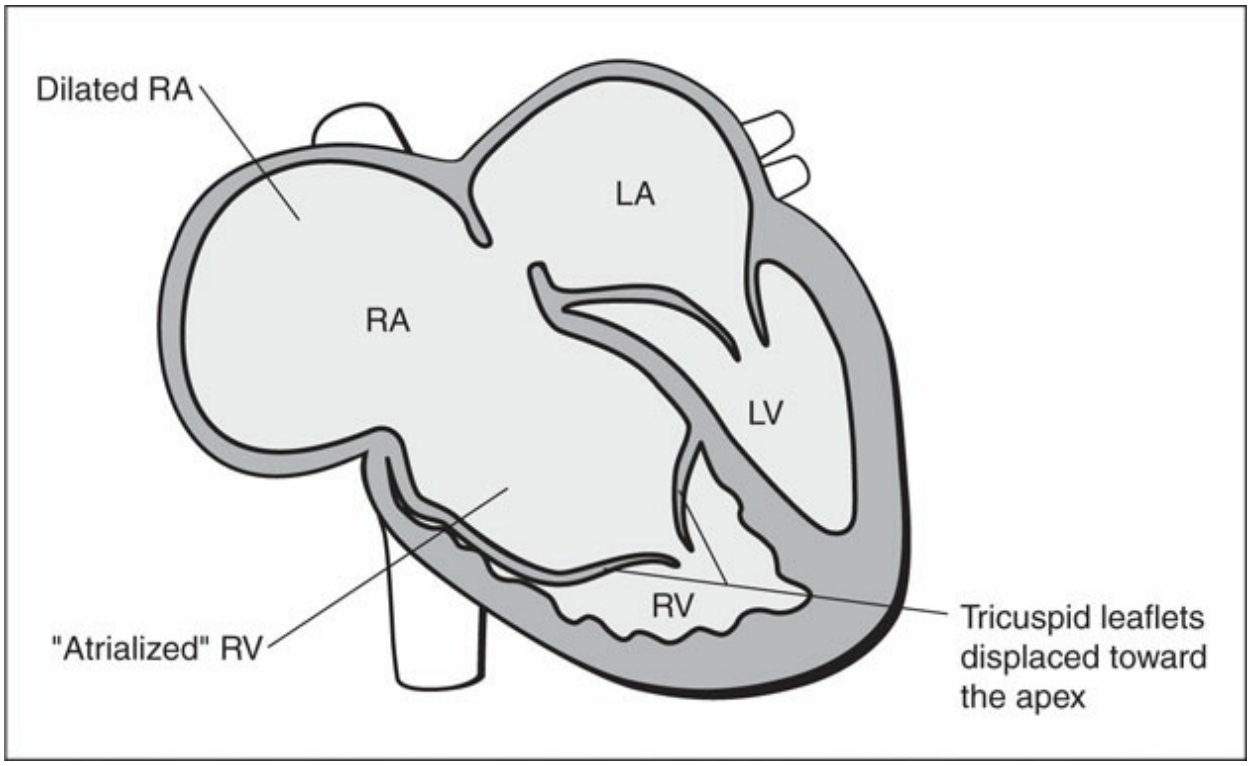


Figure 27-13 Ebstein anomaly. With Ebstein anomaly, there is either malposition or malformation of the tricuspid valve and an atrialized right ventricle.

SONOGRAPHIC FINDINGS OF COARCTATION OF THE AORTA

1. Narrowing of the aortic arch
2. Right ventricular enlargement
3. Pulmonary artery enlargement

Tetralogy of Fallot

Tetralogy of Fallot is defined as an overriding aortic root, subaortic VSD, pulmonary stenosis, and right ventricular hypertrophy (Fig. 27-14). The right ventricular hypertrophy is not always noted in utero but rather manifests after birth.

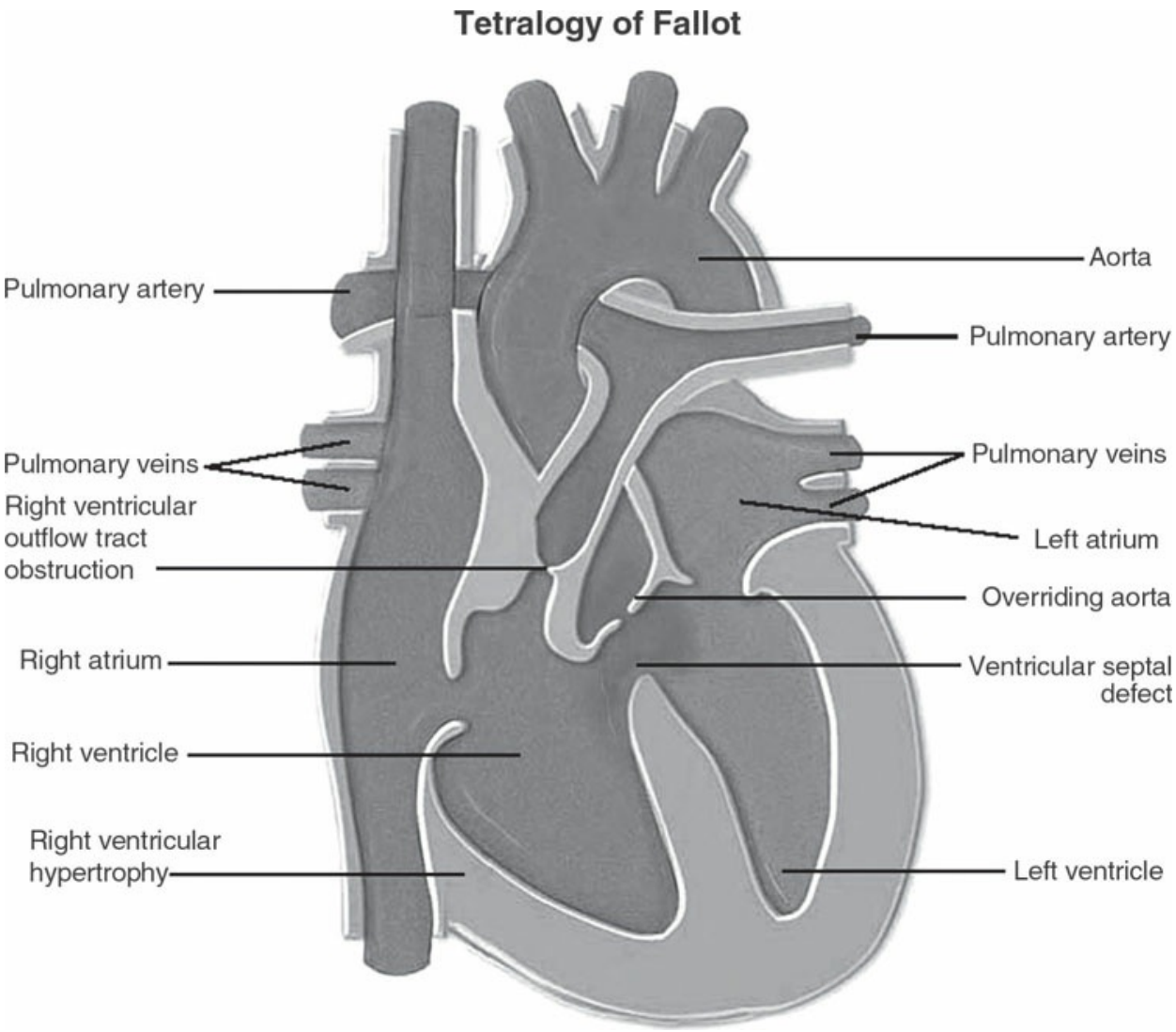


Figure 27-14 Illustration of Tetralogy of Fallot. A large aorta overrides a ventricular septal defect, and the pulmonary outflow tract is hypoplastic.

SONOGRAPHIC FINDINGS OF TETRALOGY OF FALLOT

1. Overriding aortic root
2. VSD
3. Pulmonary stenosis
4. Right ventricular hypertrophy

Transposition of the Great Vessels

With transposition of the great vessels, the outflow tracts are reversed. That means, the pulmonary artery abnormally arises from the left ventricle, and the aorta abnormally arises from the right ventricle. Often, the four-chamber view of the heart is normal. However, when the outflow tract images are obtained in a fetus with transposition, instead of the normal crisscross orientation of the outflow tracts, they will be positioned parallel to each other, with the aorta noted anterior and to the right of the pulmonary artery

(Fig. 27-15). Occasionally, a VSD or other heart abnormalities may be present. For this reason, if technically feasible, outflow tracts should be attempted during the screening examination. Transposition of the great vessels has a good prognosis if it is discovered in utero, because corrective surgery can be performed shortly after birth.

SONOGRAPHIC FINDINGS OF TRANSPOSITION OF THE GREAT VESSELS

1. The pulmonary artery abnormally arises from the left ventricle, and the aorta abnormally arises from the right ventricle.
2. The outflow tracts will be positioned parallel to each other rather than crisscrossing.
3. VSD may be present

SOUND OFF
Often, the four-chamber view of the heart is normal in the presence of transposition of the great vessels.

Echogenic Intracardiac Focus

An echogenic intracardiac focus (EIF) is most often seen within the left ventricle of the heart (Fig. 27-16). This is thought to represent the calcification of the papillary muscle or chordae tendineae. An EIF may be seen in the normal fetus. However, there have been studies that have linked the incidence of an EIF with trisomy 21, particularly if there is more than one EIF detected. The echogenicity of the EIF is comparable to that of the fetal bone.

SONOGRAPHIC FINDINGS OF AN ECHOGENIC INTRACARDIAC FOCUS

1. Echogenic structure most commonly located within the left ventricle

SOUND OFF
An EIF may be seen in the normal fetus. However, there have been studies that have linked the EIF with trisomy 21.

Rhabdomyoma

The most common fetal cardiac tumor is the rhabdomyoma. These tumors, located within the myocardium of the heart, are associated with tuberous

sclerosis, eventual cardiac failure, and subsequent development of fetal hydrops. These tumors, typically, are echogenic and may be isolated or multiple (Fig. 27-17).

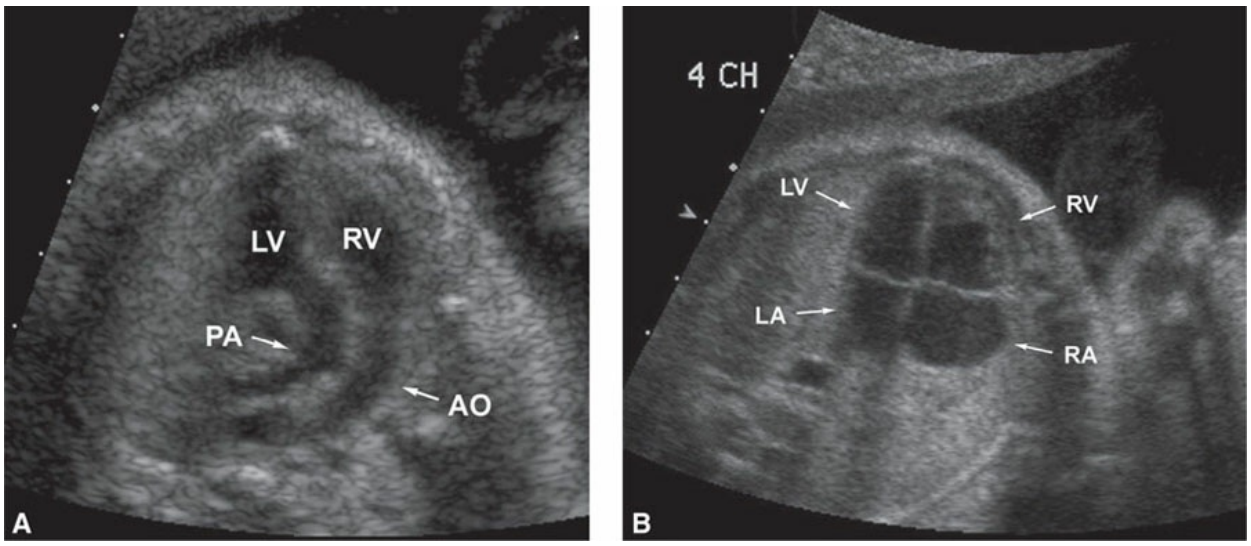


Figure 27-15 Transposition of the great vessels. **A.** Image of outflow tracts demonstrating the aorta (*AO small arrow*) arising from the right ventricle (*RV*) and the pulmonary artery (*PA small arrow*) arising from the left ventricle (*LV*). **B.** The four-chamber view of the heart is normal. *LA*, small arrow, left atrium; *LV*, small arrow, left ventricle; *RA*, small arrow, right atrium; *RV*, small arrow, right ventricle.

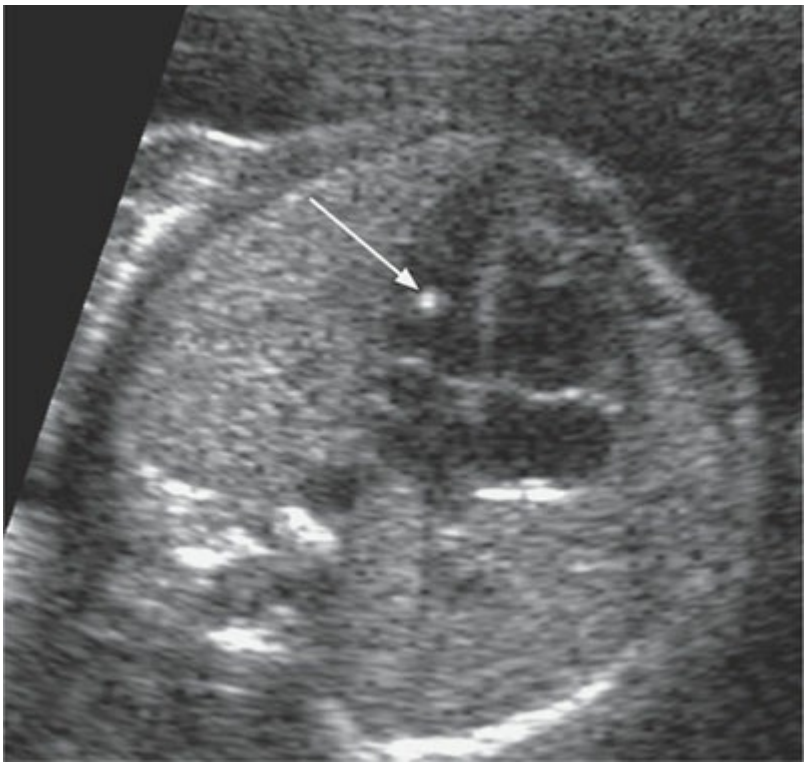


Figure 27-16 Echogenic intracardiac focus. This echogenic focus *(arrow)* is noted within the left ventricle. (Image reprinted with permission from Nyberg D, McGaham J, Pretorius D, et al. Diagnostic Imaging of Fetal Anomalies. Philadelphia: Lippincott Williams & Wilkins, 2003:491.)

SONOGRAPHIC FINDINGS OF A RHABDOMYOMA

1. Echogenic tumor(s) within the myocardium of the heart

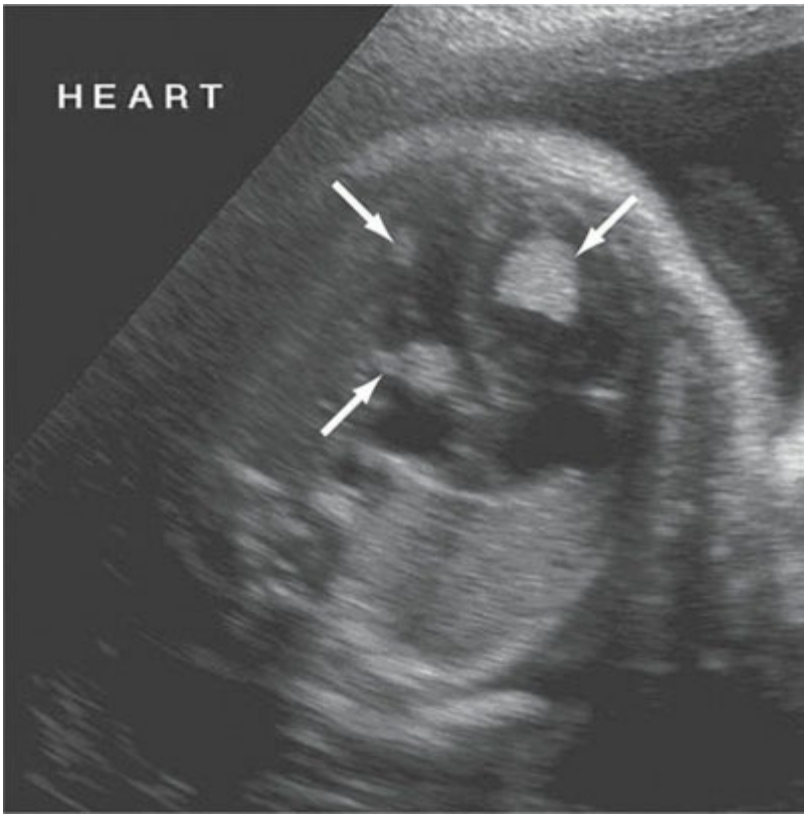


Figure 27-17 Rhabdomyomas. Several echogenic masses are noted within the fetal heart representing rhabdomyomas.

SOUND OFF

The most common fetal cardiac tumor is the rhabdomyoma. It is associated with tuberous sclerosis.

Pericardial Effusion

Pericardial effusion is fluid located around the heart. This condition can be isolated or associated with fetal hydrops. The sonographer should evaluate the fetus closely for other signs of fetal hydrops, such as ascites and pleural effusion (Fig. 27-18). It is important to note that the normal hypoechoic appearance of the myocardium can mimic the sonographic appearance of small pericardial effusions.

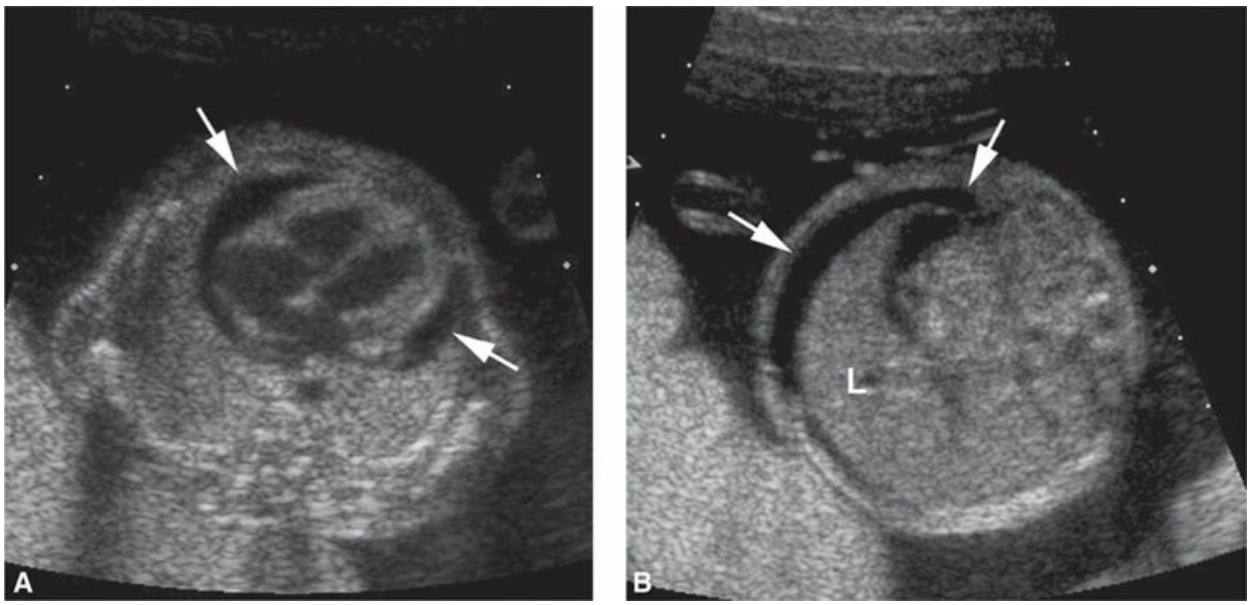


Figure 27-18 Pericardial effusion with hydrops due to anemia. **A.** Transverse image of fetal thorax demonstrating pericardial fluid *(arrows)* around heart. **B.** Transverse image of abdomen in same fetus demonstrating moderate amount of ascites *(arrows)* surrounding the liver (*L*).

SONOGRAPHIC FINDINGS OF PERICARDIAL EFFUSION

1. Anechoic fluid surrounding the heart

Ectopic Cordis

With ectopic cordis, the heart is located either partially or completely outside the chest (Fig. 27-19). Pentalogy of Cantrell is a group of anomalies that combines ectopic cordis and an existing omphalocele. The prognosis is poor.

SONOGRAPHIC FINDINGS OF ECTOPIC CORDIS

1. Heart located either partially or completely outside the chest

FETAL LUNG DEVELOPMENT AND FUNCTION

The lungs develop in early embryogenesis. However, functional fetal lung tissue does not typically exist until after 25 weeks. Fetal lung maturity can be assessed using the lecithin to sphingomyelin ratio (L/S ratio). An amniocentesis is performed for this test, and the laboratory findings indicate the levels of lecithin and sphingomyelin within the amniotic fluid. Normally, as the lungs mature, the level of lecithin increases, whereas the level of sphingomyelin decreases.

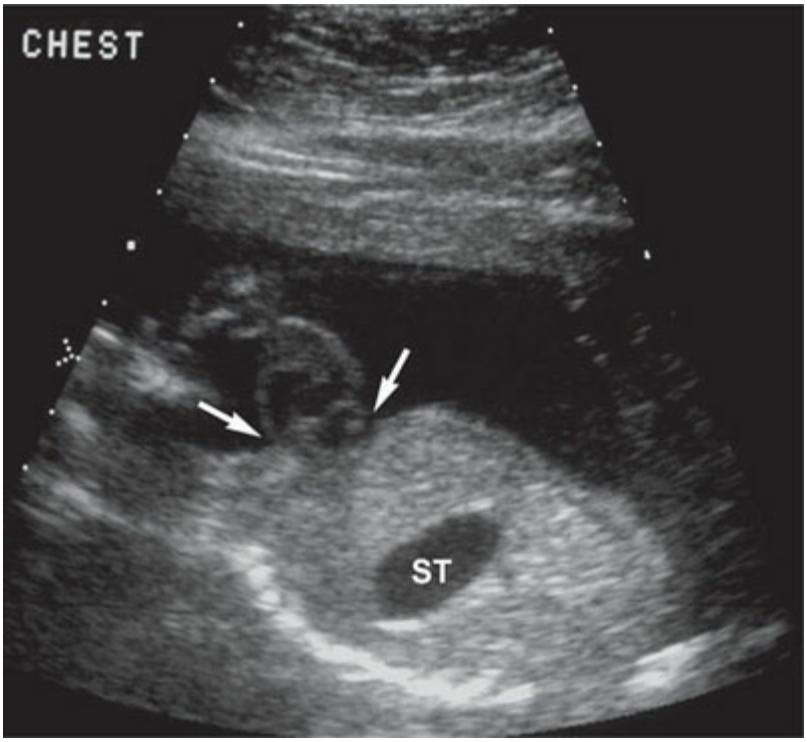


Figure 27-19 Ectopic cordis. Oblique longitudinal image demonstrating a defect in the anterior chest wall *(arrows)* through which the heart has herniated (*ST*, stomach).

FETAL LUNG ABNORMALITIES

Pulmonary Hypoplasia

Pulmonary hypoplasia, or underdevelopment of the lungs, is caused by a decreased number of lung cells, airways, and alveoli. Pulmonary hypoplasia is often associated with major structural and chromosomal abnormalities. The most common lesion that occupies the chest, resulting in pulmonary hypoplasia, is the diaphragmatic hernia. Amniotic fluid plays an important role in the development of the fetal lungs; therefore, the fetus, surrounded by little or no amniotic fluid, is at increased risk of pulmonary hypoplasia. Consequently, pulmonary hypoplasia is a common finding with oligohydramnios. It is also associated with bilateral renal agenesis and the abnormal facial features in the condition known as Potter syndrome.

Pleural Effusion

Fluid surrounding the lungs is referred to as a pleural effusion or hydrothorax. Pleural effusions that occur in utero may spontaneously resolve or may be found in the presence of fetal hydrops, other chest abnormalities, and Turner syndrome. They can be unilateral or bilateral (Fig. 27-20). A pleural effusion will appear sonographically as anechoic fluid within the chest surrounding the fetal lung. The “bat-wing” sign has been used to describe the appearance of pleural effusions. Fetal pleural effusions can be

treated with an ultrasound-guided thoracentesis.

SONOGRAPHIC FINDINGS OF A PLEURAL EFFUSION

1. Anechoic fluid surrounding the fetal lung(s) - “bat-wing” sign
2. Other signs of hydrops may be present

Cystic Adenomatoid Malformation

Cystic adenomatoid malformation (CAM), also referred to as congenital cystic adenomatoid malformation (CCAM), is actually a mass consisting of abnormal bronchial and lung tissue. Although there are three types (Types 1 to 3), a common sonographic appearance of CAM is that of a mass that has both cystic and solid components. However, it can also appear completely echogenic (Type 3), and therefore sonographically similar to pulmonary sequestration (Fig. 27-21). Most CAMs are unilateral and may resolve spontaneously, although large masses can lead to fetal hydrops and carry a poor prognosis.

SONOGRAPHIC APPEARANCE OF CYSTIC ADENOMATOID MALFORMATIONS

1. Lung mass with varying degrees of cystic and solid components
2. Completely echogenic mass within the lungs
3. Pleural effusion may be present

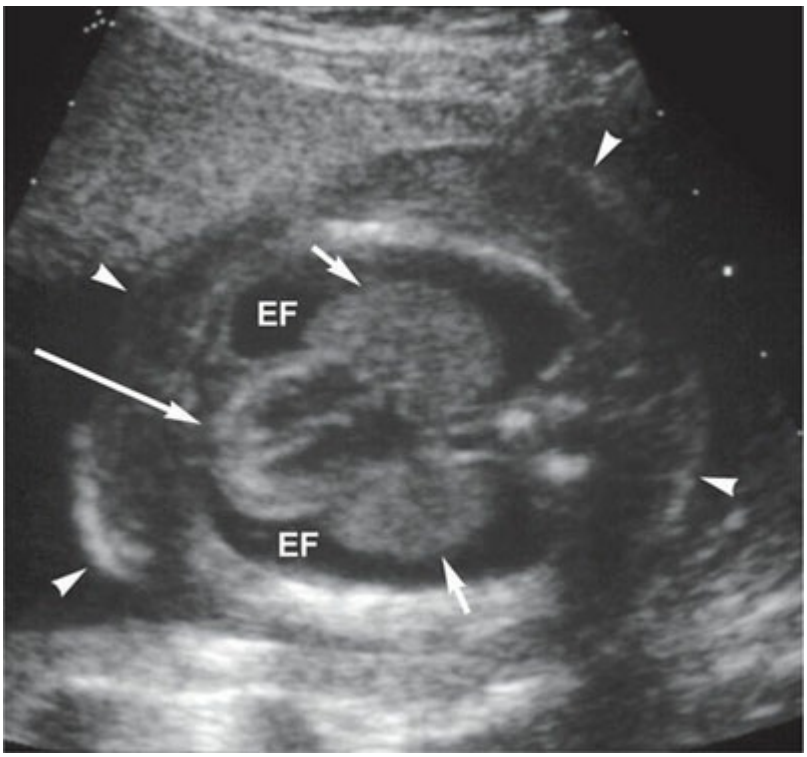


Figure 27-20 Bilateral pleural effusions. Transverse view through the thorax demonstrating moderate-size bilateral pleural effusions (*EF*) surrounding the fetal lungs *(arrows)*. This fetus also has subcutaneous edema *(arrowheads)* around the thorax.

Pulmonary Sequestration

Pulmonary sequestration, or bronchopulmonary sequestration, is a separate mass of nonfunctioning lung tissue with its own blood supply. The fetal form of this disease is specifically referred to as extrapulmonary sequestration, which denotes its location. The most common sonographic appearance of pulmonary sequestration is an echogenic, triangular-shaped mass, typically located within the left side of the fetal chest. Pulmonary sequestration may resolve spontaneously or lead to the development of fetal hydrops.

SONOGRAPHIC FINDINGS OF PULMONARY SEQUESTRATION

1. Echogenic, triangular-shaped mass within the fetal chest
2. Pleural effusion may be present

SOUND OFF

Pulmonary sequestration, or bronchopulmonary sequestration, is a separate mass of nonfunctioning lung tissue with its own blood supply.

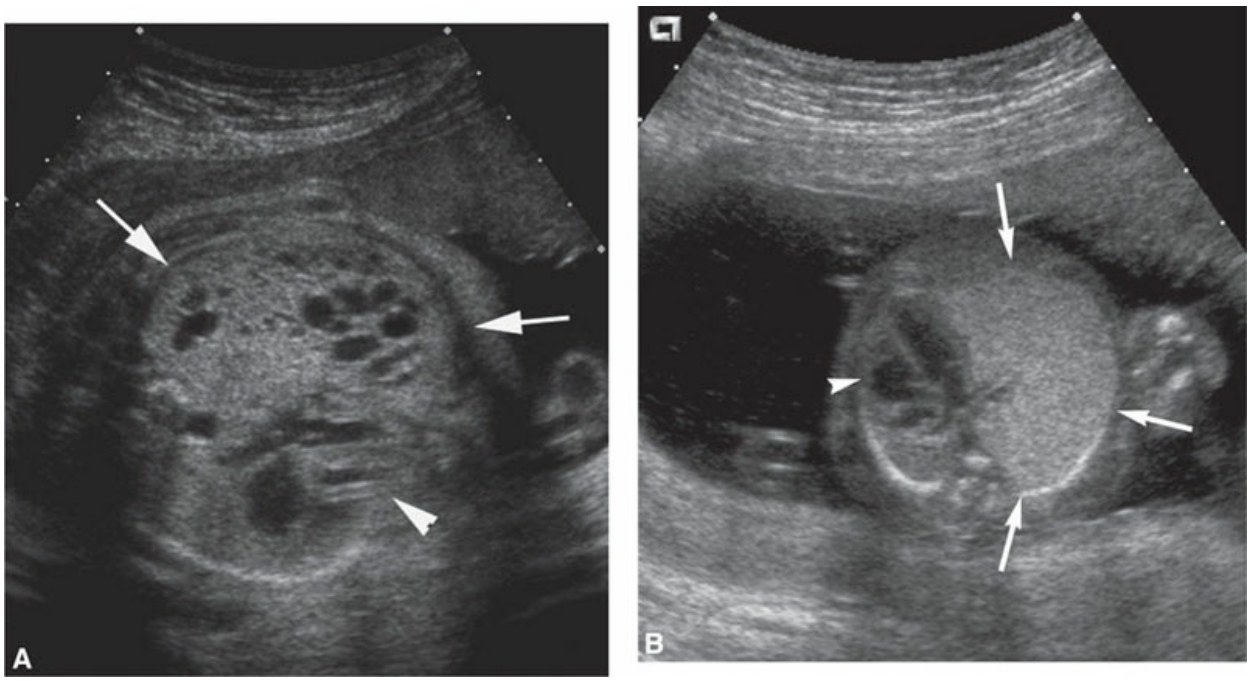


Figure 27-21 Cystic adenomatoid malformation. **A.** Axial image of the chest containing a complex mass with cystic components *(arrows)* that has altered the position of the fetal heart. **B.** Echogenic form of cystic adenomatoid malformation of the lung. Transverse view through the fetal chest demonstrating an echogenic mass

(arrows) in the left hemithorax displacing the heart (*arrowhead*) to the right.

Diaphragmatic Hernias

The most common reason for fetal cardiac malposition is the existence of a diaphragmatic hernia. A diaphragmatic hernia results in an abnormal opening in the fetal diaphragm that allows the herniation of abdominal contents into the chest cavity. The most common location of a diaphragmatic hernia is on the left side. This type may also be referred to as a Bochdalek hernia. The foramen of Bochdalek is located in the left posterolateral portion of the diaphragm. In most cases, the stomach, bowel, and the left lobe of the liver are found within the chest (Fig. 27-22). The foramen of Morgagni, which is located right anteromedially within the diaphragm, may lead to a right-sided diaphragmatic hernia, thus allowing the entire liver to herniate into the chest. Diaphragmatic hernias that are located on the right side may be more difficult to diagnose, given the similar echogenicity of the fetal lungs and fetal liver.

SOUND OFF

The most common location of a diaphragmatic hernia is on the left side. This type may also be referred to as a Bochdalek hernia.

The sonographic findings of a diaphragmatic hernia include malposition of the heart as a result of the stomach or other abdominal organs being located within the chest. Often, sagittal and coronal imaging at the level of the diaphragm can be helpful to confirm this abnormality. One differential diagnosis of a diaphragmatic hernia is eventration of the diaphragm, which is a lack of muscle in the dome of the diaphragm. This will have a similar sonographic appearance to a diaphragmatic hernia and can therefore be difficult to distinguish sonographically.

SONOGRAPHIC FINDINGS OF A DIAPHRAGMATIC HERNIA

1. Malposition of the heart
2. Anechoic stomach bubble noted adjacent to the fetal heart in the four-chamber heart view
3. Other abdominal organs, including the liver, pancreas, and spleen, may be located along the chest

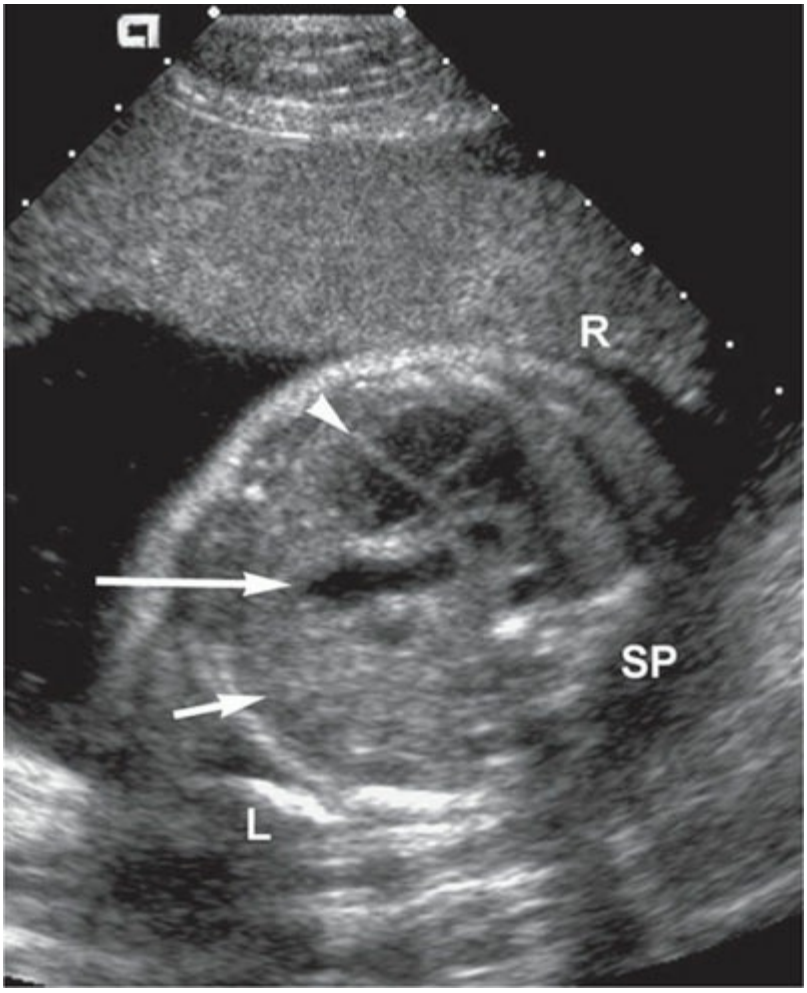


Figure 27-22 Left diaphragmatic hernia. Transverse view of the fetal thorax (*L*, left side; *R*, right side; *SP*, spine) demonstrating the heart *(arrowhead)* deviated to the right by the intrathoracic stomach *(long arrow)* and bowel *(short arrow)*.

FETAL THYMUS

The thymus gland is located anterior to the mediastinum. It is part of the immune system because it provides a place for the maturation of T cells, which are specialized white blood cells. Although not routinely specifically imaged, the thymus may be seen during a fetal sonogram. Sonographically, it appears as a hypoechoic structure located in the anterior chest at the level of the sternum between the lungs. DiGeorge syndrome is a genetic disorder characterized by an absent or a hypoplastic thymus, which ultimately leads to impairment of the immune system and susceptibility to infection, as well as cognitive disorders, congenital heart defects, palate defects, and hormonal abnormalities.

REVIEW QUESTIONS

1. What is the opening located right anteromedially within the diaphragm?
   a. Foramen of Bochdalek
   b. Foramen of Morgagni
   c. Foramen of Monro
   d. Foramen ovale

2. A group of anomalies characterized by a small or an absent left ventricle is:
   a. Turner syndrome
   b. Hypoplastic right heart syndrome
   c. Hypoplastic left heart syndrome
   d. Coarctation of the aorta

3. What is described as the absence of the pulmonary valve, which in turn prohibits blood flow from the right ventricle into the pulmonary artery and essentially to the lungs?
   a. Pulmonary atresia
   b. Pulmonary stenosis
   c. Pulmonary sequestration
   d. Pulmonary effusion

4. A group of anomalies characterized by a small or an absent right ventricle is:
   a. Turner syndrome
   b. Hypoplastic right heart syndrome
   c. Hypoplastic left heart syndrome
   d. Coarctation of the aorta

5. All of the following are sonographic signs of Ebstein anomaly except:
   a. Enlarged right atrium
   b. Fetal hydrops
   c. Narrowing of the aortic arch
   d. Malpositioned tricuspid valve

6. What is an opening within the septum that separates the right and the left ventricles?
   a. Endocardial cushion
   b. Tricuspid regeneration
   c. VSD
   d. ASD

7. The narrowing of the aortic arch is indicative of:
   a. Tetralogy of Fallot

b. Coarctation of the aorta
c. Ebstein anomaly
d. Hypoplastic right heart syndrome

8. An EIF is most often seen within the:
   a. Right atrium
   b. Left atrium
   c. Right ventricle
   d. Left ventricle

9. What is the term for underdevelopment of the lungs?
   a. Pulmonary atresia
   b. Pulmonary stenosis
   c. Pulmonary agenesis
   d. Pulmonary hypoplasia

10. An EIF would most likely be associated with:
    a. Trisomy 21
    b. Trisomy 13
    c. Trisomy 8
    d. Turner syndrome

11. The most common fetal cardiac tumor is the:
    a. Rhabdomyoma
    b. Chordae tendineae
    c. Cardiomyoma
    d. CAM

12. All of the following are sonographic features of pentalogy of Cantrell except:
    a. Omphalocele
    b. Gastroschisis
    c. Cleft sternum
    d. Diaphragmatic defect

13. What is the fetal shunt that connects the pulmonary artery to the aortic arch?
    a. Foramen ovale
    b. Ductus arteriosis
    c. Ductus venosis
    d. Foramen of Bochdalek

14. The accumulation of fluid around the lungs is termed:

a. Ascites
b. Extracorporeal effusion
c. Peripleural fluid
d. Pleural effusion

15. The normal heart will fill approximately ___ of the fetal chest.
a. one half
b. one-fourth
c. one-fifth
d. one-third

16. The condition in which the heart is located outside the chest wall is termed:
a. CAM
b. Coarctation of the heart
c. Cardiac sequestration
d. Ectopic cordis

17. The most common form of diaphragmatic hernia is the:
a. Foramen of Morgagni
b. Foramen of Magendie
c. Foramen of Luschka
d. Foramen of Bochdalek

18. The moderator band is located within the:
a. Right atrium
b. Left atrium
c. Right ventricle
d. Left ventricle

19. The most common cause of cardiac malposition is:
a. Diaphragmatic hernia
b. Omphalocele
c. Gastroschisis
d. Pulmonary hypoplasia

20. A separate mass of nonfunctioning fetal lung tissue is referred to as:
a. Pulmonary adenomatoid malformation
b. Pulmonary sequestration
c. CAM
d. Bat wing sign

21. The tricuspid valve is located:

a. Between the right atrium and the left atrium
b. Between the right ventricle and the right atrium
c. Between the left ventricle and the left atrium
d. Between the left atrium and the aorta

22. The most common sonographic appearance of pulmonary sequestration is a(n):
a. Dilated pulmonary artery and hypoechoic chest mass
b. Pleural effusion and ipsilateral hiatal hernia
c. Triangular, echogenic mass within the chest
d. Anechoic mass within the chest

23. The embryonic heart begins as:
a. Two tubes
b. Four tubes
c. Eight folds
d. One tube

24. Tetralogy of Fallot consists of all of the following except:
a. Overriding aortic root
b. VSD
c. Pulmonary stenosis
d. Left ventricular hypertrophy

25. Eventration of the diaphragm is best described as:
a. A lack of muscle in the dome of the diaphragm
b. A defect in the anterior lateral wall of the diaphragm
c. A defect in the posterolateral wall of the diaphragm
d. Congenital absence of the diaphragm

26. The visualization of the fetal stomach within the fetal chest is most indicative of:
a. Pulmonary sequestration
b. Diaphragmatic hernia
c. Turner syndrome
d. CAM

27. The sonographic “bat-wing” sign is indicative of:
a. Pericardial effusion
b. Pulmonary atresia
c. Pleural effusion
d. Endocardial cushion defects

28. The mitral valve is located:
    a. Between the right atrium and the left atrium
    b. Between the right ventricle and the right atrium
    c. Between the left ventricle and the left atrium
    d. Between the left atrium and the aorta

29. Which statement is true concerning fetal outflow tracts?
    a. The normal pulmonary artery should be positioned posterior to the aorta and should be visualized passing under it.
    b. The normal pulmonary artery should be positioned anterior to the aorta and should be visualized crossing over it.
    c. The right ventricular outflow tract leads to the aorta.
    d. The left ventricular outflow tract leads to the pulmonary artery.

30. Fetal lung maturity can be assessed using the:
    a. LS ratio
    b. Systolic to diastolic ratio
    c. Estriol to alpha-fetoprotein ratio
    d. Lung size formula

31. Which of the following are fetal rhabdomyomas associated with?
    a. Tracheoesophageal fistulas
    b. Tuberous sclerosis
    c. Eventration of the diaphragm
    d. Tuberculosis

32. Which of the following is considered to be the most common cardiac defect?
    a. Hypoplastic right heart syndrome
    b. Transposition of the great vessels
    c. Hypoplastic left heart syndrome
    d. VSD

33. What is the normal opening in the lower middle third of the atrial septum?
    a. Foramen of Magendie
    b. Foramen of Monro
    c. Foramen ovale
    d. Ductus arteriosus

34. What structure shunts blood into the IVC from the umbilical vein?
    a. Ductus venosus
    b. Ductus arteriosus

c. Foramen ovale
d. Foramen of Luschka

35. Which of the following is not a true statement about the normal fetal heart?
    a. The ventricular septum should be uninterrupted and of equal thickness to the left ventricular wall.
    b. There is a normal opening within the atrial septum.
    c. Between the right ventricle and the right atrium, one should visualize the tricuspid valve.
    d. The mitral valve is positioned closer to the cardiac apex than the tricuspid valve.

36. The blood returning from the lungs through the pulmonary veins enters into the:
    a. Right atrium
    b. Left atrium
    c. Right ventricle
    d. Left ventricle

37. Which of the following is a true statement about the fetal heart?
    a. The apex of the heart will be angled to the right of the midline.
    b. The apex of the heart is the portion closest to the spine.
    c. The normal fetal heart will fill approximately two-third of the fetal chest.
    d. The chamber closest to the fetal spine is the left atrium.

38. The fetal heart is fully formed by:
    a. 2 weeks
    b. 4 weeks
    c. 8 weeks
    d. 10 weeks

39. A coexisting pericardial effusion and a pleural effusion is consistent with the diagnosis of:
    a. Tetralogy of Fallot
    b. Pentalogy of Cantrell
    c. Fetal hydrops
    d. Potter syndrome

40. Which of the following best describes transposition of the great vessels?
    a. The aorta arises from the left ventricle, and the pulmonary artery arises from the right ventricle.

b. The aorta arises from the right ventricle, and the pulmonary artery arises from the left ventricle.
c. The aortic arch is narrowed and positioned anterior to the pulmonary vein.
d. The presence of an omphalocele and ectopic cordis.

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28

The Fetal Gastrointestinal System

Introduction

The gastrointestinal system and abdominal wall defects of the fetus are discussed in this chapter. Most of the fetal abdominal abnormalities can be detected during a routine sonographic examination. While acquiring the abdominal circumference measurements, the sonographer can assess the position of gastrointestinal organs and their size. The sonographic appearance and relationship of the stomach with the fetal heart is an important objective. It is the obligation of the sonographer to utilize critical thinking when abnormalities are discovered in the fetal abdomen, because many of them have multiple associated findings in other systems of the body.

Key Terms

abdominal circumference—fetal biometric measurement made of the abdomen in the second and third trimesters; used in conjunction with other measurements to date the pregnancy and size the fetus

anorectal atresia—congenital maldevelopment of the rectum and absence of the anal opening

ascites—excessive fluid in the peritoneal cavity

Beckwith–Wiedemann syndrome—a growth disorder syndrome synonymous with enlargement of several organs, including the skull, tongue, and liver

cholangitis—inflammation of the bile ducts

choledochal cyst—the cystic dilatation of the common bile duct

cystic fibrosis—an inherited disorder in which mucus secreting organs such as the lungs, pancreas, and other digestive organs produce thick and sticky secretions instead of normal secretions

double bubble sign—classic sonographic sign of duodenal atresia representing the stomach and proximal duodenum

duodenal atresia—congenital maldevelopment or absence of duodenum

esophageal atresia—congenital absence of part of the esophagus

gastroschisis—herniation of abdominal contents through a right-sided, periumbilical abdominal wall defect

hepatomegaly—enlargement of the liver

Hirschsprung disease—a disease that leads to a functional bowel obstruction because of the lack of nerve cells within the colon wall

intrauterine growth restriction—a fetus that is below the 10th percentile for gestational age (small for gestational age) and whose growth is impeded for some reason

meconium—fetal stool that is composed of fetal skin, hair, amniotic fluid, and bile

omphalocele—an anterior abdominal wall defect where there is herniation of the fetal bowel and other abdominal organs into the base of the umbilical cord

pentalogy of Cantrell—a group of anomalies that includes an omphalocele, along with ectopic cordis, cleft sternum, anterior diaphragmatic defect, and pericardial defects

physiologic bowel herniation—the normal developmental stage when the midgut migrates into the base of the umbilical cord

polyhydramnios—an excessive amount of amniotic fluid for the gestational age

portal hypertension—the elevation of blood pressure within the portal venous system

tracheoesophageal fistula—an abnormal connection between the esophagus and the trachea

Turner syndrome—a chromosomal aberration where one sex chromosome is absent; may also be referred to as monosomy X

VACTERL—acronym for associated anomalies; stands for vertebral anomalies, anal atresia, cardiac anomalies, tracheoesophageal fistula or esophageal atresia, renal anomalies, and limb anomalies

NORMAL FETAL GASTROINTESTINAL ANATOMY AND THE ABDOMINAL CIRCUMFERENCE

The fetal gut develops at the end of the fifth menstrual week and can be divided into the foregut, midgut, and hindgut. Abdominal organs, such as the stomach, liver, spleen, gallbladder, pancreas, small intestine, and colon, may all be evaluated during a sonographic examination. The esophagus may be visualized when needed as several parallel echogenic lines within the thorax. Transvaginally, the fetal stomach can be visualized as early as 8 weeks' gestation, but most certainly should be seen by 14 weeks in the left upper quadrant as an anechoic, circular organ. The position of the stomach should be noted in relationship to the fetal heart. Both small bowel and the colon can be examined using sonography. Differentiating small bowel from the colon is achieved late in gestation, because the colon offers larger loops within the periphery of the abdomen and contains hypoechoic material representing meconium.

The abdominal circumference is a measurement of the fetal abdomen that is made in the second and third trimesters. The abdominal circumference is made in the axial view of the fetus and should include the fetal stomach, transverse thoracic spine, and intrahepatic portion of the umbilical vein. The electronic calipers are placed around the entire outer perimeter of the abdomen. The abdominal diameter measurement is taken at the same level, with two perpendicular caliper sets. The formula for the abdominal diameter is $AC = 1.57 \times (AD_1 + AD_2)$.



SOUND OFF

The abdominal circumference is made in the axial view of the fetus and should include the fetal stomach, transverse thoracic spine, and intrahepatic portion of the umbilical vein.

FETAL GASTROINTESTINAL ABNORMALITIES

Gastrointestinal Abnormalities and Polyhydramnios

Polyhydramnios, or excessive amniotic fluid, can be noted with multiple anomalies. However, sonographers must understand why polyhydramnios results from some gastrointestinal abnormalities. During fetal development, there are several structures that are thought to produce amniotic fluid. Initially, in early embryologic development, the origin of amniotic fluid is thought to result from an osmotic process, because water crosses the amniotic space freely. In later gestation, somewhere around 9 weeks, the

fetal kidneys begin to produce urine, a liquid that eventually comprises most of the amniotic fluid.

SOUND OFF
Fetal urine contributes greatly to the amount of amniotic fluid.

Amniotic fluid is a substance that contains valuable proteins that are essential for normal fetal development. The fetus ingests amniotic fluid by swallowing. The fluid passes through the esophagus, into the stomach, and travels through the small bowel and into the colon, where absorption takes place. Polyhydramnios results when there is an obstruction or disturbance to the normal flow and absorption of amniotic fluid. For instance, the fetus that suffers from esophageal atresia or duodenal atresia cannot transport amniotic fluid into the intestines. The fluid exits back out of the esophagus, and absorption cannot take place. Consequently, there is a buildup of amniotic fluid resulting from the continual production of urine by the fetal kidneys, resulting in polyhydramnios.

SOUND OFF
When polyhydramnios is detected, the sonographers should evaluate the fetal gastrointestinal tract carefully for signs of abnormalities such as duodenal or esophageal atresia.

Esophageal Atresia

The congenital absence of part of the esophagus is termed esophageal atresia. Consequently, the esophagus and the trachea often form an abnormal connection known as a tracheoesophageal fistula. This condition is associated with esophageal atresia approximately 90% of the time. The fetal stomach may appear sonographically small or completely absent with esophageal atresia, and there will be evidence of polyhydramnios (Fig. 28-1). Associated anomalies are often present and include duodenal atresia, VACTERL association, Down syndrome, intrauterine growth restriction, and trisomy 18.

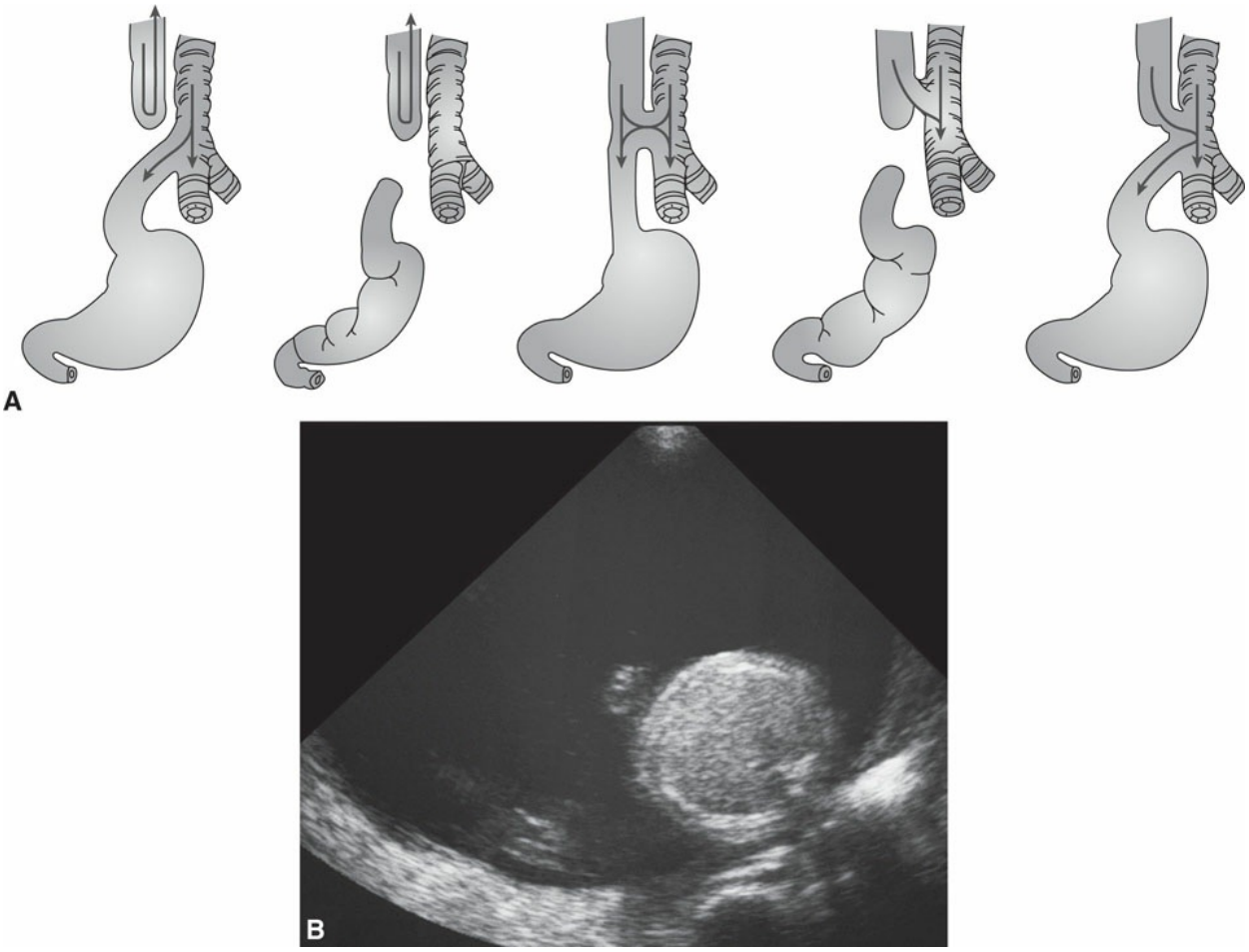


Figure 28-1 Esophageal atresia. **A.** Drawing depicting the varying manifestations of esophageal atresia. **B.** Transverse view of the fetal abdomen revealing no identifiable stomach and severe polyhydramnios.

SONOGRAPHIC FINDINGS OF ESOPHAGEAL ATRESIA

1. Absent or small stomach
2. Polyhydramnios
3. Intrauterine growth restriction

Duodenal Atresia

The congenital maldevelopment or absence of the proximal portion of the small bowel, the duodenum, is termed duodenal atresia (Fig. 28-2). Duodenal atresia classically presents sonographically as a dilated, fluid-filled anechoic stomach and an anechoic fluid-filled proximal duodenum, offering the "double bubble" sign (Fig. 28-3). Duodenal atresia has a proven association with trisomy 21, and thus additional sonographic markers of trisomy 21 should be aggressively investigated during the examination. Other associated anomalies include esophageal atresia, VACTERL association, intrauterine growth restriction, and cardiac anomalies.

SONOGRAPHIC FINDINGS OF DUODENAL ATRESIA

1. “Double bubble” sign
2. Polyhydramnios
3. Intrauterine growth restriction



SOUND OFF
Duodenal atresia classically presents as the “double bubble” sign.

Abnormalities of the Fetal Liver, Spleen, Gallbladder, and Biliary Tree

The fetal liver may be evaluated in utero. It is essential to remember that in the fetus, the left lobe of the liver is typically larger than the right lobe. This is secondary to the way in which the fetal circulatory system provides more oxygen to the left lobe in utero. Hepatomegaly is the most common abnormality of the fetal liver. Hepatomegaly may occur as a result of intrauterine infections, fetal anemia (Rh incompatibility), or be seen with Beckwith–Wiedemann syndrome. Enlargement of the fetal spleen—splenomegaly—can accompany hepatomegaly and may be suggestive of intrauterine infections or Rh incompatibility with hydrops.

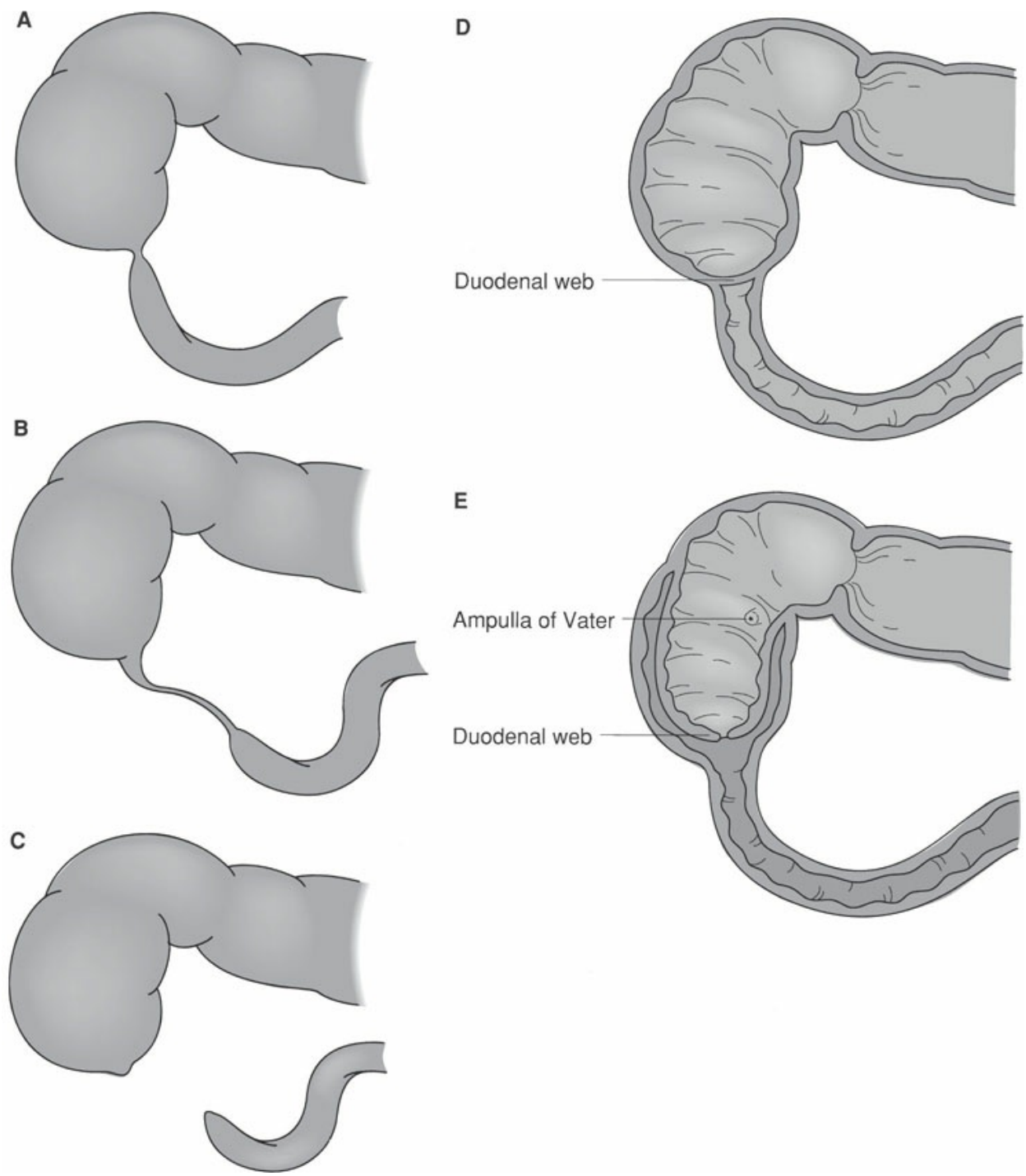


Figure 28-2 Duodenal atresia. *A–E*. Anatomic variants of duodenal atresia.

Fetal gallstones and sludge within the gallbladder may be noted in utero, most often in the third trimester. Gallstones appear sonographically as echogenic foci in the right upper quadrant of the fetus that may or may not produce posterior shadowing (Fig. 28-4). Gallstones that persist postnatally typically resolve spontaneously. An additional rare abnormality of the biliary tree is the choledochal cyst. There are four different types of choledochal cysts, with the most common being described as the cystic dilatation of the common bile duct. Choledochal cysts can lead to cholangitis, portal hypertension, pancreatitis, and liver failure.

SOUND OFF

Hepatomegaly is the most common abnormality of the fetal liver. It can be associated with intrauterine infection, fetal anemia, or Beckwith–Wiedemann syndrome.

FETAL BOWEL ABNORMALITIES AND THE ABDOMINAL WALL

Echogenic Bowel

The analysis of the echogenicity of the fetal small intestine may be part of the fetal screening examination in some institutions. In general, the echogenicity of the small intestine should not be isoechoic to or greater than that of fetal bone (Fig. 28-5). However, the transducer frequency plays a role in the diagnosis of echogenic bowel. One author suggests that if a higher frequency transducer suggests echogenic bowel, that the sonographer should decrease the frequency to ≤5 MHz and decrease the overall gain. Echogenic bowel has been linked with Down syndrome, cystic fibrosis, growth restriction, fetal demise, congenital infections such as cytomegalovirus, and gastrointestinal obstructions.

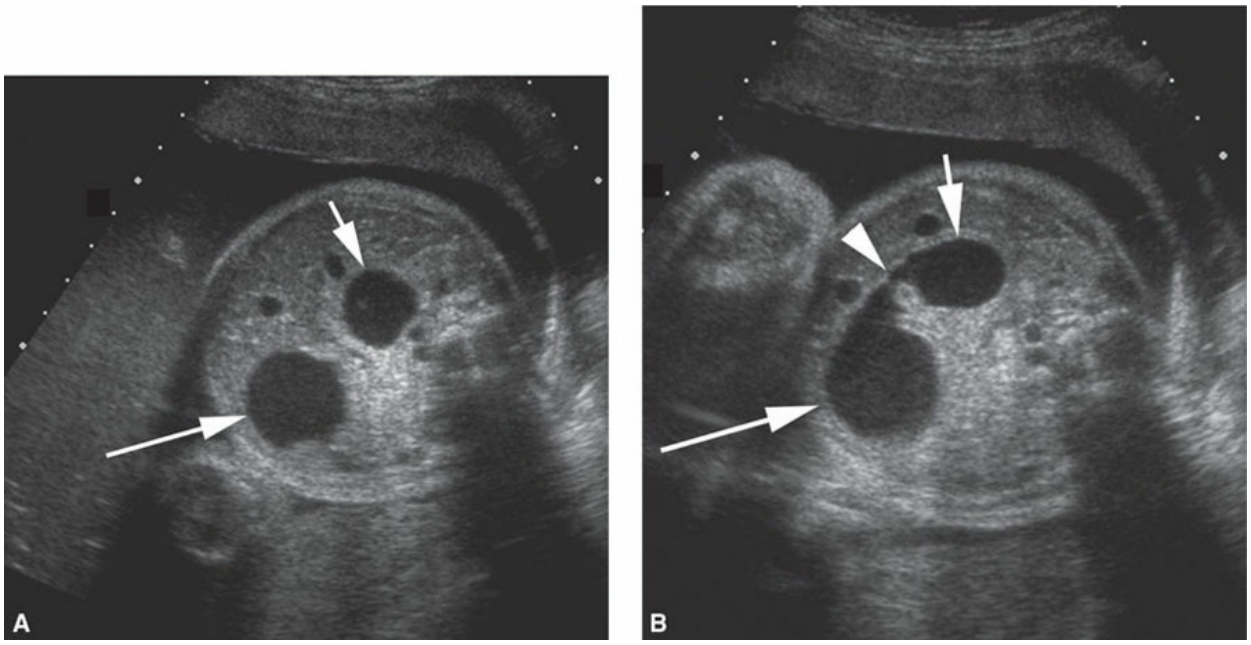


Figure 28-3 Duodenal atresia ("double bubble") in a fetus with trisomy 21. **A.** Transverse view of the fetal upper abdomen demonstrating dilated stomach *(long arrow)* and duodenum *(short arrow)*. **B.** Image in a slightly different plane demonstrating the connection *(arrowhead)* between the stomach *(long arrow)* and duodenum *(short arrow)*.

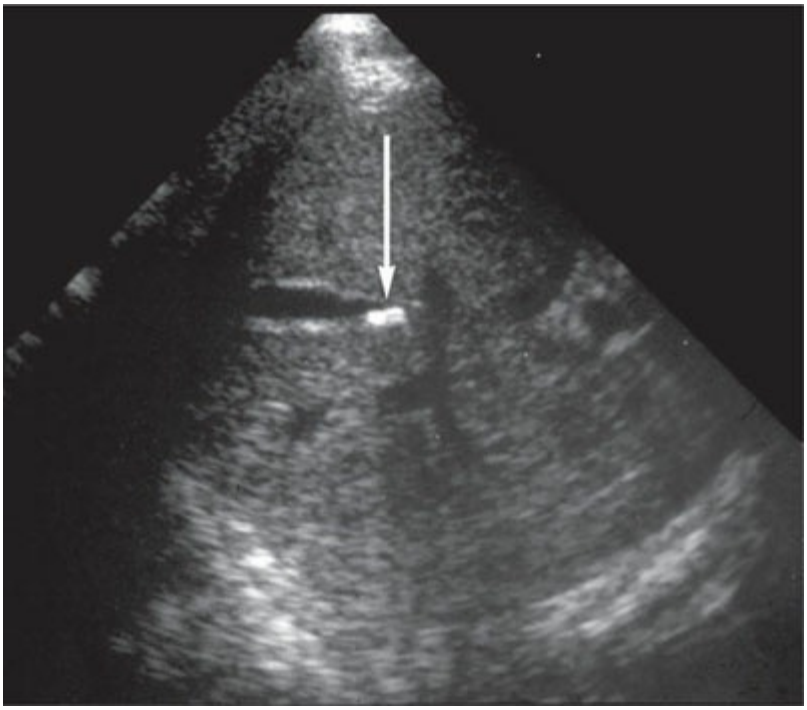


Figure 28-4 Fetal cholelithiasis. Transverse view of the fetal abdomen revealing a gallstone *(arrow)* that produces distal shadowing.



Figure 28-5 Echogenic bowel. At 25 weeks, echogenic small bowel was noted in this fetus with cystic fibrosis.

SOUND OFF
Echogenic bowel has been linked with Down syndrome, cystic fibrosis, growth restriction, fetal demise, congenital infections such as cytomegalovirus, and gastrointestinal obstructions.

Fetal Bowel Obstruction and Anorectal Atresia

Hirschsprung disease, which causes a functional fetal bowel obstruction, is caused by the absence of nerves within the bowel wall. The sonographic finding of dilated loops of bowel within the fetal abdomen is indicative of a fetal bowel obstruction. Obstruction of the fetal bowel most often occurs when there is a meconium plug causing the barrier, a condition referred to as meconium plug syndrome. The most common type of colonic atresia that will lead to a bowel obstruction is anorectal atresia. This congenital maldevelopment of the rectum and anal opening causes dilation of the bowel. Anorectal atresis may be linked with VACTERL association and chromosomal abnormalities, and thus a thorough analysis of the fetus for other abnormalities is vital. Anorectal atresia will most often lead to the visualization of a dilated fetal rectum.



SOUND OFF

Anorectal atresia will most often lead to the visualization of a dilated fetal rectum.

Abdominal Wall Defects and Alpha-Fetoprotein

Gastroschisis and omphalocele are two of the most common ventral abdominal wall defects. As mentioned previously in Chapter 24, alpha-fetoprotein (AFP) exits the fetus through an opening in the neural tube (i.e., an opening in the cranium or spine). AFP may also exit the fetus through an abdominal wall defect, thereby increasing the level of maternal serum alpha-fetoprotein (MSAFP). If an opening is present, a greater amount of AFP is allowed to pass into the maternal circulation. Although MSAFP screening is not specific for abdominal wall defects, elevated levels of MSAFP are found in the presence of omphalocele and gastroschisis and thus can be used as a reliable screening test for the early detection of these and other abnormalities. Furthermore, it is important to note that MSAFP levels have been shown to be much higher in gastroschisis than in omphalocele.



SOUND OFF

If the fetus has an abdominal wall defect (opening in the abdomen), then a greater amount of AFP is allowed to pass into the maternal circulation.

Physiologic (Normal) Bowel Herniation

As a part of normal fetal development during the first trimester, the midgut herniates into the base of the umbilical cord; this is termed physiologic bowel herniation. The intestines return to the abdomen by the 12th gestational

week. Although omphalocele or gastroschisis may be suggested with high-resolution transvaginal imaging in the first trimester, a diagnosis of an abdominal wall defect, such as omphalocele or gastroschisis, may be difficult before 12 weeks, and thus follow-up examinations are often required to confirm the diagnosis. This topic is also discussed in Chapter 23 of this book.

Gastroschisis

Gastroschisis is the herniation of abdominal contents through a right-sided, periumbilical abdominal wall defect (Fig. 28-6). Gastroschisis is thought to be caused by a vascular incident occurring to either the right umbilical vein or the omphalomesenteric artery. Most often, there is herniation of the small intestine, but with larger defects, the stomach and other organs may be found outside the abdomen. The bowel that is exposed to amniotic fluid may become dilated, thick walled, and have decreased peristaltic activity. Gastroschisis, unlike omphalocele, does not have a strong association with chromosomal abnormalities. Although they may suffer from intrauterine growth restriction, the prognosis after surgery for newborns with isolated gastroschisis is much better than for those with omphalocele. Sonographically, normal cord insertion into the abdomen is noted, and most often the right-sided periumbilical mass will be easily identified (Fig. 28-7). Recognizable loops of bowel are often noted outside the abdomen floating in the amniotic fluid, and color Doppler should be used to demonstrate the relationship of the mass to the umbilical cord.

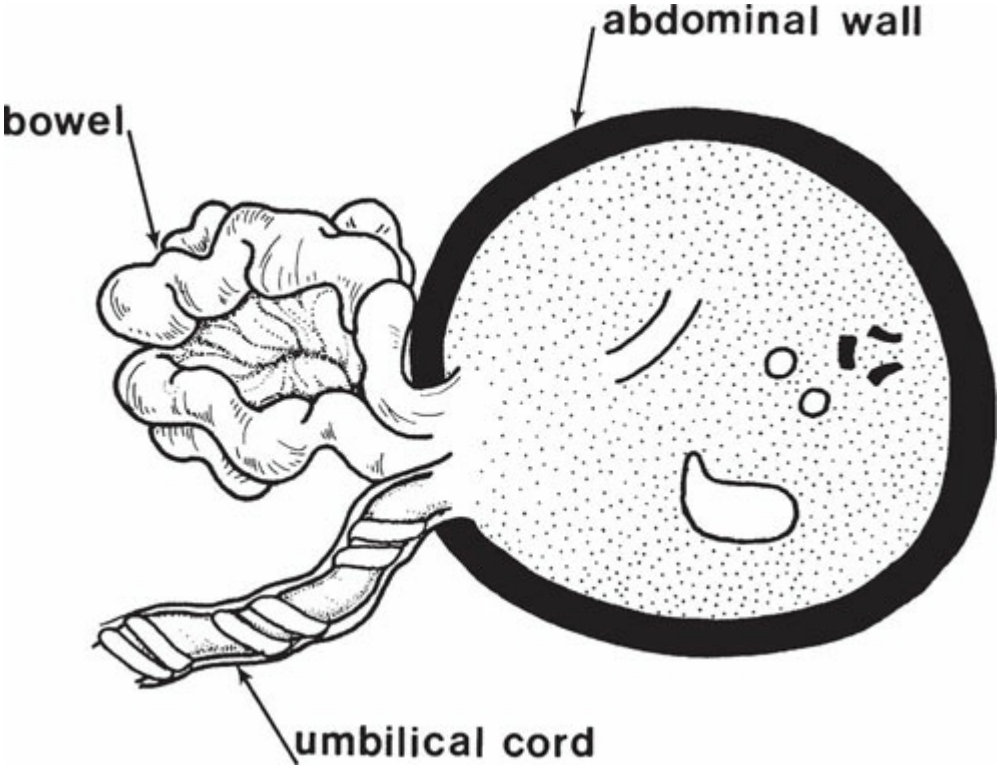
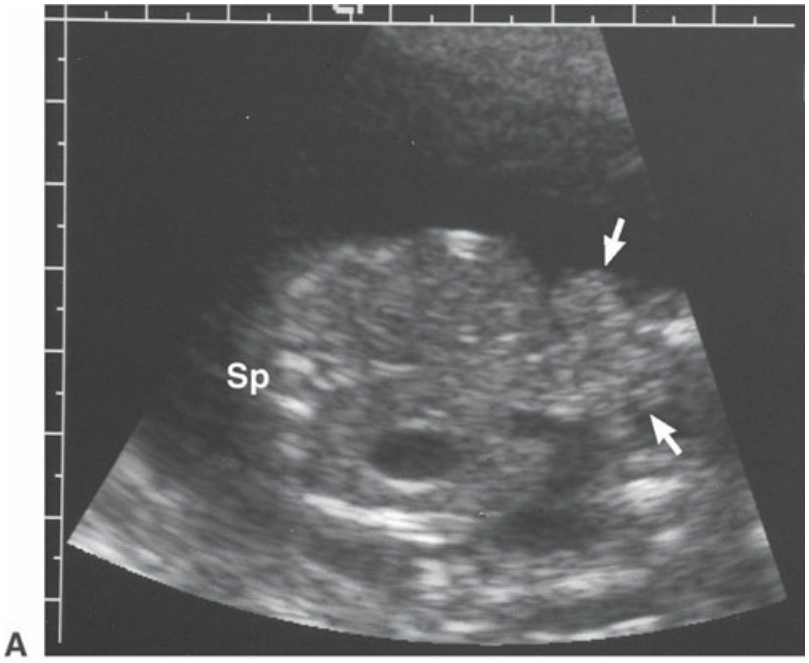
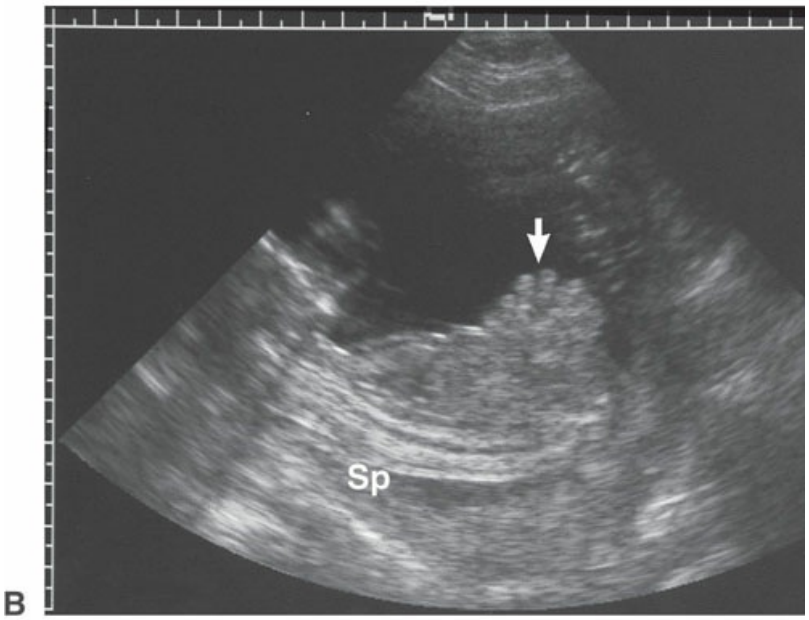


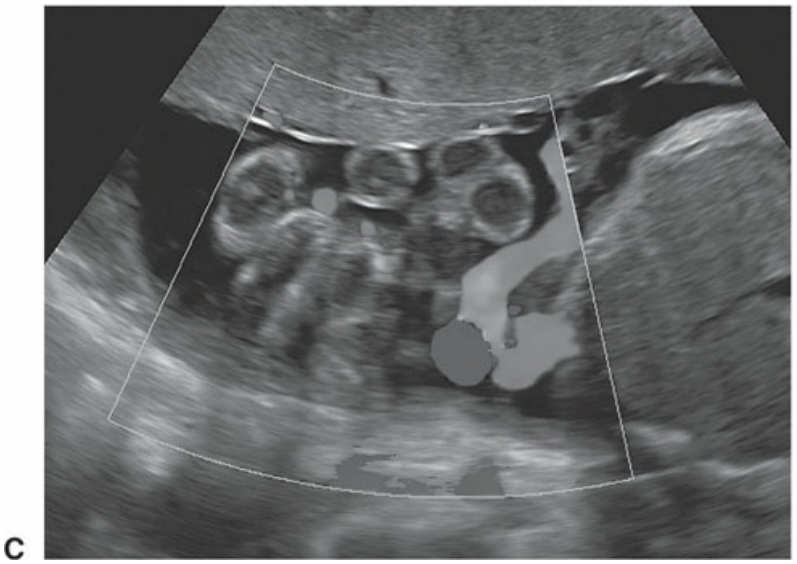
Figure 28-6 Schematic of gastroschisis. Cross-sectional drawing of gastroschisis.



A



B



C

Figure 28-7 Gastroschisis. Transverse (**A**) and longitudinal (**B**) views of a 16-week fetus revealing gastroschisis *(arrows)*. The fetal spine is also noted (*Sp*). **C.** Gastroschisis at 32 weeks. Transverse color Doppler demonstrating the umbilical cord surrounded by dilated bowel loops outside the abdomen. Color image provided online.

CLINICAL FINDINGS OF GASTROSCHISIS

1. Elevated MSAFP

SONOGRAPHIC FINDINGS OF GASTROSCHISIS

1. Normal cord insertion
2. Periumbilical, right-sided mass
3. Recognizable loops of bowel outside the abdomen
4. Intrauterine growth restriction

SOUND OFF
Gastroschisis is the herniation of abdominal contents through a right-sided, periumbilical abdominal wall defect. It generally has a better prognosis than omphalocele.

Omphalocele

The evidence of persistent herniation of the bowel, and potentially other abdominal organs, into the base of the umbilical cord leads to the diagnosis of an omphalocele (Fig. 28-8). An omphalocele is located within the midline of the abdomen. The umbilical cord will insert into this mass. The entire content is contained and covered by peritoneum and amnion. Ascites is often noted within an omphalocele, as well as within the abdomen of the fetus. Ascites may be helpful in demarcating the contents of the mass. It is important to note whether the mass contains liver, because a poorer prognosis corresponds with this type of omphalocele.

SOUND OFF
Omphalocele has a more significant risk for heart defects and chromosomal anomalies than gastroschisis.

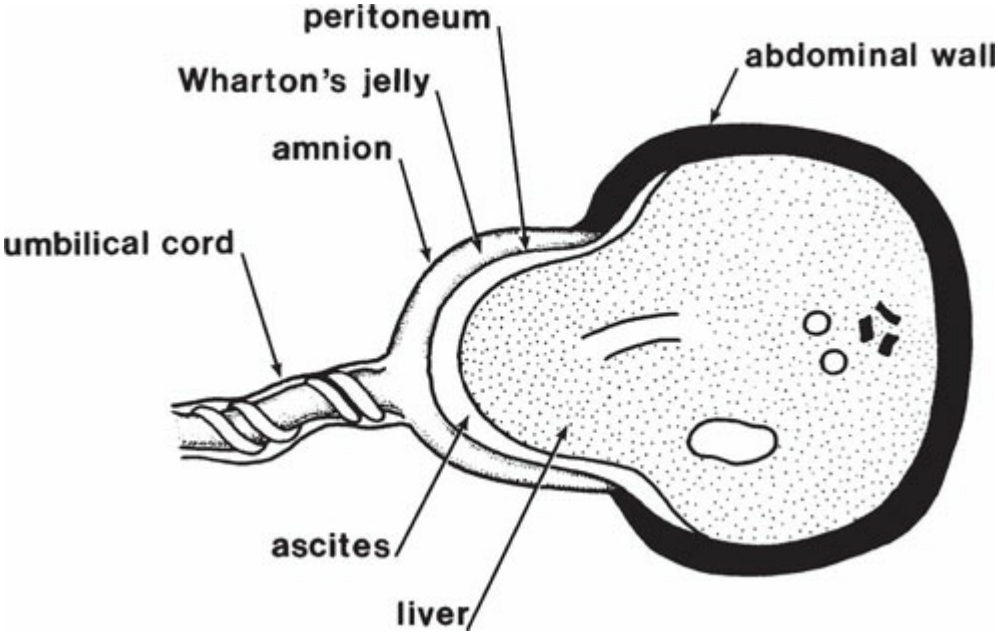


Figure 28-8 Schematic of omphalocele. Cross-sectional drawing of omphalocele containing part of the liver.

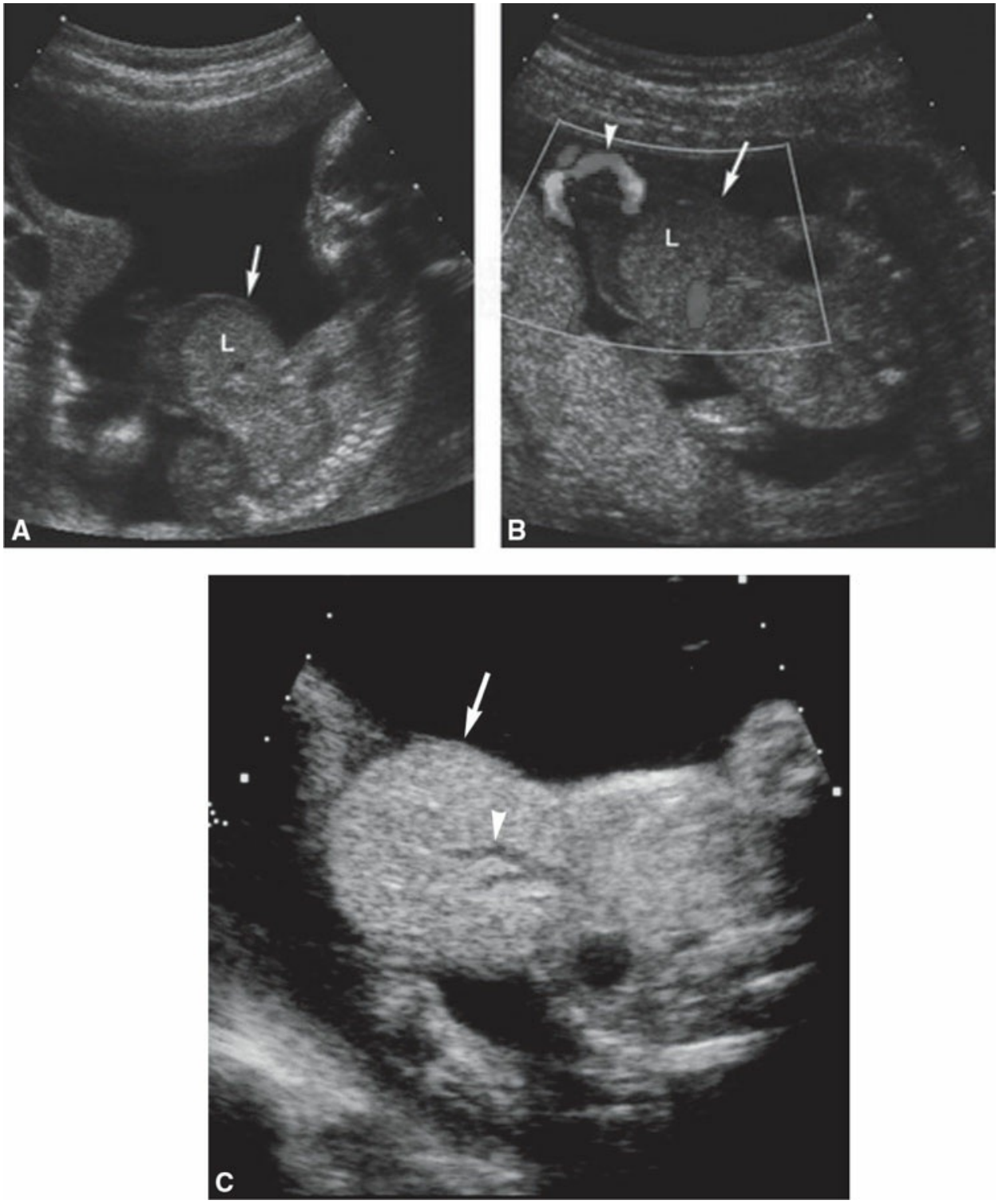


Figure 28-9 Omphalocele containing liver. **A.** Sagittal image of fetus demonstrating large omphalocele *(arrow)* containing a region of homogeneous tissue representing liver (*L*). **B.** Color Doppler image of large omphalocele *(arrow)* showing vessels in the herniated portion of the liver (*L*). Umbilical vessels *(arrowhead)* are seen inserting into the omphalocele sac. Color image provided online. **C.** Transverse image of the fetal abdomen demonstrating a large, rounded omphalocele *(arrow)* that contains part of the liver. The hepatic veins are noted within the liver *(arrowhead)*.

The sonographic appearance of an omphalocele is that of a midline

abdominal mass that contains bowel, the liver, or other abdominal organs (Fig. 28-9). Omphalocele has a more significant risk for heart defects and chromosomal anomalies than gastroschisis. Trisomy 18, trisomy 13, Turner syndrome, and Beckwith–Wiedemann syndrome have all been linked with omphaloceles. Pentalogy of Cantrell is another group of anomalies that includes an omphalocele, along with ectopic cordis, cleft sternum, anterior diaphragmatic defect, and pericardial defects.

CLINICAL FINDINGS OF OMPHALOCELE

1. Elevated MSAFP

SONOGRAPHIC FINDINGS OF OMPHALOCELE

1. Midline abdominal mass at the base of the umbilical cord that contains bowel, the liver, and/or other abdominal organs
2. Abnormal cord insertion into the midline abdominal mass
3. Multiple associated anomalies

REVIEW QUESTIONS

1. Hepatomegaly would least likely be associated with:
   a. Beckwith–Wiedemann syndrome
   b. Fetal anemia
   c. Intrauterine infections
   d. Gastroschisis

2. Normally, physiologic bowel herniation resolves by:
   a. 8 weeks
   b. 10 weeks
   c. 24 weeks
   d. 12 weeks

3. Which of the following is most often associated with duodenal atresia?
   a. Trisomy 21
   b. Trisomy 18
   c. Trisomy 13
   d. Triploidy

4. Hepatomegaly would be seen in conjunction with:
   a. Down syndrome
   b. Edwards syndrome

c. Beckwith–Wiedemann syndrome
d. Hirschsprung disease

5. Pentalogy of Cantrell includes all of the following findings except:
   a. Cardiovascular malformations
   b. Diaphragmatic malformations
   c. Omphalocele
   d. Gastroschisis

6. An excessive amount of amniotic fluid is termed:
   a. Polyhydramnios
   b. Oligohydramnios
   c. Esophageal atresia
   d. Amniotic fluid index

7. The most common abnormality of the fetal liver is:
   a. Gallstones
   b. Hepatocellular lymphadenopathy
   c. Cirrhosis
   d. Hepatomegaly

8. Congenital maldevelopment of the proximal portion of the small intestine is termed:
   a. VACTERL association
   b. Esophageal atresia
   c. Duodenal atresia
   d. Jejunal atresia

9. A functional bowel disorder within the fetus that is caused by the absence of intestinal nerves is found in:
   a. Gastroschisis
   b. Beckwith–Wiedemann syndrome
   c. Omphalocele
   d. Hirschsprung disease

10. Which of the following is associated with echogenic bowel?
    a. Fetal anemia
    b. Cystic fibrosis
    c. Radial ray syndrome
    d. Portal hypertension

11. What chromosomal anomaly is associated with echogenic bowel?
    a. Trisomy 18

b. Trisomy 13
c. Trisomy 21
d. Triploidy

12. The herniation of the bowel into the base of the umbilical cord before 12 weeks is termed:
    a. Gastroschisis
    b. Omphalocele
    c. Hernia umbilicus
    d. Physiologic herniation

13. All of the following are associated with omphalocele except:
    a. Trisomy 18
    b. Pentalogy of Cantrell
    c. Intrauterine growth restriction
    d. Hirschsprung disease

14. The fetal stomach should be visualized by:
    a. 6 weeks
    b. 14 weeks
    c. 20 weeks
    d. 18 weeks

15. All of the following are associated with esophageal atresia except:
    a. Down syndrome
    b. VACTERL association
    c. Edwards syndrome
    d. Oligohydramnios

16. An abnormal connection between the esophagus and trachea is termed:
    a. Esophageal-duodenal herniation
    b. Double bubble sign
    c. Esophageal atresia
    d. Tracheoesophageal fistula

17. In what location does gastroschisis occur more often?
    a. Left lateral of the cord insertion
    b. Right lateral of the cord insertion
    c. Just superior to the fetal bladder
    d. Base of the umbilical cord

18. The congenital absence of part of the esophagus is termed:
    a. Duodenal atresia

b. VACTERL association
c. Down syndrome
d. Esophageal atresia

19. The “double bubble” sign is indicative of:
    a. Esophageal atresia
    b. Duodenal atresia
    c. Hydrocephalus
    d. Anorectal atresia

20. All of the following are associated with gastroschisis except:
    a. Normal cord insertion
    b. Multiple chromosomal abnormalities
    c. Elevated MSAFP
    d. Periumbilical mass

21. Which of the following laboratory values would be significant in the detection of an abdominal wall defect?
    a. MSAFP
    b. Human chorionic gonadotropin
    c. Maternal serum amylase
    d. Estradiol

22. What is an inherited disorder in which mucus secreting organs such as the lungs, pancreas, and other digestive organs produce thick and sticky secretions instead of normal secretions?
    a. Hirschsprung disease
    b. Cystic fibrosis
    c. Multiple sclerosis
    d. Turner syndrome

23. What organ(s) produces amniotic fluid after 12 weeks?
    a. Fetal liver and the spleen
    b. Fetal intestines and lungs
    c. Fetal intestines and the liver
    d. Fetal kidneys

24. An omphalocele is associated with all of the following except:
    a. Pentalogy of Cantrell
    b. Trisomy 18
    c. Patau syndrome
    d. Meconium aspiration syndrome

25. Duodenal atresia and esophageal atresia are associated with:
    a. Oligohydramnios
    b. Polyhydramnios
    c. Normal amniotic fluid index
    d. Anhydramnios

26. The fetal gut develops at the end of the fifth menstrual week and can be divided into all of the following except:
    a. Midgut
    b. Foregut
    c. Centralgut
    d. Hindgut

27. Intrauterine growth restriction is defined as:
    a. A small-for-dates fetus
    b. A fetus that falls below the 10th percentile for gestational age
    c. A fetus that is immunocompromised and has decreased umbilical cord Doppler ratios for gestational age
    d. A fetus that fall below the fifth percentile for gestational age

28. Which of the following best describes a choledochal cyst?
    a. It is the cystic dilatation of the common bile duct.
    b. It is the herniation of the abdominal contents into the umbilical cord.
    c. It is the congenital absence of the cystic duct.
    d. It is the inflammation of the biliary tree caused by extrinsic obstruction.

29. Fetal stool is termed:
    a. Plicae
    b. Meconium
    c. Laguna
    d. Lanugo

30. All of the following are associated with omphalocele except:
    a. Normal cord insertion
    b. Multiple chromosomal abnormalities
    c. Elevated MSAFP
    d. Periumbilical mass

31. An omphalocele may contain:
    a. Fetal liver
    b. Ascites
    c. Fetal colon

d. All of the above

32. The congenital maldevelopment of the rectum and absence of anal opening is termed:
    a. Jejunal atresia
    b. Intussusception
    c. Anorectal atresia
    d. Duodenal atresia

33. All of the following are associated with duodenal atresia except:
    a. Trisomy 21
    b. Esophageal atresia
    c. VACTERL association
    d. Turner syndrome

34. Which of the following would be least likely associated with an elevated MSAFP?
    a. Pentalogy of Cantrell
    b. Anorectal atresia
    c. Gastroschisis
    d. Omphalocele

35. Which of the following is considered to be the most common type of colonic atresia?
    a. Duodenal atresia
    b. Jejunal atresia
    c. Anorectal atresia
    d. Intussusception

36. Fetal meconium typically consists of all of the following except:
    a. Skin
    b. Hair
    c. Bile
    d. Blood

37. Which of the following would be most likely associated with an excessive amount of amniotic fluid?
    a. Duodenal atresia
    b. Hepatomegaly
    c. Bilateral renal agenesis
    d. Physiologic bowel herniation

38. Which of the following would be most likely associated with

oligohydramnios?
a. Duodenal atresia
b. Hepatomegaly
c. Bilateral renal agenesis
d. Physiologic bowel herniation

39. The majority of amniotic fluid is composed of:
a. Fetal blood
b. Fetal serous fluid
c. Maternal serous fluid
d. Fetal urine

40. All of the following are sonographic findings of esophageal atresia except:
a. Absent stomach
b. Polyhydramnios
c. Macrosomia
d. Intrauterine growth restriction

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29

The Fetal Genitourinary System

Introduction

The most common abnormal findings on a prenatal sonogram are those of the genitourinary system. This chapter provides a review of the normal sonographic findings of the fetal kidneys and bladder. In addition, an overview of the pathology of the fetal genitourinary system is offered. Although the adrenal glands are not part of the genitourinary system, a discussion on the sonographic appearance of the adrenal glands is also provided.

Key Terms

allantois—a membrane that is present during early embryonic development that contributes to urinary bladder formation and development

ambiguous genitalia—a birth defect in which the sex of the fetus cannot be determined

anhydramnios—no amniotic fluid

autosomal dominant—a way in which a disorder or trait can be inherited by a fetus; at least one of the parents has to be the carrier of the gene for the disease

autosomal dominant polycystic kidney disease—an inherited disease that results in the development of renal, liver, and pancreatic cysts late in life; also referred to as adult polycystic kidney disease

autosomal recessive—a way in which a disorder or trait can be inherited by

a fetus; both parents must be carriers of the gene for the disease

autosomal recessive polycystic kidney disease—an inherited renal disease that results in bilateral enlargement of the fetal kidneys and microscopic renal cysts; also referred to as infantile polycystic kidney disease

bladder exstrophy—a birth defect in which the bladder is located outside of the abdomen

caliectasis—dilation of the calices

clitoromegaly—enlargement of the clitoris

cloaca—the embryonic structure that develops into the normal rectum and urogenital sinus

cloacal exstrophy—birth defect consisting of omphalocele, bladder exstrophy, imperforate anus, and spina bifida; also referred to as OEIS complex

compensatory hypertrophy—enlargement of an organ secondary to an increased workload; often seen when part of an organ has been destroyed or when there is absence or decreased function of paired organs

encephalocele—protrusion of the brain and meninges through a defect in the skull

horseshoe kidneys—the attachment of the lower poles of the kidneys by a band of renal tissue that crosses the midline of the abdomen

hydrocele—a fluid collection within the scrotum between the two layers of the tunica vaginalis

hydronephrosis—the dilation of the renal collecting system resulting from the obstruction of the flow of urine from the kidney(s) to the bladder; also referred to as pelvocaliectasis or pelvicaliectasis

hydroureter—distension of the ureter with fluid because of obstruction

hypospadias—abnormal ventral curvature of the penis as a result of a shortened urethra that exits on the ventral penile shaft

infantile polycystic kidney disease—an inherited renal disease that results in bilateral enlargement of the fetal kidneys and microscopic renal cysts; also referred to as autosomal recessive polycystic kidney disease

“keyhole” sign—the sonographic appearance of a dilated fetal bladder and urethra in the presence of a bladder outlet obstruction

“lying down” adrenal sign—the sonographic appearance of the adrenal gland in a parallel position within the abdomen as a result of renal agenesis

macroscopic—large enough to be discerned by the naked eye

Meckel–Gruber syndrome—fetal syndrome associated with microcephaly, occipital encephalocele, polydactyly, and polycystic kidneys

megacystis—an abnormally enlarged urinary bladder

megaureter—an enlarged ureter; can be congenital or acquired

mesoblastic nephroma—the most common sold fetal renal mass

micropenis—an abnormally small penis

microscopic—too small to be seen by the naked eye and thus requiring the aid of a microscope

moiety—(renal) refers to a separate collecting system in the upper pole or the lower pole of the kidney in a duplex collecting system

multicystic dysplastic kidney disease—a fetal renal disease thought to be caused by an early renal obstruction; leads to the development of multiple noncommunicating cysts of varying sizes in the renal fossa

neuroblastoma—malignant tumor that can occur within the adrenal gland and anywhere within the sympathetic nervous system

obstructive cystic dysplasia—a fetal disorder caused by an early renal obstruction; leads to small and echogenic kidneys that have cysts located along their margins

OEIS complex—acronym that stands for omphalocele, bladder exstrophy, imperforate anus, and spina bifida; also referred to as cloacal exstrophy

oligohydramnios—a lower-than-normal amount of amniotic fluid for the gestational age

pelvic kidney—a kidney located within the pelvis

pelviectasis—dilation of the renal pelvis; may also be referred to as pyelectasis

pelviureteral junction—see key term ureteropelvic junction

pelvocaliectasis—see key term hydronephrosis

perineum—the region between the external genitalia and the anus

polydactyly—having more than the normal number of fingers or toes

posterior urethral valves—irregular thin membranes of tissue located within the male posterior urethra that does not allow urine to exit the urethra

Potter facies—facial features seen with severe oligohydramnios, including low set ears, flattened nose, wrinkled skin, and micrognathia

Potter syndrome—physical features of a fetus as a result of oligohydramnios; characterized by bilateral renal agenesis, abnormal facies, pulmonary hypoplasia, and limb abnormalities; also referred to as Potter sequence

prune belly syndrome—syndrome that is a consequence of the abdominal wall musculature being stretched by the extremely enlarged urinary bladder

pulmonary hypoplasia—underdevelopment of the lungs

renal agenesis—failure of the kidney to develop; may be unilateral or bilateral

renal calices—the part of the collecting system that encompasses the apex of the renal pyramids

renal ectopia—refers to an abnormal location of the kidney or kidneys

renal fossa—the region where the kidney is located in the abdomen

renal pelvic diameter—measurement of the fetal renal pelvis; this dimension is obtained from the transverse kidney plane

renal pelvis—the funnel-shaped collecting system in the central portion of the kidney that allows urine to flow from the kidney to the ureter

sirenomelia—a fetal abnormality characterized by fusion of the lower extremities, renal agenesis, and oligohydramnios; may also be referred to as mermaid syndrome

undescended testis—testicles that do not descend into the scrotum; also referred to as cryptorchidism

urachus—canal connecting the fetal bladder with the allantois; normally closes during fetal development and becomes a fibrous cord

ureterocele—an abnormality in which the distal ureter projects into the urinary bladder

ureteropelvic junction—the junction of the ureter and the renal pelvis

ureteropelvic junction obstruction—an obstruction located in the region where the ureter meets the renal pelvis

ureterovesicular junction—the junction of the ureter and the urinary bladder

ureterovesicular junction obstruction—an obstruction located in the region where the ureter meets the bladder

urethral atresia—the congenital absence of the urethra

VACTERL—acronym for associated anomalies; stands for vertebral anomalies, anal atresia, cardiac anomalies, tracheoesophageal fistula or esophageal atresia, renal anomalies, and limb anomalies

vesicoureteral junction—see key term ureteropelvic junction

vesicoureteral reflux—the retrograde flow of urine from the urinary bladder into the ureter

SONOGRAPHY OF THE FETAL GENITOURINARY SYSTEM

The fetal kidneys develop within the pelvis and ascend into their normal

position by 9 weeks. By the 10th week of gestation, fully functional kidneys exist. If the kidneys fail to ascend into the normal position, the result is an ectopic kidney, most often located within the pelvis (Fig. 29-1). This is referred to as a pelvic kidney. The most common renal anomaly is the duplex collecting system, also referred to as a duplicated or double collecting system. In this variant, the kidney is composed of two separate collecting systems, divided into what is termed an upper pole moiety and a lower pole moiety. Horseshoe kidneys are kidneys that are attached at their lower poles. Initially, the bladder is continuous with the allantois, although eventually this channel closes and develops into a fibrous cord referred to as the urachus. Thus, the urachus is located between the apex of the bladder and the umbilicus. In newborns, occasionally the urachus can remain patent or open. The gonads develop in the upper fetal abdomen and descend into the pelvis. The testicles move down into the scrotum during the seventh month of gestation.

SOUND OFF
The urachus is located between the apex of the bladder and the umbilicus.

The kidneys can be sonographically identified as early as 11 weeks with endovaginal imaging, and by 12 weeks with transabdominal imaging. Indeed, by the second-trimester fetal anatomy screening examination, the kidneys should be consistently seen adjacent to the fetal spine bilaterally (Fig. 29-2). The renal cortex, medulla, and sinus can be well differentiated within the fetus. The fetal bladder can be seen as early as 12 weeks and should always be seen by 15 weeks and beyond (Fig. 29-3). It is important to note that the fetal urinary bladder normally fills and empties once in every 30 to 45 minutes. Normal fetal ureters are not perceived with sonography. Therefore, visualization of the ureters would indicate some pathologic process. The adrenal glands are triangular-shaped hypoechoic structures located superior to the upper pole of the kidneys. They are easily identified within the fetus (Fig. 29-4).

SOUND OFF
The fetal urinary bladder normally fills and empties once in every 30 to 45 minutes.

VACTERL ASSOCIATION

VACTERL stands for vertebral anomalies, anal atresia, cardiac anomalies, tracheoesophageal fistula or esophageal atresia, renal anomalies, and limb anomalies (Fig. 29-5). Patients are considered to have this association if three of the organ systems listed have abnormalities. Therefore, if an irregularity is noted within one structure, this should prompt the sonographer to further investigate the other systems for associated anomalies. VACTERL association may also be referred to as VATER sequence, VATER, or VACTEL syndrome.

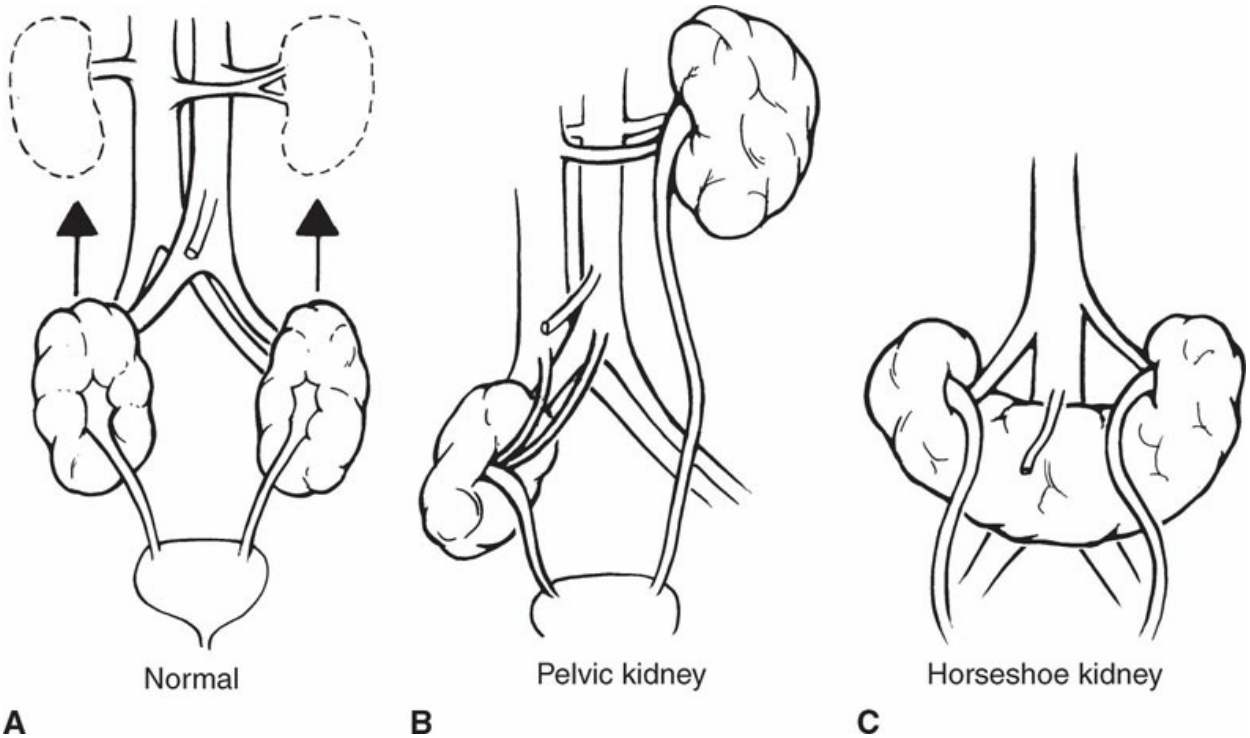


Figure 29-1 Normal and abnormal ascension of the kidneys. **A.** The kidneys initially develop in the fetal pelvis and ascend into the upper quadrants. **B.** A kidney that fails to ascend results most often in a pelvic kidney. **C.** If the inferior poles of the kidneys fuse, this is termed a horseshoe kidney.

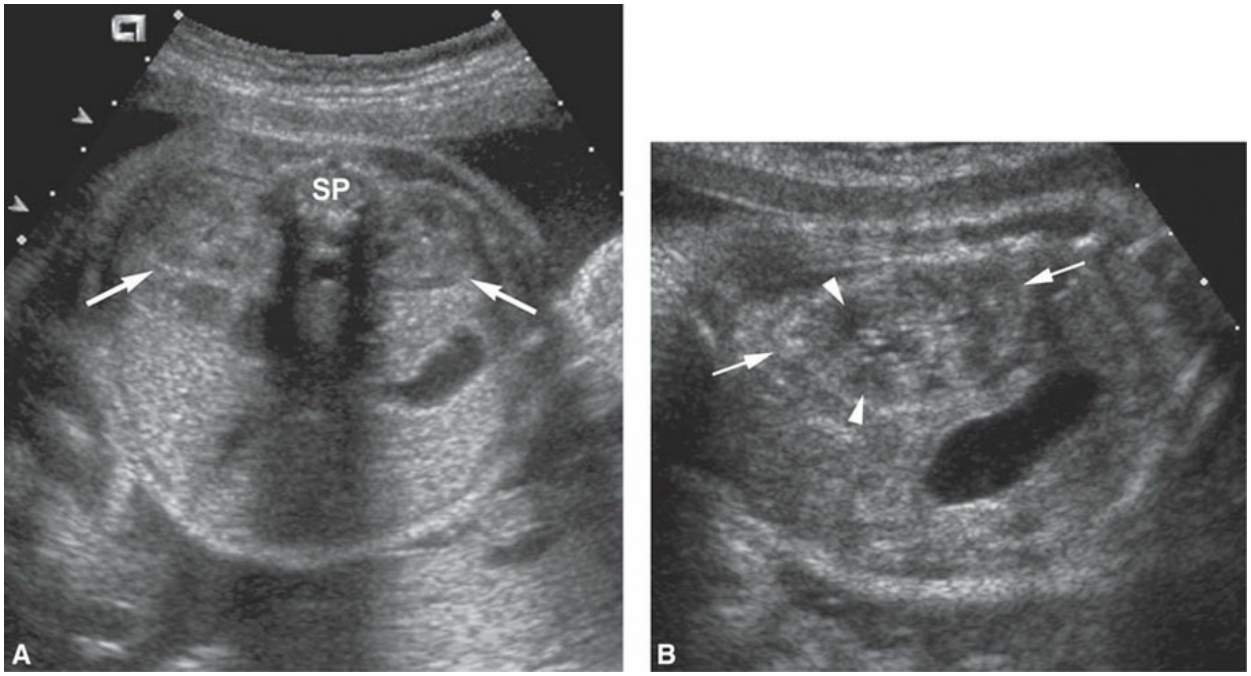


Figure 29-2 Fetal kidneys. **A.** Transverse view of the fetal abdomen revealing the kidneys (*arrows*) on both sides of the spine (*SP*). **B.** Longitudinal image of the fetal kidney *(between arrows)* revealing coricomedullary differentiation, with several identifiable medullary pyramids *(arrowheads)*.

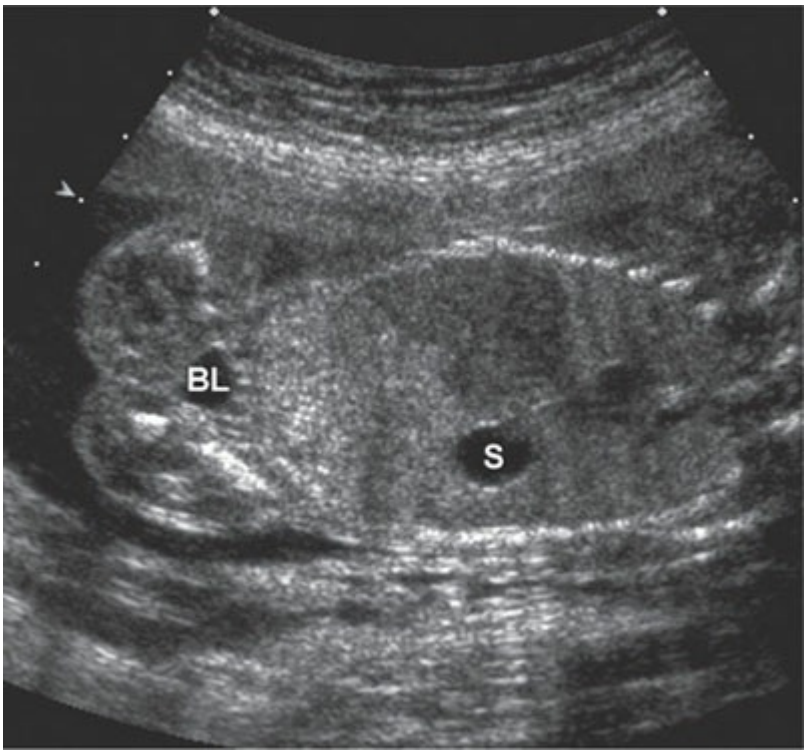


Figure 29-3 Fetal bladder. Longitudinal image of the fetal bladder *(BL)*. The fetal stomach *(S)* is also noted in this image.

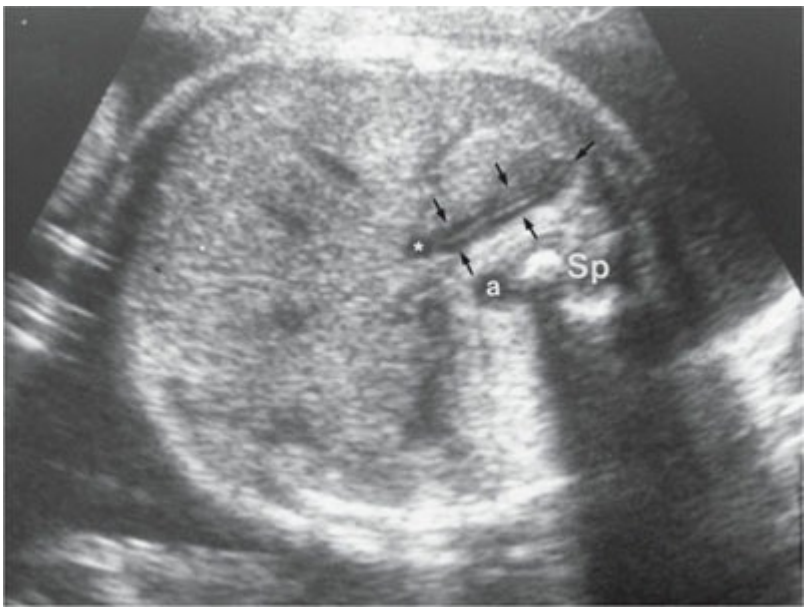


Figure 29-4 Fetal adrenal glands. Transverse view of the fetal abdomen revealing the normal sonographic appearance of the adrenal gland (*arrows*) adjacent to the fetal aorta (*a*) and spine (*Sp*).

RENAL ABNORMALITIES, OLIGOHYDRAMNIOS, AND PULMONARY HYPOPLASIA

Renal abnormalities are the most frequent cause of oligohydramnios. During fetal development, around 9 weeks, the fetal kidneys begin to produce urine. Urine comprises the greater part of amniotic fluid after 14 weeks. Amniotic fluid is a substance that contains valuable proteins that are essential for normal fetal development. It also contributes greatly to normal fetal growth and maturation.

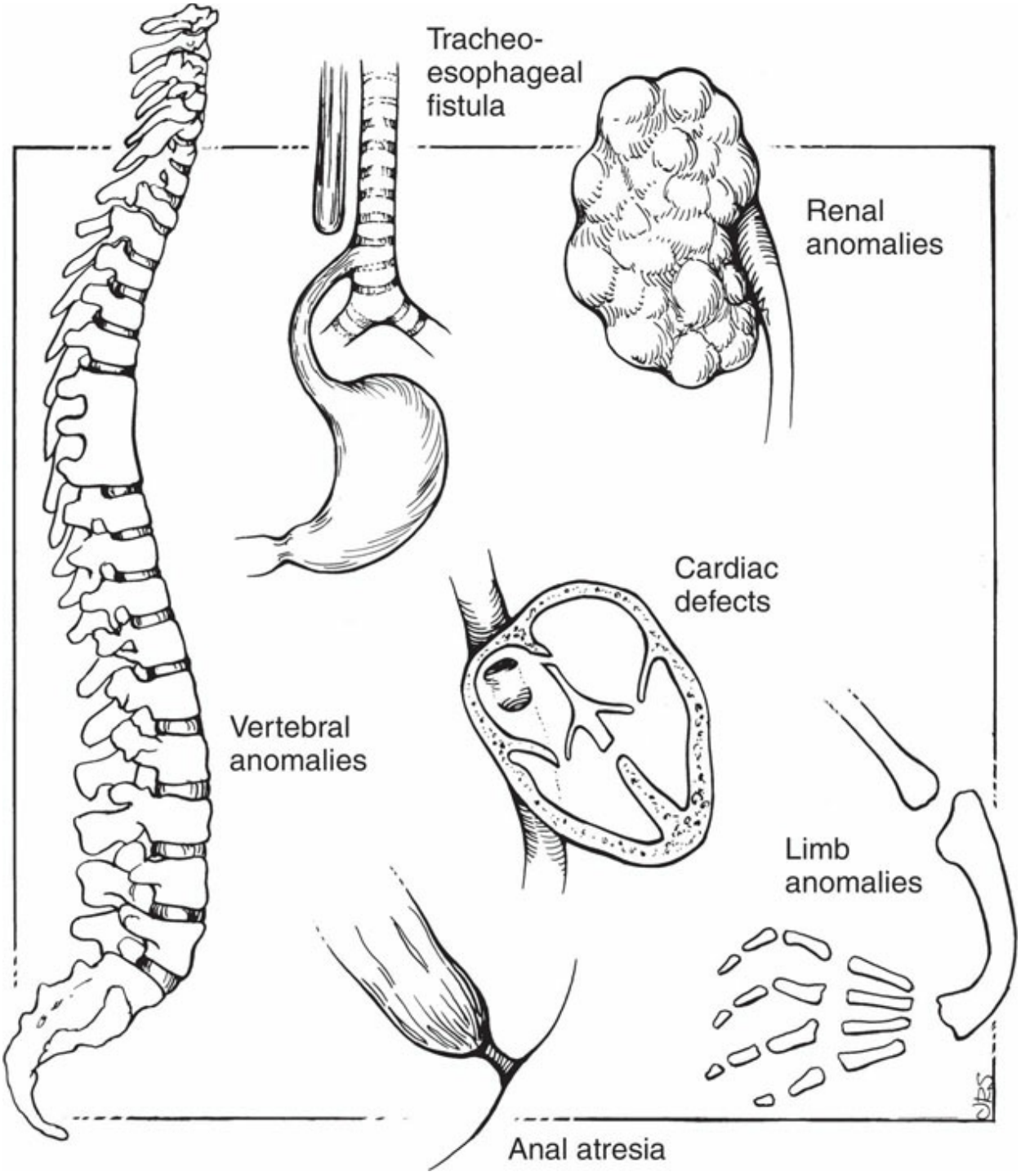


Figure 29-5 The VACTERL association: *v*ertebral anomalies, *a*nal atresia, *c*ardiac defects, *t*racheoesophageal fistula or *e*sophageal atresia, *r*enal anomalies, and *l*imb anomalies.

SOUND OFF

Renal abnormalities are the most frequent cause of oligohydramnios. Therefore, if oligohydramnios is discovered, a thorough analysis of the fetal urinary tract is warranted.

The fetus ingests amniotic fluid by swallowing. The fluid passes through

the esophagus, into the stomach, and travels through the small bowel and into the colon, where normal absorption takes place. In circumstances in which the fetus has a renal abnormality, specifically those that are linked with bilateral renal agenesis, inadequately functioning kidneys, or obstruction of the urinary tract, oligohydramnios will be present, and in some cases anhydramnios may occur (Fig. 29-6). Therefore, if a normal amount of fluid is noted during a sonogram, one can assume that there is at least one functioning fetal kidney present.

The most worrisome consequence of oligohydramnios is pulmonary hypoplasia, or underdevelopment of the lungs. In the upcoming discussion on fetal renal disease, keep in mind that while unilateral conditions carry a better prognosis, bilateral disease often leads to oligohydramnios, and is thus related to a poor outcome in most cases as a result of pulmonary hypoplasia.

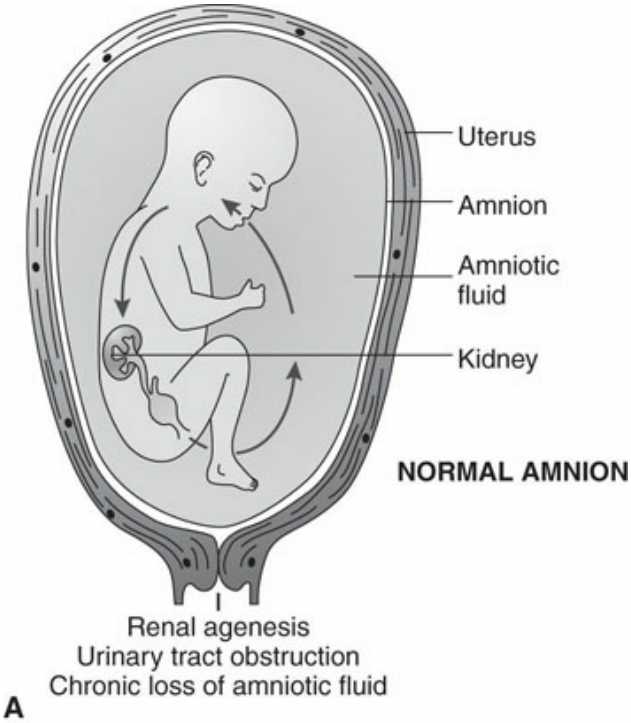


SOUND OFF

The most worrisome consequence of oligohydramnios is pulmonary hypoplasia, or underdevelopment of the lungs.

Renal Agenesis

Failure of a kidney to form is referred to as renal agenesis. Renal agenesis can be unilateral or bilateral. There are two sonographic findings that are helpful in making the sonographic diagnosis of renal agenesis. First, when the kidney is absent in the abdomen, the adrenal gland can be noted in a parallel, flattened position, a sonographic finding known as the “lying down” adrenal sign (Fig. 29-7). Second, color Doppler can be employed over the renal artery branches of the abdominal aorta. When there is absence of the kidney, there will be no identifiable renal artery branches (Fig. 29-8).


Uterus
Amnion
Amniotic fluid
Kidney
NORMAL AMNION
Renal agenesis
Urinary tract obstruction
Chronic loss of amniotic fluid
A

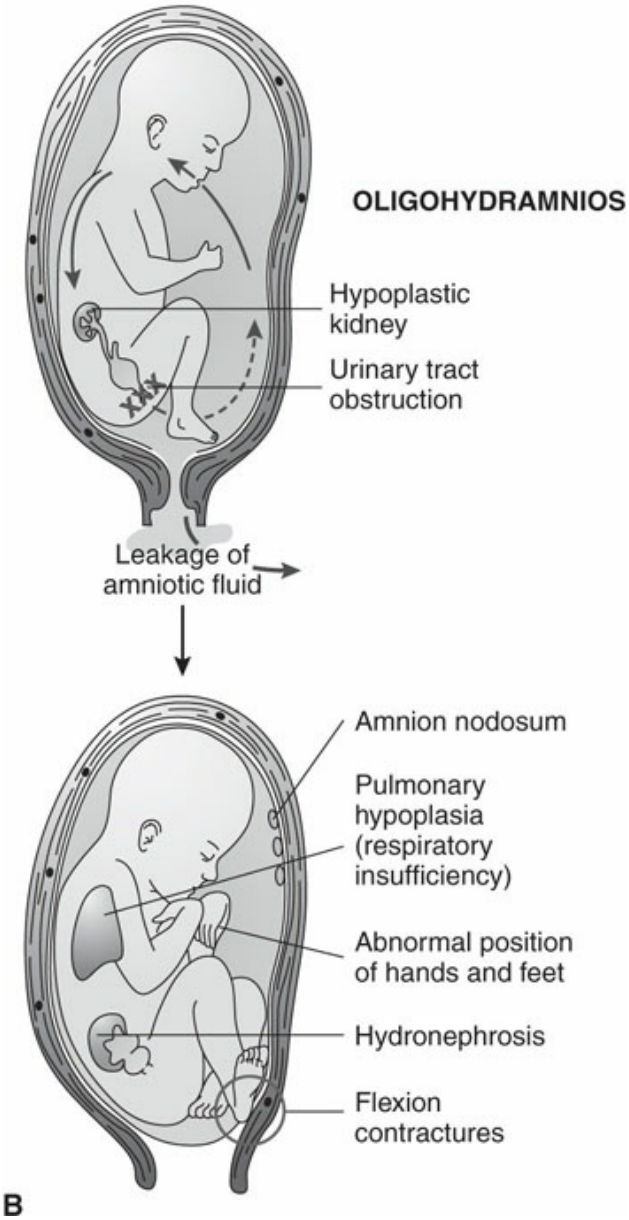

OLIGOHYDRAMNIOS
Hypoplastic kidney
Urinary tract obstruction
XXX
Leakage of amniotic fluid
Amnion nodosum
Pulmonary hypoplasia (respiratory insufficiency)
Abnormal position of hands and feet
Hydronephrosis
Flexion contractures
B

Figure 29-6 Normal amniotic fluid production and cycle. **A.** The kidneys produce urine, which comprises the majority of amniotic fluid. The fetus ingests amniotic fluid by swallowing. The fluid passes through the esophagus, into the stomach, and travels through the small bowel and into the colon, where normal absorption takes place. **B.** In circumstances in which the fetus has a renal abnormality, specifically those that are linked with bilateral renal agenesis, inadequately functioning kidneys, or obstruction of the urinary tract, oligohydramnios will be present, and in some cases anhydramnios may occur. Oligohydramnios will also occur when there is leakage of amniotic fluid.



SOUND OFF
The "lying down" adrenal sign is associated with renal agenesis.

Bilateral renal agenesis, also known as Potter syndrome or Potter sequence, is a fatal condition (Table 29-1). The absence of both the fetal kidneys can be difficult to detect sonographically, secondary to the lack of amniotic fluid surrounding the fetus. Therefore, it is extremely beneficial to utilize color Doppler to investigate the renal area. Nonvisualization of the urinary bladder and kidneys, with associated severe oligohydramnios, is considered to be a trustworthy finding consistent with bilateral renal agenesis. Bilateral renal agenesis may be seen in conjunction with sirenomelia and various cardiovascular malformations.

Fortunately, unilateral renal agenesis is much more common than bilateral renal agenesis. Most often, with unilateral renal agenesis, there is an average amount of amniotic fluid, and the prognosis is good. Before making the conclusion of unilateral renal agenesis, the sonographer should always analyze the fetal pelvis for a pelvic kidney, because this is the most common location of an ectopic kidney. In the presence of unilateral renal agenesis, the contralateral kidney will enlarge, a condition known as compensatory hypertrophy.

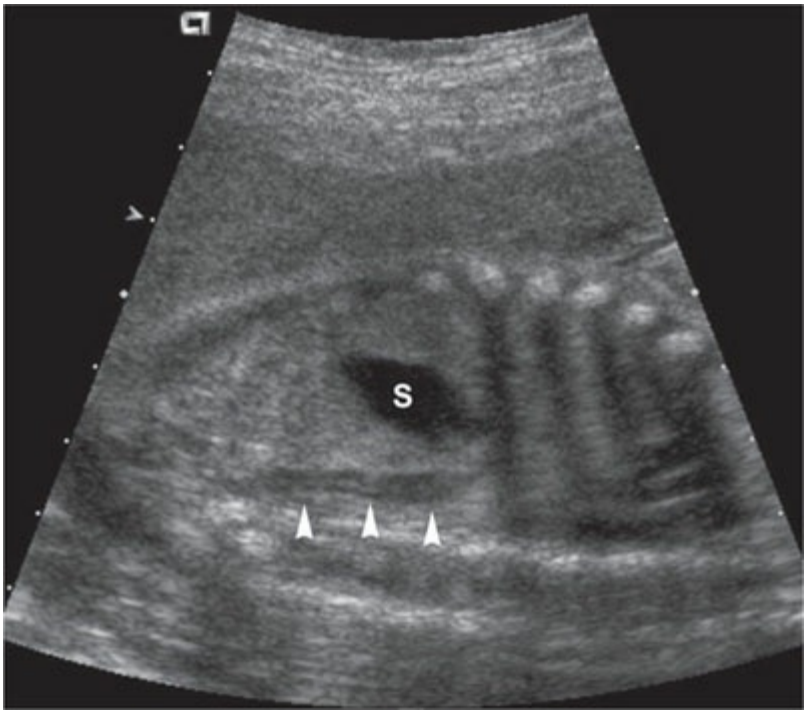


Figure 29-7 "Lying down" adrenal sign. Left parasagittal view of the fetal abdomen demonstrating the left adrenal gland (*arrowheads*) to be lying in a cephalocaudal orientation behind the stomach (*S*).

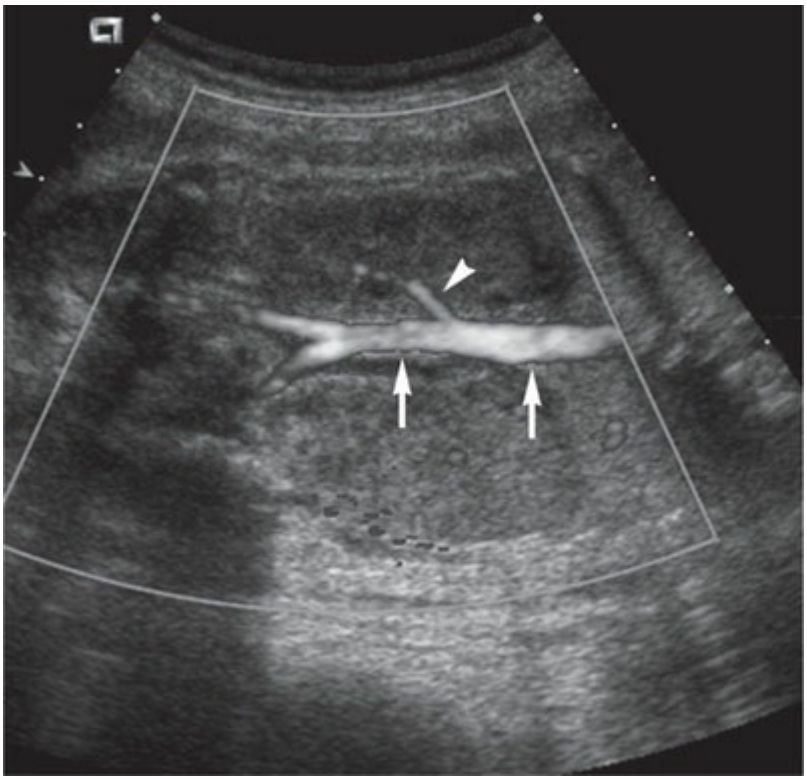


Figure 29-8 Unilateral renal agenesis. Power Doppler demonstrating a renal artery (*arrowhead*) and no identifiable renal artery branch or kidney on the other side (*arrows*). Color image provided online.

TABLE 29-1 Features of Potter syndrome

Bilateral renal agenesis
Abnormal facial features (**Potter facies**)
Pulmonary hypoplasia
Limb abnormalities
Intrauterine growth restriction

SONOGRAPHIC FINDINGS OF BILATERAL RENAL AGENESIS

1. Absent kidneys
2. Absent urinary bladder
3. Severe oligohydramnios or anhydramnios
4. Bilateral lying down adrenal signs
5. Undetectable renal artery branches with color Doppler (bilateral)

SONOGRAPHIC FINDINGS OF UNILATERAL RENAL AGENESIS

1. Absent kidney
2. Compensatory hypertrophy of the contralateral kidney
3. Visible urinary bladder
4. Normal amniotic fluid volume
5. Unilateral lying down adrenal sign
6. Undetectable renal artery branch with color Doppler (unilateral)



SOUND OFF

Most often, with unilateral renal agenesis, there is an average amount of amniotic fluid, and the prognosis is good.

Understanding the Nomenclature of Fetal Renal Cystic Disease

There are several distinct categories of fetal renal cystic disease that were formerly described by Potter: autosomal recessive polycystic kidney disease (ARPKD), autosomal dominant polycystic kidney disease (ADPKD), multicystic dysplastic kidney (MCDK) disease, and obstructive cystic dysplasia. In order for an autosomal recessive disease to be passed to the fetus, both parents must be carriers of the disease. Each offspring of parents, who are both carriers of an autosomal recessive disorder, has a 25% chance of being affected and a 50% chance of being a carrier.

In the case of an autosomal dominant disease, at least one of the parents has to be the carrier of the disease, and the gene must be dominant. That means, the dominant gene is capable of overriding the normal gene from the parent who is not a carrier. However, this does not indicate that every

offspring will be affected. Each offspring of a parent who is a carrier of an autosomal dominant disease has a 50% chance of receiving the gene from their parents. It is important to note that dominant disorders tend to be less severe than recessive disorders.

Autosomal Recessive (Infantile) Polycystic Kidney Disease

ARPKD may also be referred to as autosomal recessive polycystic renal disease or infantile polycystic kidney disease. The typical sonographic findings of a fetus affected by ARPKD are bilateral, enlarged, echogenic kidneys, nondetectable urinary bladder, and oligohydramnios (Fig. 29-9). The kidneys may be as large as 3 to 10 times the normal renal size for the gestation. ARPKD would be the most likely cause of enlarged, echogenic kidneys noted in utero.

SOUND OFF
ARPKD would be the most likely cause of enlarged, echogenic kidneys noted in utero.

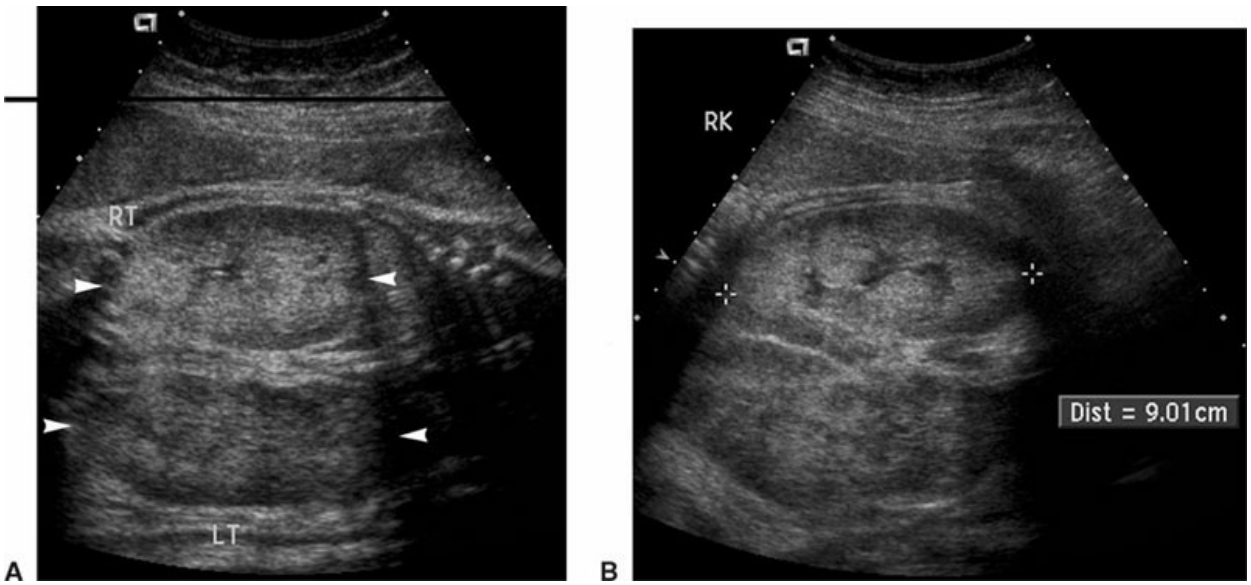


Figure 29-9 Autosomal recessive polycystic kidney disease in the third trimester. **A.** The right (*RT*) and left (*LT*) kidneys (*arrowheads*) are enlarged and have increased echogenicity at 33 weeks. **B.** The right kidney (*RK*) is visualized better and shows signs of increased echogenicity. It is enlarged and measures approximately 9 cm in length (*calipers*). There is also severe oligohydramnios.

One condition associated with ARPKD is Meckel–Gruber syndrome, which is a fatal disorder that includes renal cystic disease, occipital encephalocele, and polydactyly (Fig. 29-10). Fetuses with trisomy 13 and trisomy 18 may also have polycystic kidney disease. Referring to this

condition, a renal cystic disease can be puzzling to a sonographer because cysts are not always perceptible with sonography. This is secondary to the size of the cysts because the cysts with ARPKD are microscopic and not macroscopic. It is significant to appreciate the differences in the sonographic appearance of ARPKD and MCDK disease. Cysts are typically not identifiable in ARPKD but are evident in the MCDK.

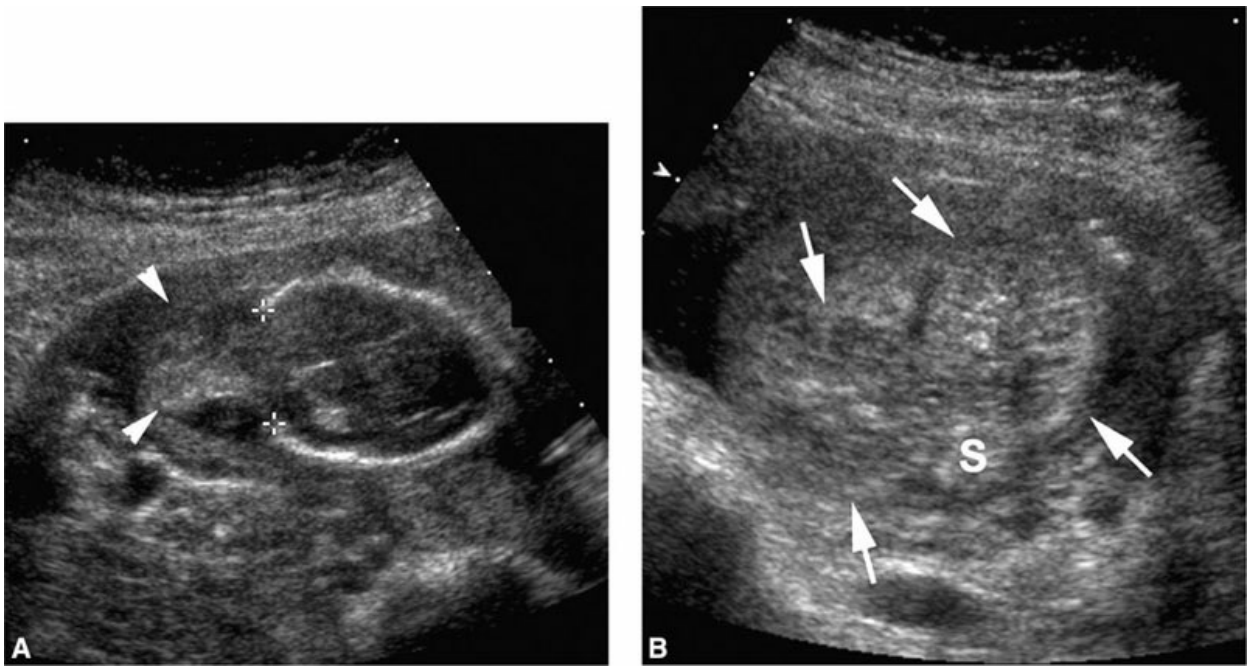


Figure 29-10 Meckel–Gruber syndrome. **A.** Meckel–Gruber syndrome is characterized by an occipital encephalocele (*arrowheads*) which herniated through a defect in the skull (*calipers*). **B.** Adjacent to the spine (*S*), both kidneys (*between arrows*) appear to be enlarged and echogenic in this fetus with Meckel–Gruber syndrome.

SONOGRAPHIC FINDINGS OF AUTOSOMAL RECESSIVE (INFANTILE) POLYCYSTIC KIDNEY DISEASE

1. Bilateral, enlarged echogenic kidneys
2. Absent urinary bladder
3. Oligohydramnios

Autosomal Dominant (Adult) Polycystic Kidney Disease

ADPKD may also be referred to as autosomal dominant polycystic renal disease. The sonographic appearance of fetal kidneys with ADPKD is similar to that of ARPKD in that both kidneys will appear enlarged and echogenic, although the kidneys may appear completely normal. If the kidneys do appear enlarged and echogenic, a distinguishing difference between the two diseases is that in the fetus with ADPKD, the urinary bladder is often present

and there is a normal amniotic fluid volume, whereas with ARPKD, the bladder is absent and there is oligohydramnios. However, ADPKD does not typically manifest until approximately the fourth or fifth decade of life, at which time the adult will develop renal cysts and may die from end-stage renal failure. Adult renal cystic disease is also associated with the development of cysts within the liver, pancreas, and spleen.

SONOGRAPHIC FINDINGS OF AUTOSOMAL DOMINANT (ADULT) POLYCYSTIC KIDNEY DISEASE

1. Normal-appearing or bilateral, enlarged echogenic kidneys
2. Visible urinary bladder
3. Normal amniotic fluid volume
4. Cysts do not manifest until approximately the fifth decade of life

SOUND OFF

The sonographic appearance of fetal kidneys with ADPKD is similar to that of ARPKD in that both kidneys will appear enlarged and echogenic, although the kidneys may appear completely normal.

Multicystic Dysplastic Renal Disease

Multicystic dysplastic renal disease may also be referred to as multicystic dysplastic kidney (MCDK) disease and multicystic renal dysplasia. MCDK disease is thought to be caused by an early, first-trimester obstruction of the ureter. The sonographic findings of MCDK disease are the identification of unilateral or bilateral multiple, smooth-walled, noncommunicating cysts of varying sizes in the area of the renal fossa(e) (Fig. 29-11). There is typically no normal-functioning renal tissue present in the kidney affected by MCDK disease. Therefore, MCDK disease is fatal if bilateral, with the consistent associated findings of oligohydramnios and absent bladder. Fortunately, most cases of MCDK disease are unilateral, and consequently have a normal amniotic fluid volume. Fetuses with MCDK disease can also have additional related anomalies, such as abnormalities of the gastrointestinal tract and central nervous system, limb anomalies, and further renal abnormalities.

SOUND OFF

MCDK disease is fatal if bilateral, but fortunately, most cases of MCDK are unilateral.

SONOGRAPHIC FINDINGS OF BILATERAL MULTICYSTIC

DYSPLASTIC RENAL DISEASE

1. Bilateral, smooth-walled, noncommunicating cysts of varying sizes located within the renal fossae
2. Absent urinary bladder
3. Oligohydramnios

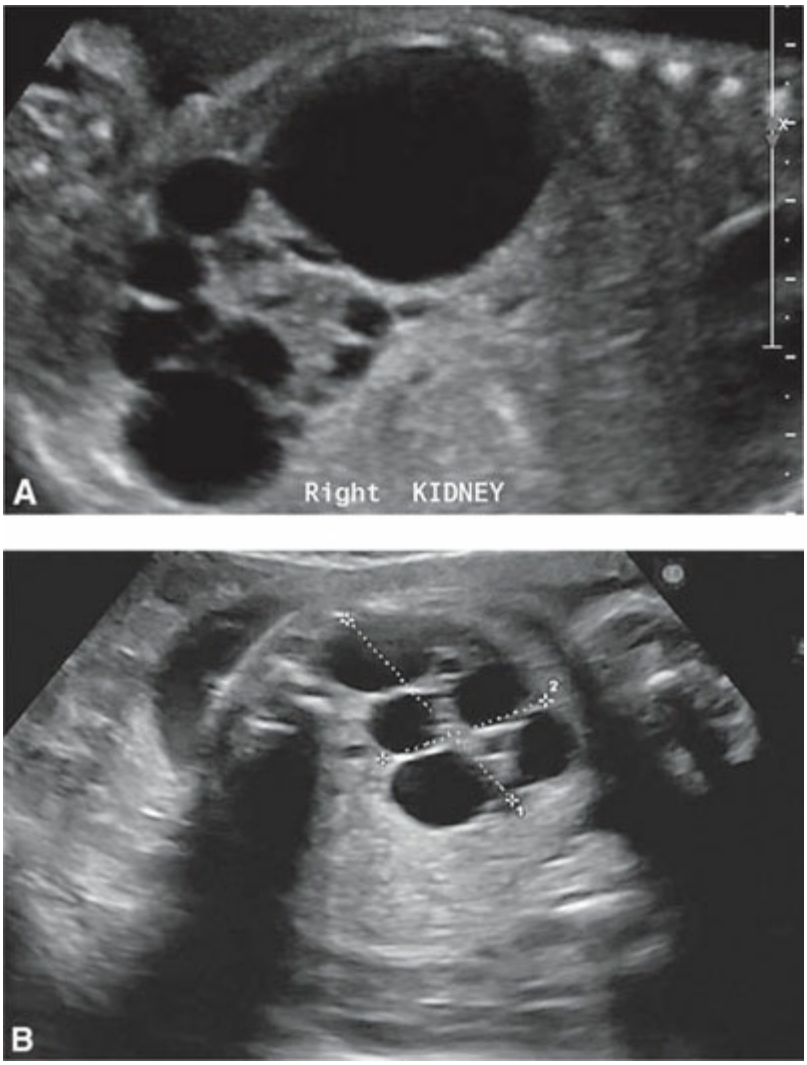


Figure 29-11 Multicystic dysplastic kidney disease. **A.** Multiple cysts of varying sizes are noted within the fetal renal fossa. **B.** Transverse view of a unilateral multicystic dysplastic kidney *(between calipers)*.

SONOGRAPHIC FINDINGS OF UNILATERAL MULTICYSTIC DYSPLASTIC RENAL DISEASE

1. Unilateral, smooth-walled, noncommunicating cysts of varying sizes located within the renal fossa
2. Compensatory hypertrophy of the contralateral kidney
3. Visible urinary bladder
4. Normal amniotic fluid volume

Obstructive Cystic Dysplasia

Obstructive cystic dysplasia, like MCDK disease, is caused by an early renal obstruction. It can be unilateral or bilateral. A ureterocele, or a severe bladder outlet obstruction, early in gestation, can lead to bilateral obstructive cystic dysplasia, in which case oligohydramnios will be present. Unilateral obstructive cystic dysplasia is most often caused by a pelviureteral junction or vesicoureteral junction obstruction. Bilateral cystic dysplasia may be associated with urethral atresia or posterior urethral valves. The kidney will appear small and echogenic and have cysts located along its margins. Often, there will be evidence of hydronephrosis and a thick-walled urinary bladder.

SONOGRAPHIC FINDINGS OF BILATERAL OBSTRUCTIVE CYSTIC DYSPLASIA

1. Small, echogenic kidneys
2. Peripheral renal cysts
3. Bilateral hydronephrosis
4. Thick-walled urinary bladder
5. Oligohydramnios

Fetal Urinary Tract Obstruction

An obstruction of the fetal urinary tract can lead to distension of the bladder, ureters, and renal collecting system. Although physiologically fundamental, it is quite imperative for the sonographer to understand the creation and flow of urine through the urinary tract in order to determine the origin of a urinary tract obstruction. Urine is produced by the kidney, exits the kidney by means of the renal pelvis, travels down the ureter, into the bladder, and exits the body via the urethra. Any obstruction to this normal succession will result in a backup of urine. For example, if there is an obstruction at the region where the ureter meets the bladder, the ureterovesicular junction, then those structures that are positioned proximal to the obstruction will be dilated. That means, the entire ureter, the renal pelvis, and the renal calices will be eventually dilated and filled with urine. Conversely, if the obstruction level lies at the point at which the renal pelvis meets the ureter, the ureteropelvic junction (UPJ), then the renal pelvis and renal calices will be dilated, whereas the ureter and bladder will most likely remain normal provided that contralateral urine flow is not obstructed in any way (Fig. 29-12).

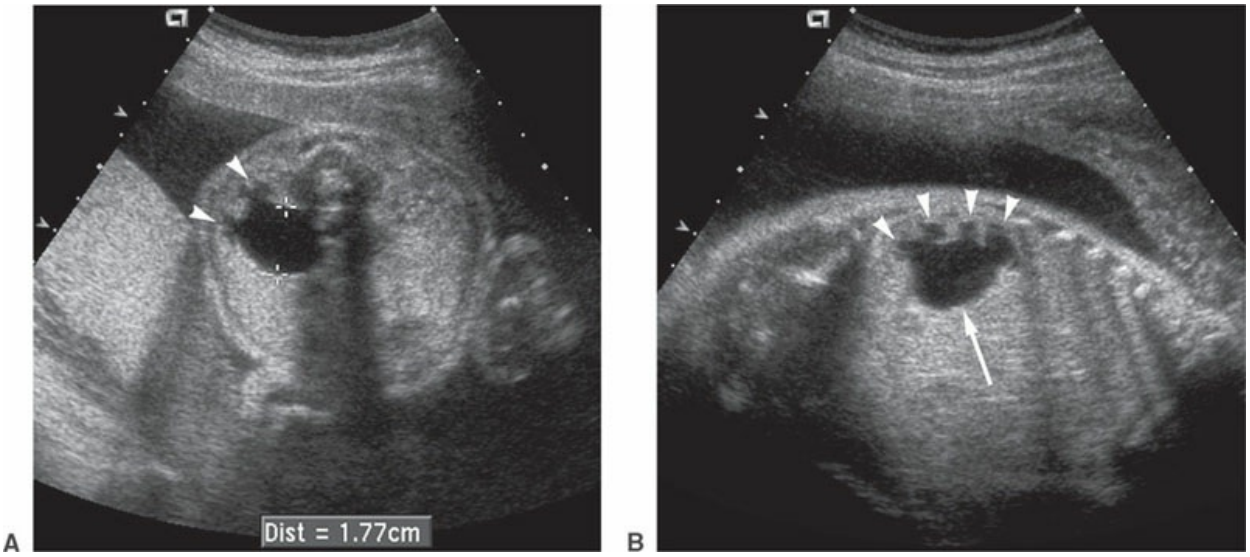


Figure 29-12 Unilateral hydronephrosis caused by a ureteropelvic junction obstruction. **A.** Transverse view of the fetal abdomen demonstrating dilation of the right renal pelvis (*calipers*), measuring 17.7 mm in the anteroposterior diameter, as well as dilation of the calices (*arrowheads*). **B.** Longitudinal view of the abdomen better demonstrating the extent of the dilation, because the calices (*arrowheads*) are clearly visible.

SOUND OFF

The sonographer must understand the creation and flow of urine through the urinary tract in order to determine the origin of a urinary tract obstruction.

Hydronephrosis is the most common fetal abnormality noted during an obstetric sonogram. Hydronephrosis, or pelvocaliectasis, may be described as pelviectasis (pyelectasis) or caliectasis, depending on which part of the collecting system is dilated. Enlargement of the bladder is called megacystis, whereas dilation of the ureter may be referred to as megaureter or hydroureter.

Fetal pelviectasis, or dilation of the renal pelvis, can be established and measured with sonography by taking a renal pelvic diameter (Fig. 29-13). The measurement of the renal pelvis is made in the anteroposterior plane and should not exceed 7 mm before 20 weeks or 10 mm after 20 weeks' gestation. However, it is important to note that borderline hydronephrosis should be reported because of the possible gradual evolution of this disorder (Table 29-2).

The UPJ, the ureterovesicular junction, and the urethra are the three most common areas where obstruction occurs. The following sections will discuss these causes of fetal hydronephrosis in more detail. It is also important to note that less common causes of hydronephrosis in the fetus include

ureterocele, ectopic ureter, vesicoureteral reflux, and urethral atresia.

Ureteropelvic Junction Obstruction

UPJ obstruction is the most common cause of hydronephrosis in the neonate and the most common form of fetal renal obstruction. The UPJ is located at the junction of the renal pelvis and the ureter. The cause of this abnormality may be due to irregular development of the smooth muscle in the area of the UPJ. Some authors suspect ureteral stenosis or kinks, adhesions, crossing vessels, or abnormal outlet shapes. The disease is usually unilateral and more common in males. The sonographic appearance of a UPJ obstruction is the dilation of the renal pelvis and renal calices (see Fig. 29-12). It is important to note that fetal pyelectasis can be a sonographic marker for Down syndrome.

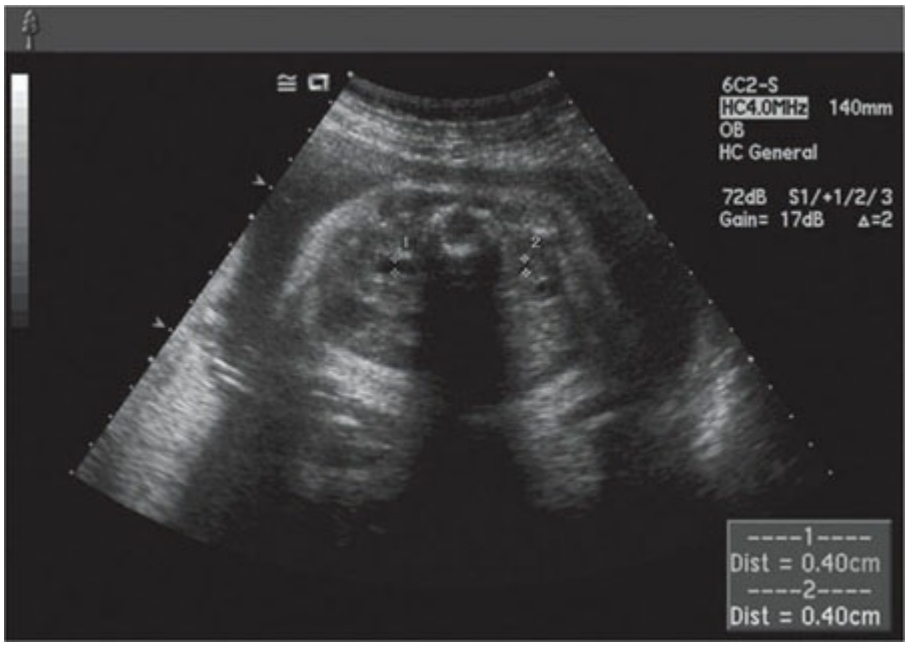


Figure 29-13 Mildly dilated renal pelvis. Transverse image of mildly dilated renal pelvis (between calipers) demonstrating the proper measurement method.

TABLE 29-2 Renal pelvis diameter measurements indicative of fetal hydronephrosis

Gestational Weeks	Renal Pelvis Diameter Measurement
Before 20 weeks	≥7 mm (borderline between 4 and 6 mm)
After 20 weeks	≥10 mm (borderline between 5 and 9 mm)

SONOGRAPHIC FINDINGS OF URETEROPELVIC JUNCTION

OBSTRUCTION

1. Hydronephrosis (dilated renal pelvis and calices)
2. Normal ureters (nonvisualization)
3. Normal bladder

SOUND OFF

It is important to note that fetal pyelectasis can be a sonographic marker for Down syndrome.

Bladder Outlet Obstructions and Posterior Urethral Valves

A bladder outlet obstruction describes the condition in which there is a blockage of the flow of urine out of the urinary bladder. It is especially significant to determine the sex of the fetus once a renal obstruction is identified. For example, posterior urethral valves are a common cause of bladder outlet obstructions in male fetuses. These thin membranes of tissue located within the posterior urethra do not allow urine to exit the urethra. The "keyhole" sign is seen when there is dilation of the urinary bladder and the posterior urethra (Fig. 29-14). Posterior urethral valves result in dilation of the bladder, ureters, and renal collecting system. Oligohydramnios and bladder wall thickening will be observed as well.

SONOGRAPHIC FINDINGS OF POSTERIOR URETHRAL VALVES

1. "Keyhole" sign (dilated bladder and urethra)
2. Bilateral hydroureter
3. Bilateral hydronephrosis
4. Oligohydramnios
5. Thickened bladder wall

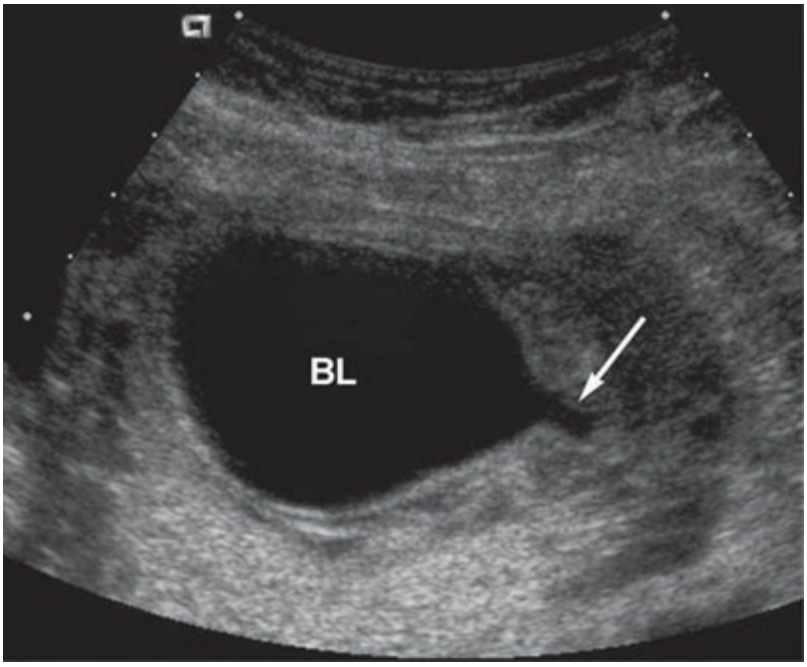


Figure 29-14 A "Keyhole" sign. A dilated posterior urethra (*arrow*) and bladder (*BL*) demonstrating the "keyhole" sign in this fetus with posterior urethral valves.

SOUND OFF
The "keyhole" sign is seen when there is dilation of the urinary bladder and posterior urethra.

Prune Belly Syndrome

Prune belly syndrome is typically caused by megacystis, a massively dilated urinary bladder. This syndrome is seen mostly in male fetuses and is the result of a urethral abnormality, which in turn leads to a bladder outlet obstruction. Prune belly describes the result of the abdominal wall musculature being stretched by the extremely enlarged urinary bladder. The sonographic finding of the "keyhole" sign is also seen with prune belly syndrome. Dilatation of the ureters and the renal collecting systems will occur (Fig. 29-15). The triad of absent abdominal musculature, undescended testis, and urinary tract abnormalities is consistent with the diagnosis of prune belly syndrome.

SONOGRAPHIC FINDINGS OF PRUNE BELLY SYNDROME

1. Dilated bladder and possibly urethra ("keyhole" sign)
2. Absent abdominal musculature
3. Undescended testis
4. Urinary tract abnormalities (megacystis and hydronephrosis)

SOUND OFF

The triad of absent abdominal musculature, undescended testis, and urinary tract abnormalities is consistent with the diagnosis of prune belly syndrome.

Ureterovesicular Junction Obstruction

Ureterovesicular junction obstruction, or UVJ obstruction, is the least common cause of hydronephrosis in the fetus. The renal collecting system and ureter will be dilated with a UVJ obstruction. Whereas unilateral UVJ obstructions lead to normal amounts of amniotic fluid, bilateral obstructions lead to oligohydramnios.

SONOGRAPHIC FINDINGS OF URETEROVESICULAR JUNCTION OBSTRUCTION

1. Hydronephrosis
2. Dilated ureter
3. Normal bladder
4. Normal amniotic fluid (if unilateral)

Bladder Exstrophy and Cloacal Exstrophy

Bladder exstrophy is an anomaly wherein the bladder is located outside the pelvis. After an extended amount of investigation, nonvisualization of the bladder in the presence of a normal amniotic fluid volume and normal kidneys should warrant a search for bladder exstrophy. The sonographic finding of bladder exstrophy is that of a lower abdominal wall mass inferior to the umbilicus (Fig. 29-16).

The cloaca is the embryonic structure that develops into the rectum and urogenital sinus. The cloaca can be persistent and result in the combination of the urinary, genitals, and intestinal tract, emptying into a common orifice located on the perineum. With cloacal exstrophy, also referred to OEIS complex, there is an omphalocele, bladder exstrophy, imperforate anus, and spina bifida.

SONOGRAPHIC FINDINGS OF BLADDER EXSTROPHY

1. Lower abdominal wall mass inferior to the umbilicus
2. Absent urinary bladder
3. Normal kidneys

SOUND OFF

OEIS complex stands for *o*mphalocele, bladder *e*xstrophy, *i*mperforate anus, and *s*pina bifida.

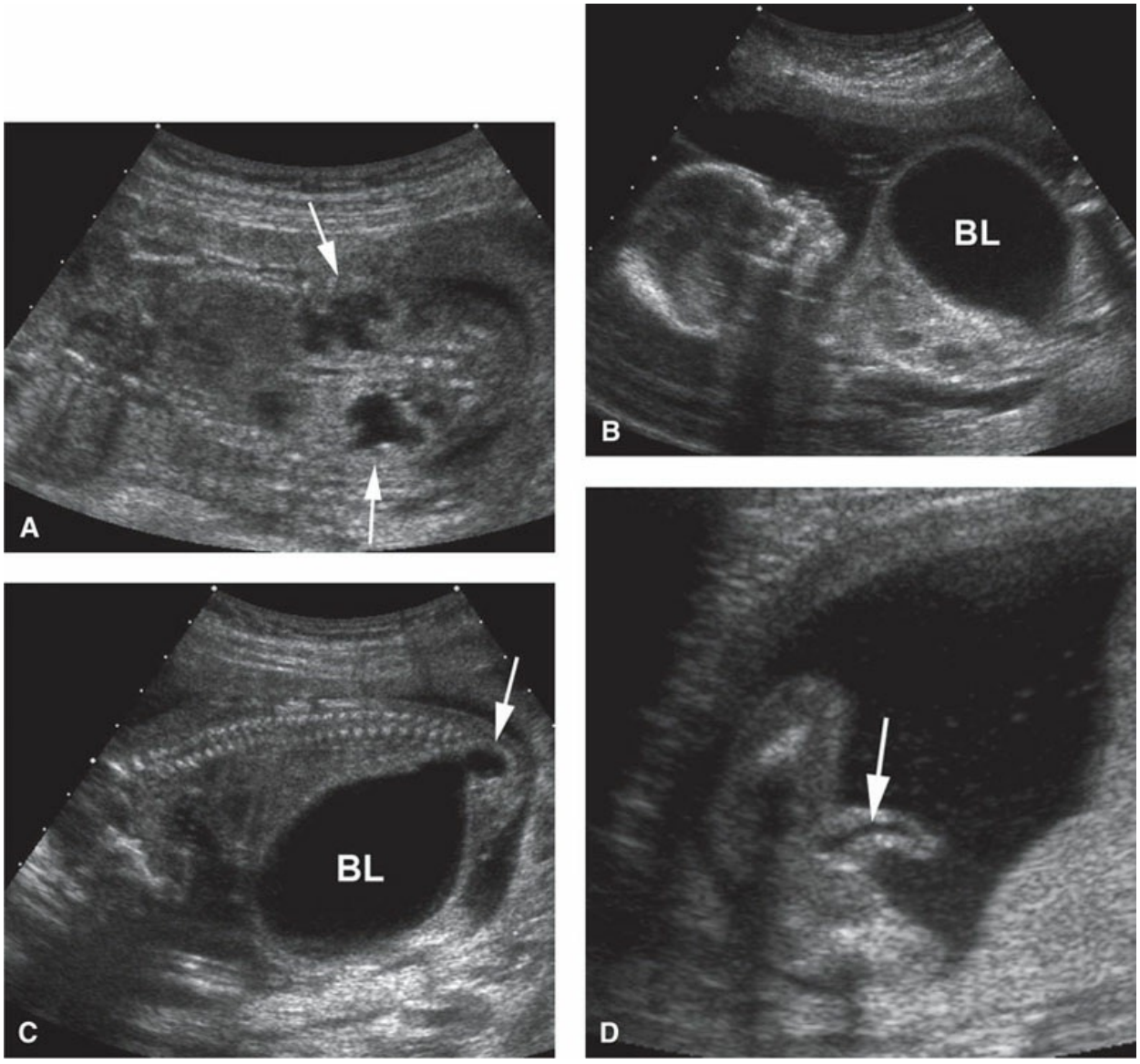


Figure 29-15 Prune belly syndrome. **A.** Bilateral obstruction to the kidneys is noted with dilated collecting systems *(arrows)*. **B.** Markedly enlarged urinary bladder *(BL)*. **C.** The "keyhole" sign is noted as a dilated bladder *(BL)* and a dilated urethra *(arrow)*. **D.** A dilated urethra *(arrow)* is noted as well.

Mesoblastic Nephroma

The most common solid fetal renal mass is the mesoblastic nephroma, which is essentially a hamartoma of the kidney. This tumor will typically appear as a solid, homogeneous mass within the renal fossa and may completely replace the kidney. However, it may contain cystic components.

SONOGRAPHIC FINDINGS OF THE MESOBLASTIC NEPHROMA

1. Solid, homogeneous mass within the renal fossa and may completely replace the kidney.

SOUND OFF
The most common solid fetal renal mass is the mesoblastic nephroma.

SONOGRAPHY OF THE FETAL GENITALIA

The sex of the embryo depends upon the male gamete. The sperm carries either an X or a Y chromosome, whereas the ovary always contributes an X chromosome. An X chromosome from the sperm will yield XX, which is female offspring. The combination of a Y chromosome will yield XY, which is male offspring. The external genitalia can be visualized and differentiated in the second trimester. Determining the sex of the fetus can offer important diagnostic information. When a urinary tract obstruction is noted, the sonographer should determine the sex of the fetus, because there may be different causes of obstructions specific for each sex. For example, posterior urethral valves are a common cause of urinary obstruction in only the male fetus. Sonography can thus be used to visualize the labia of the female and the penis and scrotum in the male.

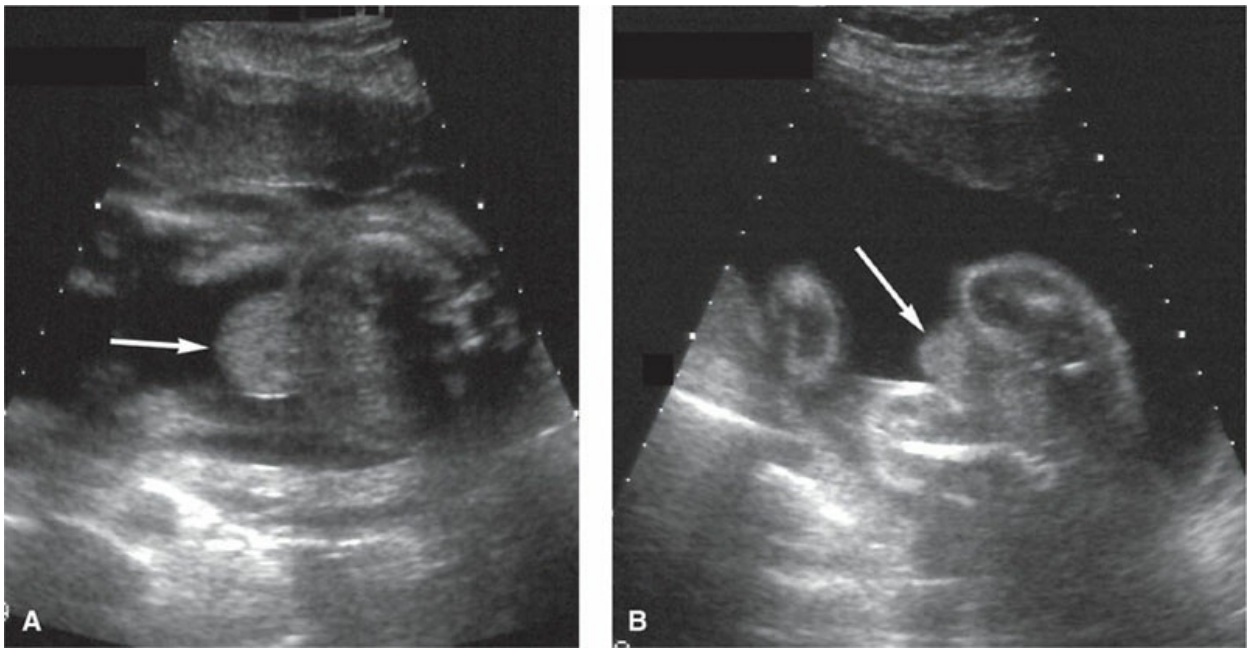


Figure 29-16 Bladder exstrophy. **A and B.** A solid, homogeneous mass *(arrow)* is noted in these transverse images just inferior to the umbilicus and extending down to the perineum with no visible bladder seen.

ABNORMALITIES OF THE FETAL GENITALIA

Ambiguous genitalia is a birth defect in which the sex of the fetus cannot be

determined. Findings of abnormal external genitalia in the male are micropenis, hypospadias, and undescended testicles. Fetal hydroceles are common findings in utero and may become fairly large (Fig. 29-17). Hypospadias is the abnormal ventral curvature of the penis as a result of a shortened urethra that exits on the ventral penile shaft.



Figure 29-17 Fetal hydroceles. Bilateral hydroceles are noted within the scrotum of this fetus.

The most common female finding is clitoromegaly. Fetal ovarian cysts may be noted in the fetal pelvis, secondary to maternal hormone stimulation (Fig. 29-18). These cysts are most often benign and resolve spontaneously, although if they continue to grow, they can lead to hemorrhage and possibly ovarian torsion.

FETAL ADRENAL GLAND ABNORMALITIES

The most common malignant abdominal mass in neonates is the neuroblastoma, located primarily within the adrenal gland. Adrenal glands may also spontaneously hemorrhage within the fetus, resembling a mass. Follow-up ultrasounds are often ordered for an adrenal hemorrhage for resolution.

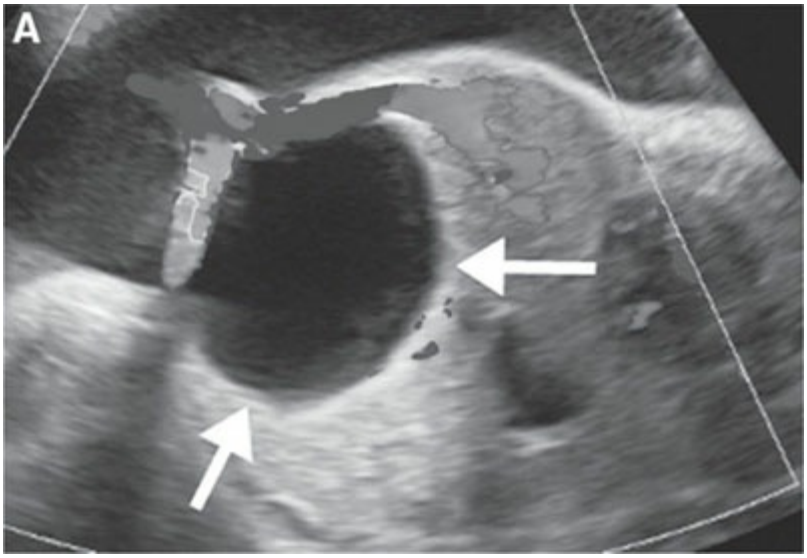


Figure 29-18 Fetal ovarian cyst. A large cyst (*arrows*) is noted within the pelvis of this female fetus.

REVIEW QUESTIONS

1. During an 18-week sonogram, multiple cysts of varying sizes are noted within the renal fossa of a male fetus. The other kidney appears to be normal. Which of the following would be an associated finding?
   a. Megacystis
   b. Ovarian dysgenesis
   c. Hypospadias
   d. Normal amniotic fluid level

2. The most common malignant adrenal pediatric tumor is the:
   a. Nephroblastoma
   b. Pheochromocytoma
   c. Hepatoblastoma
   d. Neuroblastoma

3. The “keyhole” sign would be seen in all of the following situations except:
   a. Urethral atresia
   b. Prune belly syndrome
   c. Autosomal dominant polycystic renal disease
   d. Posterior urethral valves

4. What is the most common fetal abnormality noted during an obstetric sonogram?
   a. Anencaphaly

b. Spina bifida
c. Cleft lip
d. Hydronephrosis

5. The “lying down” adrenal sign would be seen in all of the following situations except:
   a. Unilateral renal agenesis
   b. Bilateral renal agenesis
   c. Potter syndrome
   d. Pyelectesis

6. The birth defect in which the sex of the fetus cannot be determined defines:
   a. Renal agenesis
   b. Ovarian dysgenesis
   c. Clitorimegaly
   d. Ambiguous genitalia

7. What measurement should the renal pelvis not exceed prior to 20 weeks’ gestation?
   a. 2 mm
   b. 10 mm
   c. 7 mm
   d. 1.2 cm

8. Cloacal exstrophy is associated with all of the following except:
   a. Omphalocele
   b. Spina bifida
   c. Encephalocele
   d. Imperforate anus

9. The renal cystic disease that results in the development of cysts late in adulthood is:
   a. Multicystic dysplastic renal disease
   b. Autosomal dominant polycystic disease
   c. Autosomal recessive polycystic disease
   d. Obstructive cystic dysplasia

10. What is the most common cause of hydronephrosis in the neonate and the most common form of fetal renal obstruction?
    a. UVJ obstruction
    b. UPJ obstruction
    c. Vesicoureteral reflux

d. Urethral atresia

11. Bladder exstrophy describes:
    a. Absence of the cloaca
    b. Protrusion of the bladder into the umbilicus
    c. External position of the bladder
    d. Enlargement of the bladder

12. Which of the following would result in compensatory hypertrophy?
    a. Unilateral renal agenesis
    b. Bilateral renal agenesis
    c. Pelvic kidney
    d. Horseshoe kidneys

13. Which of the following would cause a bladder outlet obstruction?
    a. Posterior urethral valves
    b. Fetal ovarian cyst
    c. Pelviectasis
    d. Pelvocaliectasis

14. Which of the following is associated with enlarged echogenic kidneys and microscopic renal cysts?
    a. MCDK disease
    b. Obstructive cystic dysplasia
    c. Hydronephrotic syndrome
    d. ARPKD

15. The “lying down” adrenal sign describes the sonographic findings of:
    a. Enlarged bladder and urethra
    b. Renal agenesis
    c. MCDK disease
    d. Posterior urethral valves

16. The “I” in OEIS complex stands for:
    a. Imperforate anus
    b. Ilial dysfunction
    c. Irregular bladder enlargement
    d. Iniencephaly

17. Another name for pelvocaliectasis is:
    a. Caliectasis
    b. Hydrocele
    c. Hydronephrosis

d. Pyonephrosis

18. Which of the following best describes hypospadias?
    a. OEIS complex in the presence of a hydrocele
    b. The chronic obstruction of the renal pelvis and urethra
    c. The underdevelopment of the scrotum in the presence of a hydrocele
    d. An abnormal ventral curvature of the penis

19. The “keyhole” sign describes the sonographic findings of a(n):
    a. Enlarged bladder and dilated urethra
    b. Bilateral renal agenesis
    c. Unilateral renal agenesis
    d. Dilation of the renal pelvis and proximal ureter

20. What is the term for enlargement of the urinary bladder?
    a. Posterior urethral valves
    b. Urethral atresia
    c. Prune belly syndrome
    d. Megacystis

21. Numerous noncommunicating anechoic masses are noted within the left renal fossa of a fetus at 20 weeks’ gestation. What is the most likely etiology of these masses?
    a. ARPKD
    b. ADPKD
    c. MCDK disease
    d. Hydronephrosis

22. Fluid surrounding the fetal testicle is referred to as:
    a. Hydroureter
    b. Hydronephrosis
    c. Hydrocele
    d. Hydroscrotum

23. Fusion of the lower poles of the kidneys describes:
    a. Renal agenesis
    b. Horseshoe kidneys
    c. Moiety
    d. Meckel–Gruber syndrome

24. The syndrome associated with an occipital cephalocele, cystic renal disease, and polydactyly is:
    a. Meckel–Gruber syndrome

b. Potter syndrome
c. VACTERL association
d. Sirenomelia syndrome

25. Which of the following is not a component of prune belly syndrome?
a. Megacystis
b. Undescended testis
c. Dilated urinary bladder and urethra
d. Abdominal muscle hypertrophy

26. OEIS complex is also referred to as:
a. Bladder exstrophy
b. Omphalocele
c. Potter syndrome
d. Cloacal exstrophy

27. Obstruction at the level of the UPJ would lead to dilation of the:
a. Renal pelvis and bladder
b. Bladder and ureter
c. Ureter and renal pelvis
d. Renal pelvis and calices

28. The most common location of an ectopic kidney is within the:
a. Lower abdomen
b. Pelvis
c. Chest
d. Contralateral quadrant

29. Pyelectasis refers to:
a. Enlargement of the urinary bladder, ureter, and renal calices
b. Dilation of the ureter
c. Dilation of the renal pelvis
d. Enlargement of the ureter only

30. Prune belly syndrome is caused by:
a. An enlarged bladder
b. Unilateral renal agenesis
c. Bilateral renal agenesis
d. Hypospadias

31. All of the following would be associated with oligohydramnios except:
a. Bilateral MCDK disease
b. Unilateral renal agenesis

c. Bilateral renal agenesis
d. ARPKD

32. What is the most common fetal renal tumor?
a. Neuroblastoma
b. Nephroblastoma
c. Mesoblastic nephroma
d. Wilms tumor

33. The type of renal cystic disease associated with adult liver and pancreatic cysts is:
a. MCDK
b. ARPKD
c. ADPKD
d. VATER

34. Having more than the normal number of digits is:
a. Polydactyly
b. Clinodactyly
c. Multidigitopia
d. Sirenomelia

35. Cryptorchidism describes:
a. Bilateral pelvic kidneys
b. Urethral atresia
c. Undescended testicles
d. Ovarian dysgenesis

36. An obstruction at the ureterovesicular junction would lead to dilation of the:
a. Bladder and urethra
b. Bladder, urethra, and ureters
c. Bladder, urethra, ureters, and renal collecting system
d. Ureter and renal collecting system

37. Before 9 weeks, the fetal kidneys are located within the:
a. Renal fossae
b. Pelvis
c. Chest
d. Umbilical cord

38. Which of the following is the most common renal anomaly?
a. Horseshoe kidneys

b. Pelvic kidneys
c. Renal agenesis
d. Duplex collecting system

39. Failure of the kidneys to form is called:
a. Hydronephrosis
b. Renal dysplasia
c. Renal agenesis
d. Renal ectopia

40. Which of the following would be the most likely cause of bilateral, enlarged echogenic fetal kidneys and oligohydramnios?
a. ARPKD
b. MCKD
c. Renal cystic dysplasia
d. ADPKD

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30 Chromosomal Abnormalities

Introduction

This chapter offers a brief analysis of frequently encountered chromosomal abnormalities and a discussion on the difference between chromosomal abnormalities, anomalies, syndromes, and malformations. An overview of the application of the maternal serum screen, fetal sampling, and fetal karyotyping is also provided.

Key Terms

advanced maternal age—a maternal age of 35 years or older

agenesis of the corpus callosum—the congenital absence of corpus callosum that may be partial or complete

alpha-Fetoprotein—a protein produced by the fetal yolk sac, fetal gastrointestinal tract, and the fetal liver; may also be produced by some malignant tumors

amniocentesis—a surgical procedure in which amniotic fluid is extracted for genetic testing or removed when there is an accumulation of an excessive amount of fluid around the fetus

amnionitis—inflammation of the amniotic sac secondary to infection

aneuploidy—a condition of having an abnormal number of chromosomes

anomaly—a structural feature that differs from the norm

ascites—excessive fluid in the peritoneal cavity

brachycephaly—round skull shape

chorionic villi—fingerlike projections of gestational tissue that attach to the decidualized endometrium and allow transfer of nutrients from the mother to the fetus

chorionic villi sampling—prenatal test used that obtains placental tissue for chromosomal analysis

choroid plexus cysts—cysts located within the lateral ventricles of the brain, specifically in the choroid plexus

chromosomal abnormality—an error in either the number or structure of chromosomes

chromosomes—the cellular structures that contain genes

cleft lip—an abnormal division in the lip

cleft palate—the abnormal development of the soft and/or hard palate of the mouth where there is a division in the palate

clinodactyly—the bending of the fifth finger toward the fourth finger

clubfoot—a malformation of the bones of the foot in which the foot is most often inverted and rotated medially, and the metatarsals lie in the same plane as the tibia and fibula

coarctation of the aorta—the narrowing of the aortic arch

cordocentesis—prenatal test that obtains fetal blood for chromosomal analysis

cyclopia—fusion of the orbits

Dandy–Walker malformation—congenital brain malformation in which there is enlargement of the cisterna magna, agenesis of the cerebellar vermis, and dilation of the fourth ventricle

diaphragmatic hernia—the herniation of the abdominal contents into the chest cavity through a defect in the diaphragm

Down syndrome—see key term trisomy 21

duodenal atresia—congenital maldevelopment or absence of duodenum

Edwards syndrome—see key term trisomy 18

esophageal atresia—congenital absence of part of the esophagus

estriol—an estrogenic hormone produced by the placenta

facies—the features or appearance of the face

fetal karyotyping—an analysis of fetal chromosomes; reveals the morphology and number of chromosomes

gynecomastia—the benign enlargement of the male breast; typically located posterior to the areola

holoprosencephaly—a group of brain abnormalities consisting of varying degrees of fusion of the lateral ventricles, absence of the midline structures,

and associated facial anomalies

horseshoe kidneys—the attachment of the lower poles of the kidneys by a band of renal tissue that crosses the midline of the abdomen

human chorionic gonadotropin—hormone produced by the trophoblastic cells of the early placenta; may also be used as a tumor marker in nongravid patients and males

hydrocephalus—the increased volume of cerebrospinal fluid within the ventricular system

hydronephrosis—the dilation of the renal collecting system resulting from the obstruction of the flow of urine from the kidney(s) to the bladder; also referred to as pelvocaliectasis or pelvicaliectasis

hypoplastic—incomplete or arrested development of a structure

hypoplastic left heart—incomplete development of the left ventricle resulting in a small or absent left ventricle

hypotelorism—reduced distance between the orbits

intrauterine growth restriction—a fetus that is below the 10th percentile for gestational age (small for gestational age) and whose growth is impeded for some reason

macroglossia—enlargement of the tongue

malformation—a structural abnormality that results from an abnormal development

microcephaly—small head

micrognathia—a small mandible and recessed chin

microphthalmia—small eye or eyes

molar pregnancy—also referred to as gestational trophoblastic disease; is associated with an abnormal proliferation of the trophoblastic cells, enlargement of the placenta, and elevated levels of human chorionic gonadotropin

morphology—the form and structure of an organism

monosomy X—see key term Turner syndrome

nonimmune hydrops—fetal hydrops caused by congenital fetal anomalies and infections

nuchal—the posterior part or nape of the neck

nuchal cystic hygroma—a mass found in the neck that is the result of an abnormal accumulation of lymphatic fluid within the soft tissue

nuchal fold—a collection of solid tissue at the back of the fetal neck

nuchal translucency—the anechoic space along the posterior aspect of the fetal neck

omphalocele—an anterior abdominal wall defect where there is herniation of the fetal bowel and other abdominal organs into the base of the umbilical cord

ovarian dysgenesis—imperfect or abnormal development of the ovaries

Patau syndrome—chromosomal aberration in which there is a third chromosome 13; also referred to as trisomy 13

percutaneous umbilical cord sampling—see key term cordocentesis

pericardial effusion—fluid accumulation around the heart in the pericardial cavity

pleural effusion—the abnormal accumulation of fluid in the pleural space

polydactyly—having more than the normal number of fingers or toes

pregnancy-associated plasma protein A—a protein that is produced by the placenta and that can be monitored during pregnancy

pyelectasis—enlargement of the renal pelvis; also referred to as pelviectasis

renal agenesis—failure of the kidney to develop; may be unilateral or bilateral

rockerbottom feet—abnormal curved shape of the sole of the feet

sandal gap—a large space between the first and second toes

spina bifida—a birth defect in which there is incomplete closure of the spine

spontaneous abortion—the loss of a pregnancy before 20 gestational weeks

subcutaneous edema—a buildup of fluid under the skin

syndactyly—webbed fingers or toes

syndrome—a group of clinically observable findings that exist together and allow for classification

theca lutein cysts—functional ovarian cysts that are found in the presence of elevated levels of human chorionic gonadotropin; also referred to as a theca luteal cysts

triple screen—a maternal blood test that typically includes an analysis of human chorionic gonadotropin, alpha- fetoprotein, and estriol

trisomy—a cell having three copies of an individual chromosome

trisomy 13—chromosomal aberration in which there is a third chromosome 13; also referred to as Patau syndrome; often associated with holoprosencephaly

trisomy 18—chromosomal aberration in which there is a third chromosome 18; also referred to as Edwards syndrome

trisomy 21—chromosomal aberration in which there is a third chromosome 21; also referred to as Down syndrome

trophoblastic cells—the cells that surround the gestation that produce

human chorionic gonadotropin

Turner syndrome—a chromosomal aberration where one sex chromosome is absent; may also be referred to as monosomy X

ventriculomegaly—buildup of cerebrospinal fluid that results in an enlargement of one or more of the ventricles within the brain

CHROMOSOMAL ABNORMALITIES, ANOMALIES, SYNDROMES, AND MALFORMATIONS

Chromosomes are the structures, located in each cell in our body, that hold our genes. A chromosomal abnormality exists as an error in either the number or structure of chromosomes. The normal cell has 46 chromosomes or 2 pairs of 23. Aneuploidy is a condition in which there are an abnormal number of whole chromosomes. Specifically, an aneuploid has too many or too few chromosomes. Edwards syndrome is an example of a specific type of aneuploid in which there is an additional copy of the chromosome 18. This type of aneuploid is specifically referred to as a trisomy and thus is referred to as trisomy 18. Thus, trisomy 21 or Down syndrome has a third 21st chromosome. Turner syndrome, also referred to as monosomy X, is a different type of chromosomal abnormality in which the fetus has only one sex chromosome. Consequently, this is why it is referred to as a monosomy. Some common genetic terms that you may encounter as you study are listed in Table 30-1.



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Edwards syndrome is an example of a specific type of aneuploid in which there is an additional copy of the chromosome 18. This type of aneuploid is specifically referred to as a trisomy, and thus is referred to as trisomy 18.

Structural abnormalities of an individual chromosome may also exist. These can result in deletions, duplications, translocations, and other abnormal configurations. Environmental factors and maternal age have been suspected to increase the likelihood of chromosomal abnormalities.

An anomaly is a structural feature that differs from the norm. An example of an anomaly is agenesis of the corpus callosum in which there is congenital absence of an important midline brain structure. A syndrome is a group of clinically observable findings that exist together and allow for classification. These signs and symptoms are linked to each other in some way. Chromosomal abnormalities often exist when there are multiple defects. For

example, Down syndrome has clinically identifiable signs such as a flat facial profile and a transverse crease in the palm of the hand. An example of symptoms of Down syndrome would be developmental delays and hearing loss.

TABLE 30-1 Often encountered genetic terms and their definitions

Terms Related to Genetics	Definition
Aneuploid	A cell that has an abnormal number of whole chromosomes. The diploid number of 46 chromosomes is altered. There may be too many or too few.
Diploid	A cell having the normal pair of each chromosome. There are 46 chromosomes in this situation. Normal cells are diploid, with the exception of the gametes.
Haploid	A cell having only one member of each pair of chromosomes.
Monosomy	A cell having only one of an individual chromosome.
Mosaic	A situation in which some cells have an abnormal number of chromosomes whereas others do not.
Triploid	A cell having 3 times the normal haploid number. There are 69 chromosomes.
Trisomy	A cell having 3 copies of an individual chromosome.

A malformation is a structural abnormality that results from unusual development. For instance, Dandy–Walker malformation is a congenital brain malformation that is thought to be caused by a developmental deviation in the roof of the fourth ventricle.



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A syndrome is a group of clinically observable findings that exist together and allow for classification.

NONINVASIVE PRENATAL TESTING

As discussed in Chapter 22, the triple screen is a maternal blood test that can be helpful in the second trimester for detecting unusual levels of certain proteins or hormones with chromosomal abnormalities. The three laboratory values that typically comprise the triple screen are maternal serum alpha-

fetoprotein (MSAFP), estriol, and human chorionic gonadotropin (hCG). AFP is produced in the yolk sac and fetal liver. Estriol and hCG are produced by the placenta. The triple screen has a 60% detection rate for Down syndrome. However, the most common cause of abnormal serum screening tests is incorrect dating of the pregnancy. Atypical first-trimester laboratory findings often lead to follow-up sonographic examinations to date the pregnancy. Two supplementary proteins that can also be monitored are the pregnancy-associated plasma protein A (PAPP-A) and the dimeric inhibin A. Both of these proteins are produced by the placenta as well. One of the newer maternal blood test available is the MaterniT 21Plus test (Sequenom Laboratories, San Diego, CA), which is a type of cell-free fetal DNA testing. This simple blood test can reveal gender and is also highly accurate in detecting chromosomal anomalies, including trisomies 21, 18, and 13 and sex chromosome abnormalities, as early as 9 weeks' gestation. As this chapter progresses, laboratory findings of chromosomal abnormalities will be provided.



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The three laboratory values that typically comprise the triple screen are MSAFP, estriol, and hCG

FETAL KARYOTYPING AND GENETIC TESTING

Advanced maternal age is considered to be 35 years of age or older. Patients with advanced maternal age have a greater risk of having an abnormal pregnancy or pregnancy failure. Fetal karyotyping is an analysis of fetal chromosomes and is frequently recommended for women who are considered to be of advanced maternal age, or when the maternal or paternal history suggests the possibility of fetal abnormalities. Karyotyping is extremely valuable for detecting specific chromosomal abnormalities and the morphology of those chromosomes. During pregnancy, a sample of maternal blood, amniotic fluid, or tissue from the placenta can be used for fetal karyotyping. There are three main procedures used to obtain material for fetal karyotyping: (i) chorionic villi sampling (CVS), (ii) amniocentesis, and (iii) cordocentesis.



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Advanced maternal age is considered to be 35 years of age or older.

CVS is typically the earliest procedure that can be performed during a

pregnancy for fetal karyotyping. With CVS, a small amount of chorionic villi is obtained for chromosomal testing. CVS can be performed transabdominally or transvaginally (transcervical) between 10 and 13 gestational weeks. Under sonographic guidance, a needle or plastic catheter is placed into the placental mass for the aspiration of trophoblastic cells (Figs. 30-1 and 30-2). Existing research has made a possible association between CVS performed less than 10 weeks and fetal limb abnormalities. However, this relationship is still under investigation.

Amniocentesis is used for genetic purposes between 15 and 20 weeks. Some facilities may offer this procedure to patients as early as 10 weeks, although some studies suggest that it should not be done before 15 weeks because of an increase in fetal complications. An amniocentesis is performed transabdominally with sonographic guidance (Fig. 30-3). The physician inserts a 20 to 22G needle through the abdomen and into the amniotic sac to remove amniotic fluid for testing. The most common side effects of this procedure are uterine contractions and cramping. Rarely, patients experience vaginal spotting, amniotic fluid leakage, or amnionitis. The fetal loss rate due to miscarriage is between 2% and 3% above the typical loss rate during the sampling weeks. Although some labs produce quicker results, it may take as many as 3 weeks for a complete analysis of the fluid. An amniocentesis may also be performed to assess the fetal lungs for maturity by obtaining fluid and testing the lecithin to sphingomyelin ratio (L/S ratio). Also, a therapeutic amniocentesis can be performed to remove excess amniotic fluid or to distend the amniotic cavity with more fluid when scant fluid is noted around the fetus.

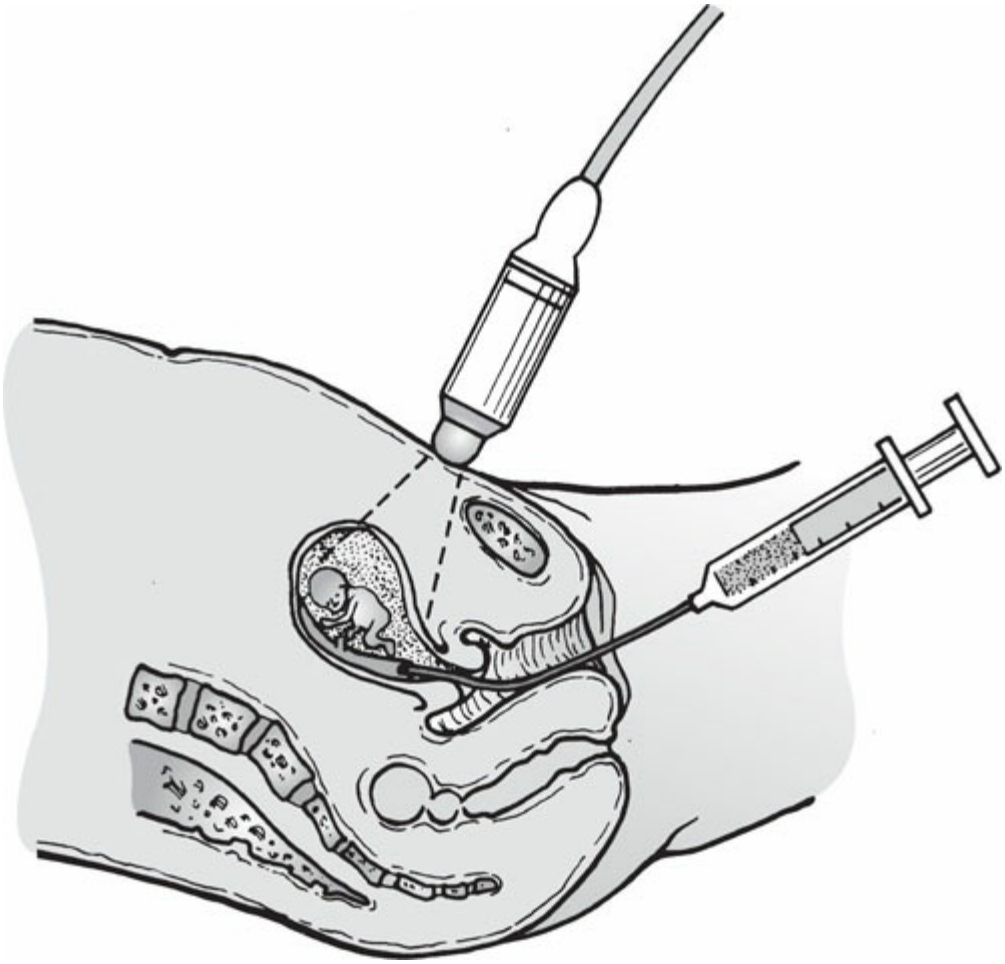
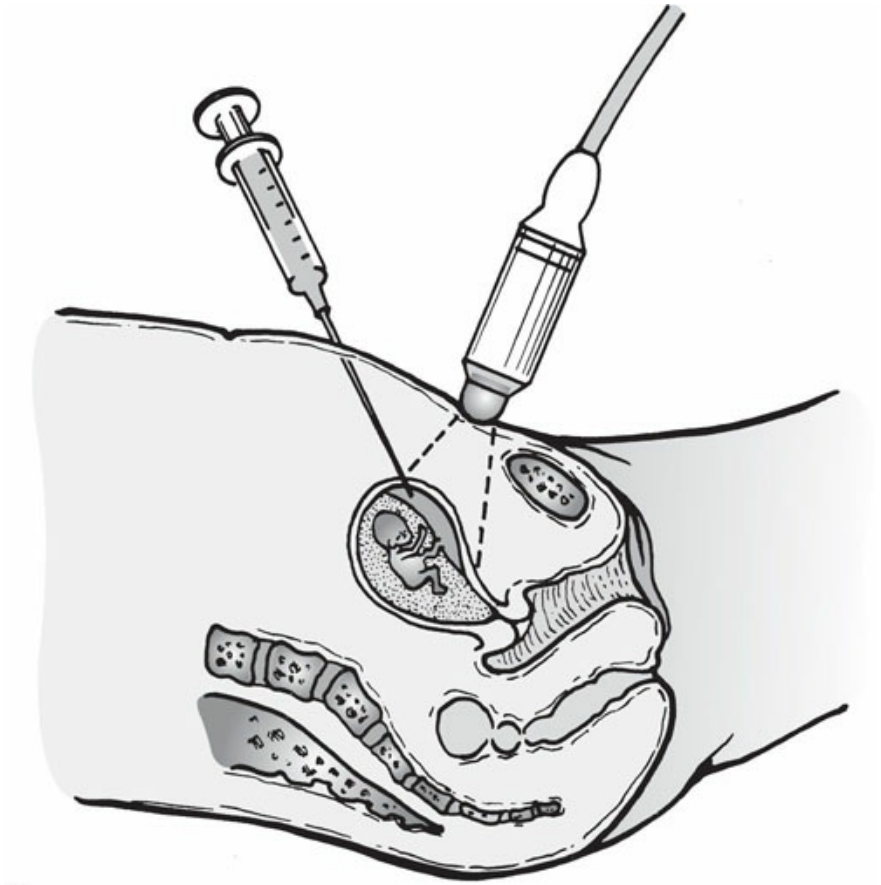
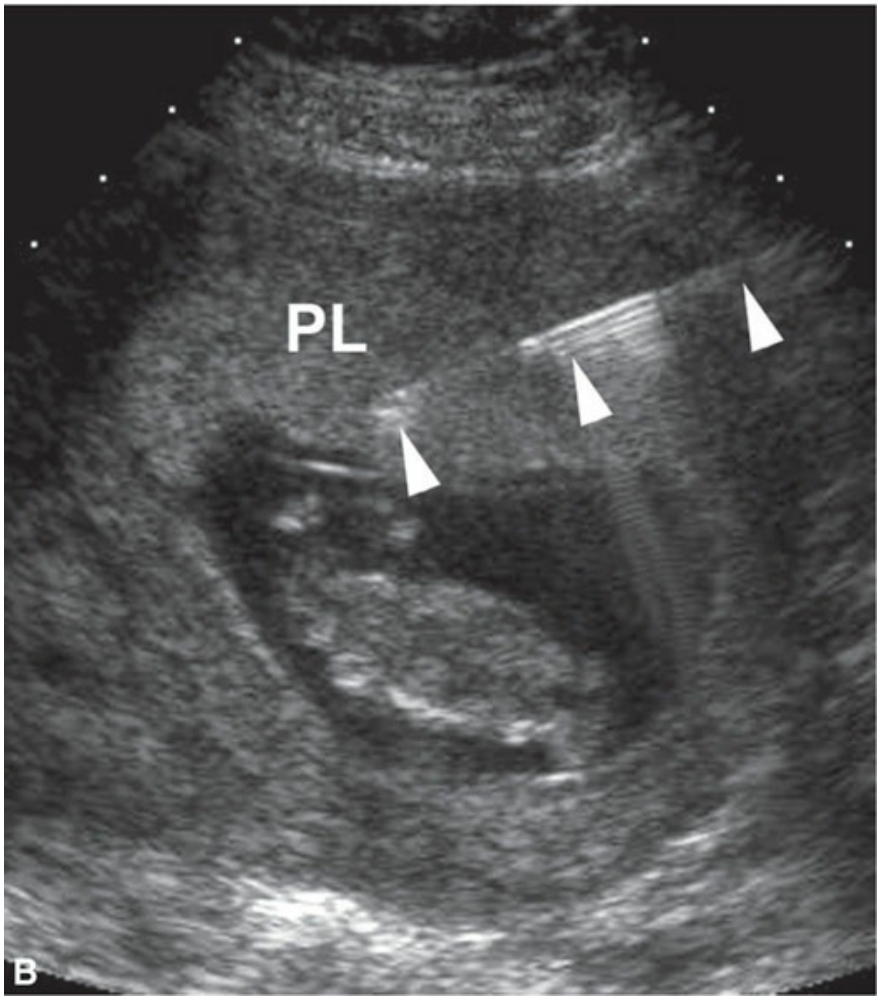


Figure 30-1 Transvaginal chorionic villi sampling.



A



B

Figure 30-2 Transabdominal chorionic villi sampling. **A.** Schematic demonstrating the procedure. **B.** Sonogram of a needle *(arrowheads)* being placed within the placenta (*PL*) during a chorionic villi sampling procedure.

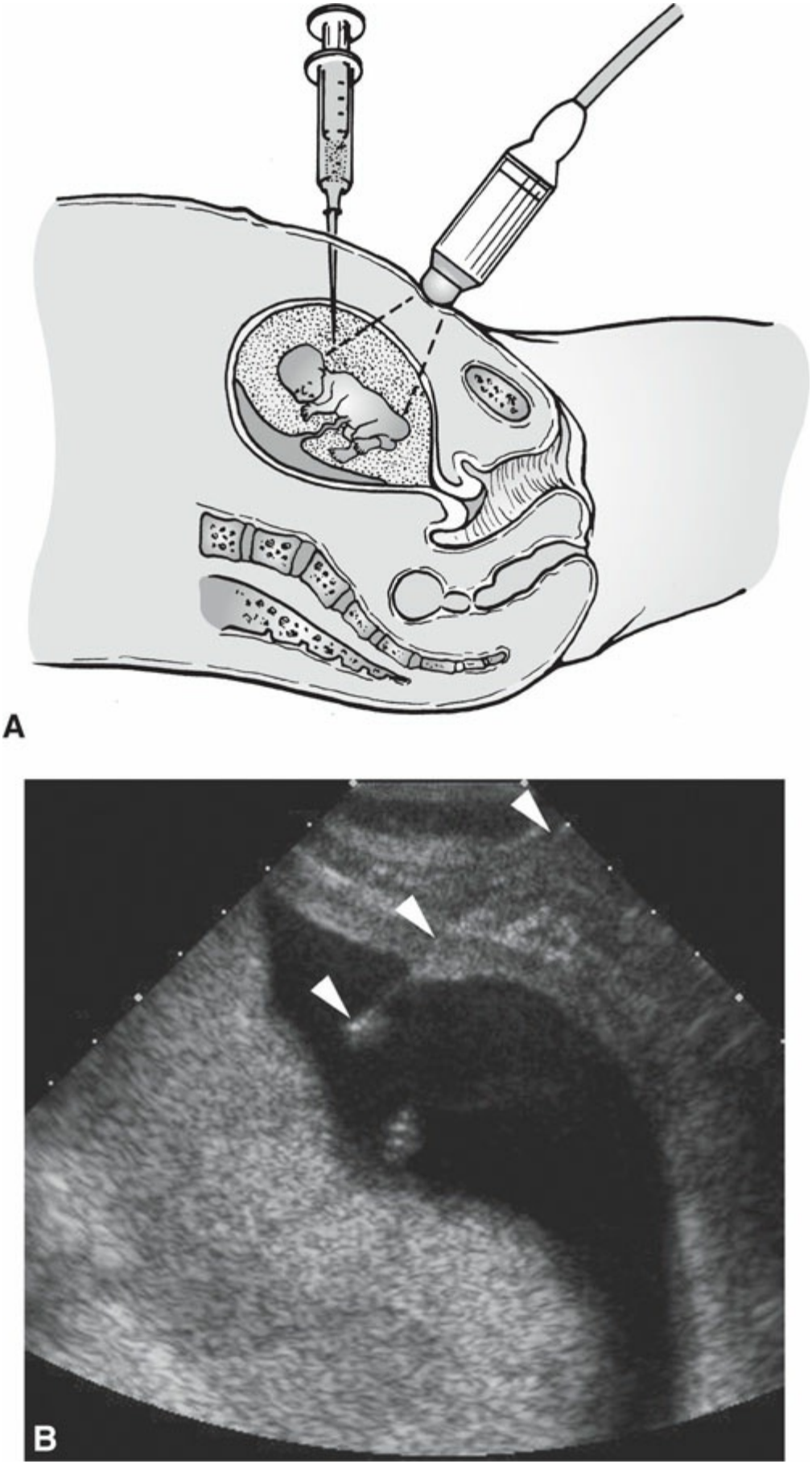


Figure 30-3 A. Amniocentesis. **B.** Sonogram of an amniocentesis demonstrating the needle *(arrowheads)* within the amniotic sac.

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Amniocentesis is used for genetic purposes between 15 and 20 weeks.

Cordocentesis, also referred to as percutaneous umbilical cord sampling (PUBS) or fetal blood sampling, is performed transabdominally after 17 weeks. A needle is placed through the maternal abdomen and into the umbilical vein. The segment of the cord that is most often accessed is at the cord insertion point into the placenta (Fig. 30-4). A sample of fetal blood is removed. PUBS has been associated with fetal bradycardia and hemorrhage at the sampling site. It also carries a higher fetal loss rate compared to amniocentesis. PUBS allows for rapid detection of chromosomal anomalies, because it requires only 48 to 72 hours for analysis.

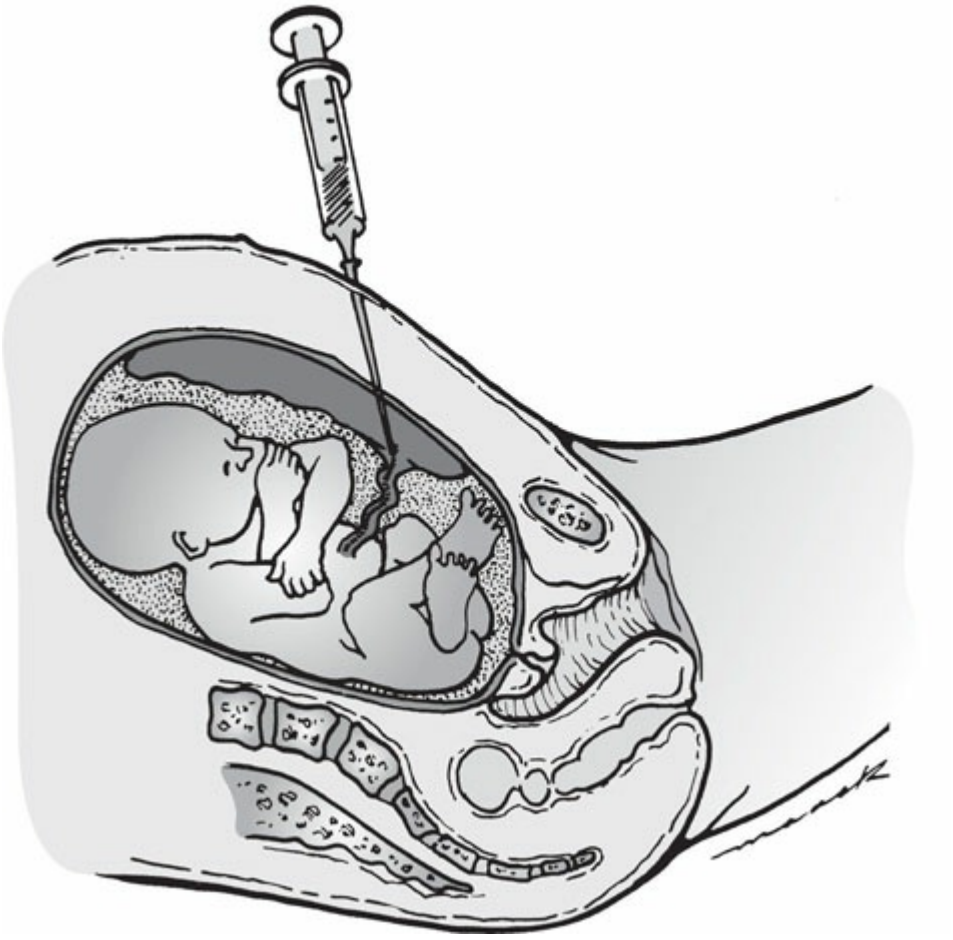


Figure 30-4 Cordocentesis (percutaneous umbilical cord sampling).

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For PUBS, a needle is placed through the maternal abdomen and into the umbilical vein. The segment of the cord that is most often accessed is at the cord insertion point into the placenta.

COMMON CHROMOSOMAL ABNORMALITIES

Down Syndrome (Trisomy 21)

Down syndrome, or trisomy 21, is the most common chromosomal abnormality. It occurs in 1 in 500 to 800 pregnancies. Fetuses with trisomy 21 have an extra chromosome 21. Various sonographic features of Down syndrome include duodenal atresia, thickened nuchal translucency in the first trimester or increased nuchal fold thickness in the second trimester, pyelectasis, and absent nasal bones (Fig. 30-5). Maternal serum screening outcomes yield evidence of elevated hCG and inhibin A levels, whereas all other laboratory values are reduced.

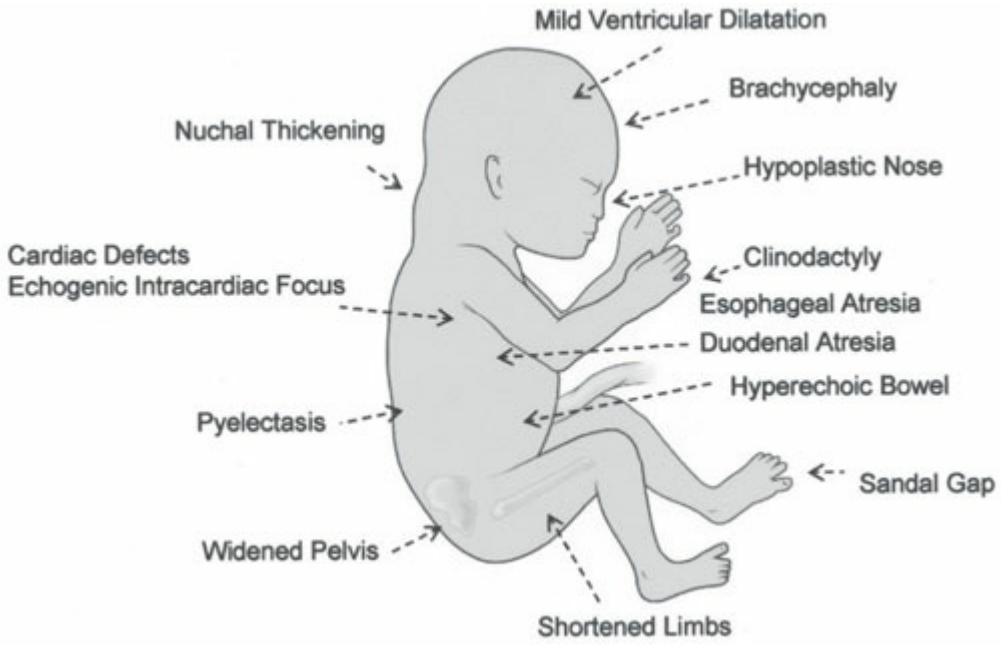


Figure 30-5 Common feature of trisomy 21.

MATERNAL SERUM SCREENING RESULTS OF DOWN SYNDROME

1. Low MSAFP
2. Low estriol
3. High hCG
4. High inhibin A
5. Low PAPP-A

SONOGRAPHIC FINDINGS OF DOWN SYNDROME

1. Absent nasal bones (**hypoplastic** nose)
2. **Brachycephaly**
3. **Clinodactyly** (Fig. 30-6)
4. Duodenal atresia (Fig. 30-7)
5. Echogenic intracardiac focus
6. Hyperechoic (echogenic) bowel
7. **Macroglossia** (Fig. 30-8)
8. Mild **ventriculomegaly**
9. **Nonimmune hydrops**
10. Nuchal thickening ≥6 mm between 15 and 21 weeks (Fig. 30-9)
11. Thickened nuchal translucency
12. **Pericardial effusion**
13. Pyelectasis
14. **Sandal gap**
15. Shortened limbs (humerus and femur)
16. Ventricular septal defects (VSD)
17. Widened pelvic angles

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Down syndrome, or trisomy 21, is the most common chromosomal abnormality.

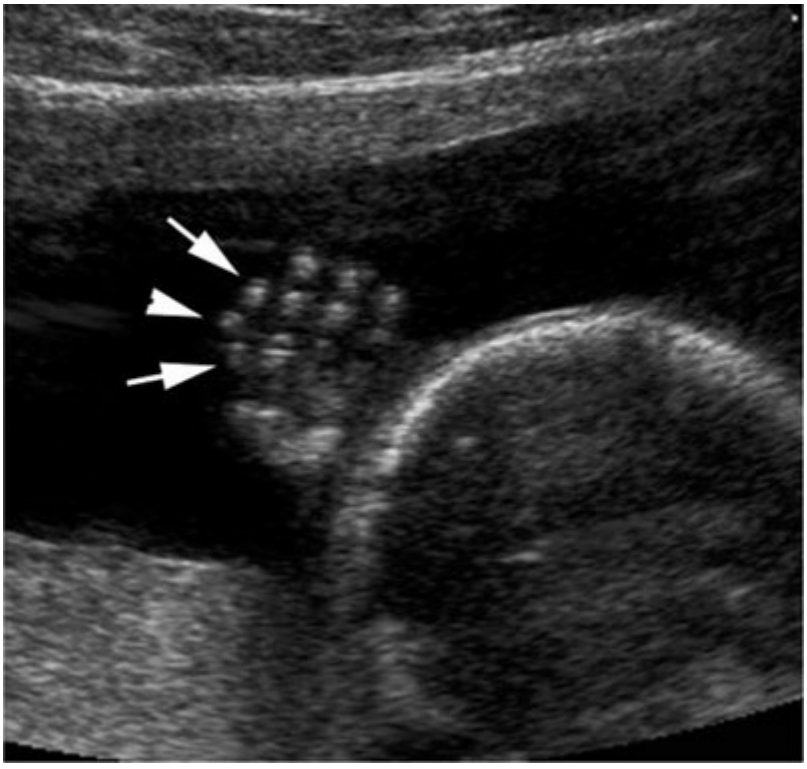


Figure 30-6 Clinodactyly of the fifth digit. Image of the open hand revealing the inward curvature of the fifth digit *(arrows)* caused by a malformed middle phalanx

(arrowhead).

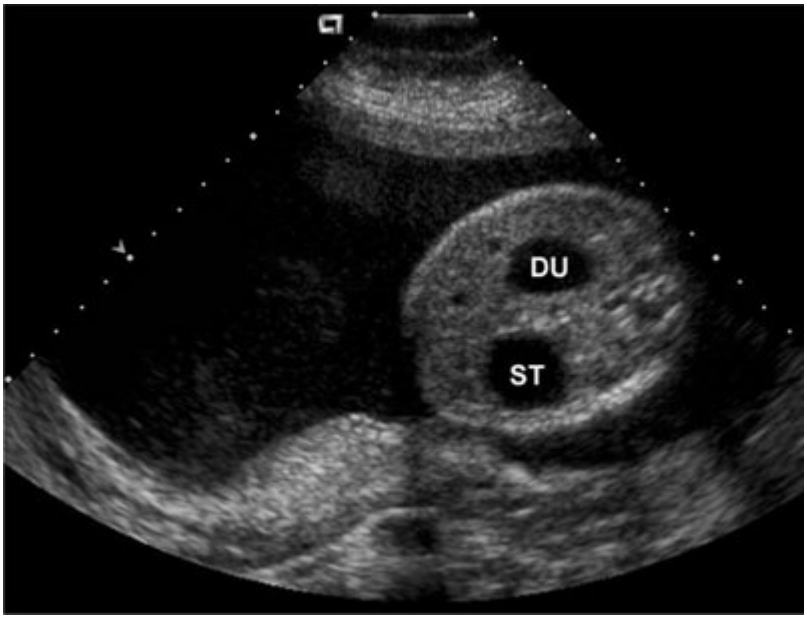


Figure 30-7 Duodenal atresia in a fetus with trisomy 21. Transverse view of the fetal abdomen revealing two fluid-filled structures representing the stomach (*ST*) and duodenum (*DU*). This is referred to as the "double bubble."

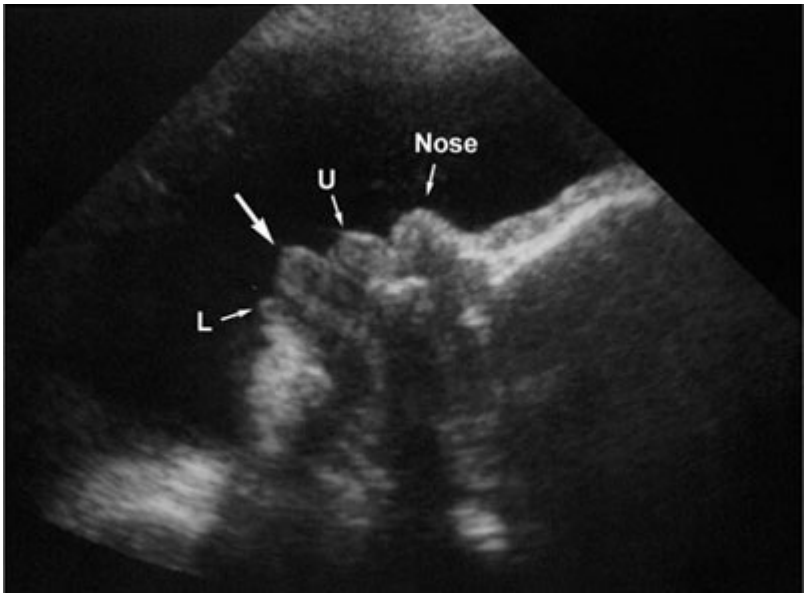


Figure 30-8 Macroglossia. Sagittal image of a fetus with macroglossia revealing the nose, upper lip (*U*), enlarged tongue (*arrow*), and lower lip (*L*).



Figure 30-9 Thick nuchal fold. Angled axial view of the fetal head demonstrating a thick nuchal fold (*calipers*) measuring 9.1 mm.

Edwards Syndrome (Trisomy 18)

Edwards syndrome is the second most common chromosomal abnormality. The majority of fetuses diagnosed with Edwards syndrome, or trisomy 18, die either before birth or shortly after birth. Fetuses with trisomy 18 have an extra chromosome 18. Various sonographic features of Edwards syndrome include a strawberry-shaped skull, choroid plexus cysts, micrognathia, rockerbottom feet, omphalocele, clenched fists, and single umbilical artery (Fig. 30-10). All laboratory values are decreased with Edwards syndrome.

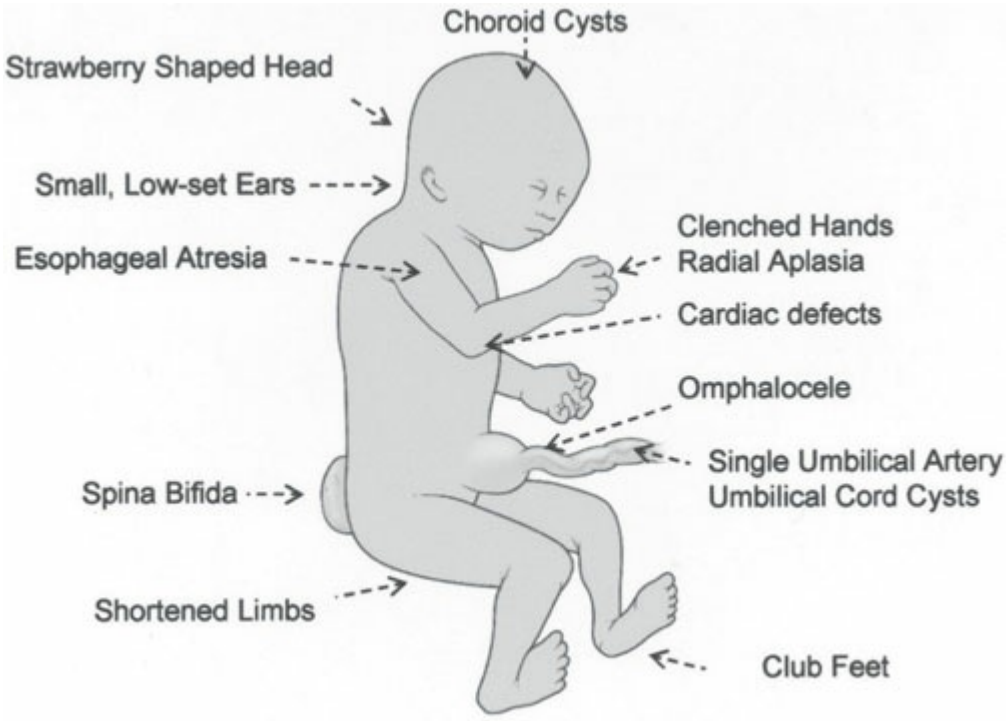


Figure 30-10 Common feature of trisomy 18.

MATERNAL SERUM SCREENING RESULTS OF EDWARDS SYNDROME

1. Low AFP
2. Low estriol
3. Low hCG
4. Low inhibin A
5. Low PAPP-A

SONOGRAPHIC FINDINGS OF EDWARDS SYNDROME

1. Strawberry-shaped skull (Fig. 30-11)
2. Agenesis of the corpus callosum
3. Choroid plexus cyst (Fig. 30-12)
4. Hypoplastic cerebellum
5. Enlarged cisterna magna
6. **Hydrocephalus**
7. Micrognathia (Fig. 30-13)
8. Small, low-set ears
9. **Esophageal atresia**
10. **Spina bifida**
11. Clenched hands, overlapping index finger, fixed wrists (see Fig. 30-11)
12. Cardiac defects (including VSD and tetrology of Fallot)
13. Omphalocele
14. Nonimmune hydrops
15. **Diaphragmatic hernia**

16. Renal anomalies
17. Single umbilical artery
18. Feet abnormalities (rockerbottom feet, **clubfeet**) (Figs. 30-14 and 30-15)

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Edwards syndrome includes a strawberry-shaped skull, choroid plexus cysts, micrognathia, rockerbottom feet, omphalocele, clenched fists, and single umbilical.

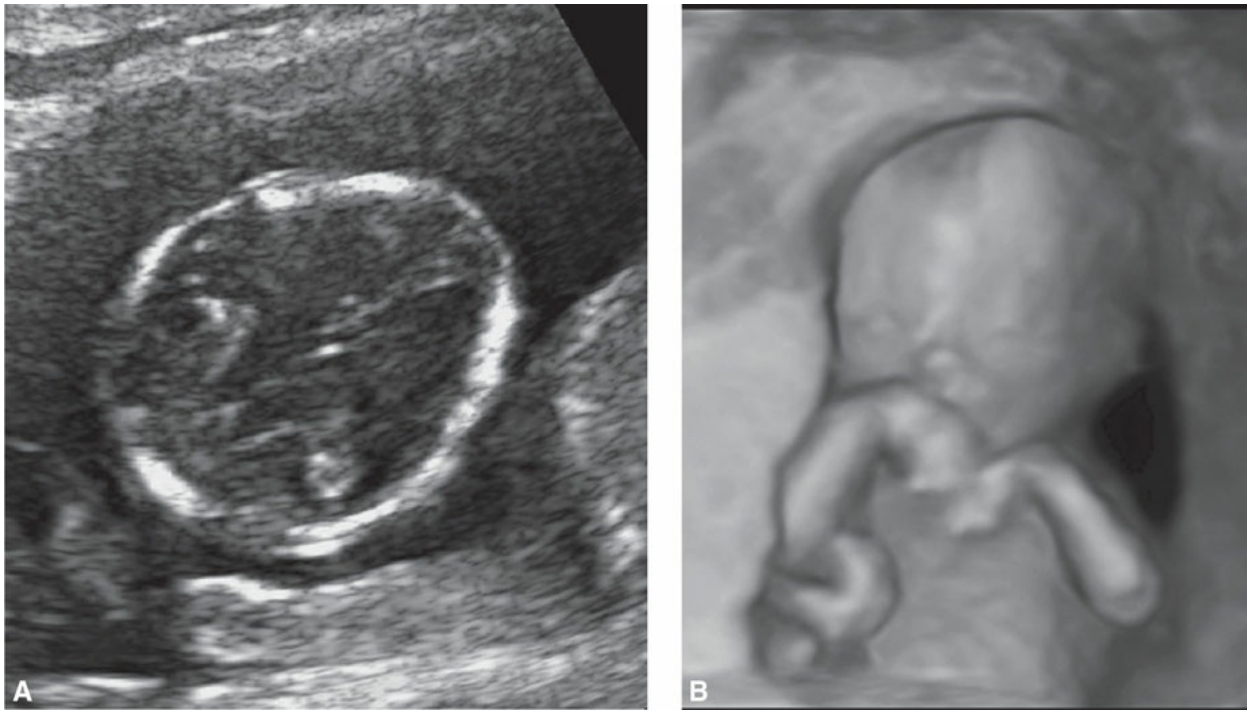


Figure 30-11 Strawberry-shaped skull (**A**) and clinched fist (**B**) in a fetus with trisomy 18.

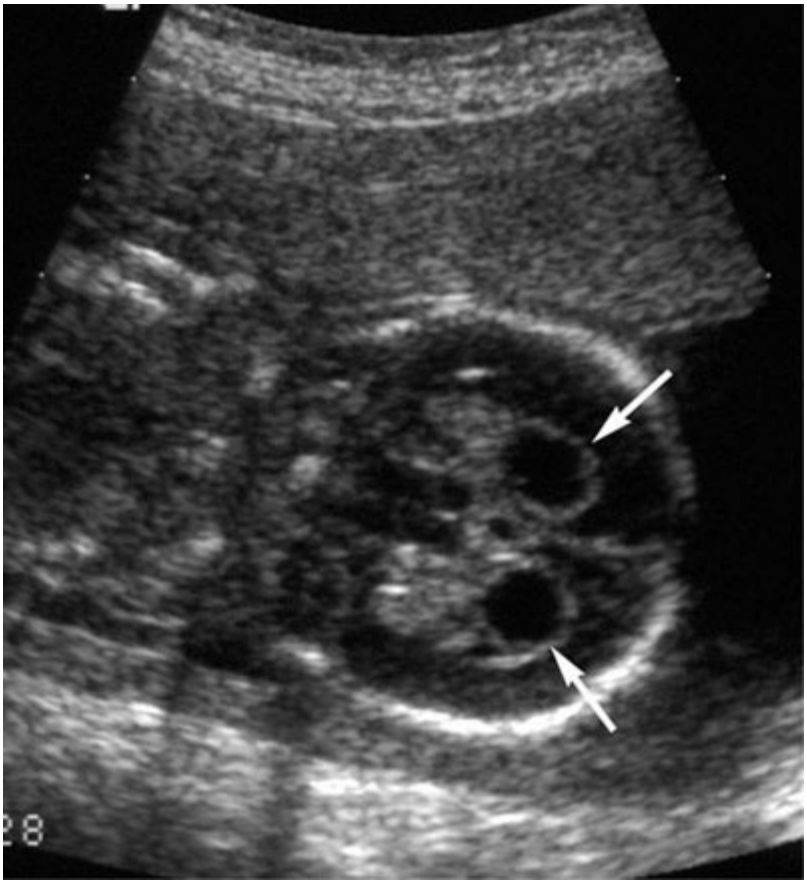


Figure 30-12 Bilateral choroid plexus cysts in a fetus with trisomy 18. Choroid plexus cysts (*arrows*) are identified in both lateral ventricles of this fetus with trisomy 18.

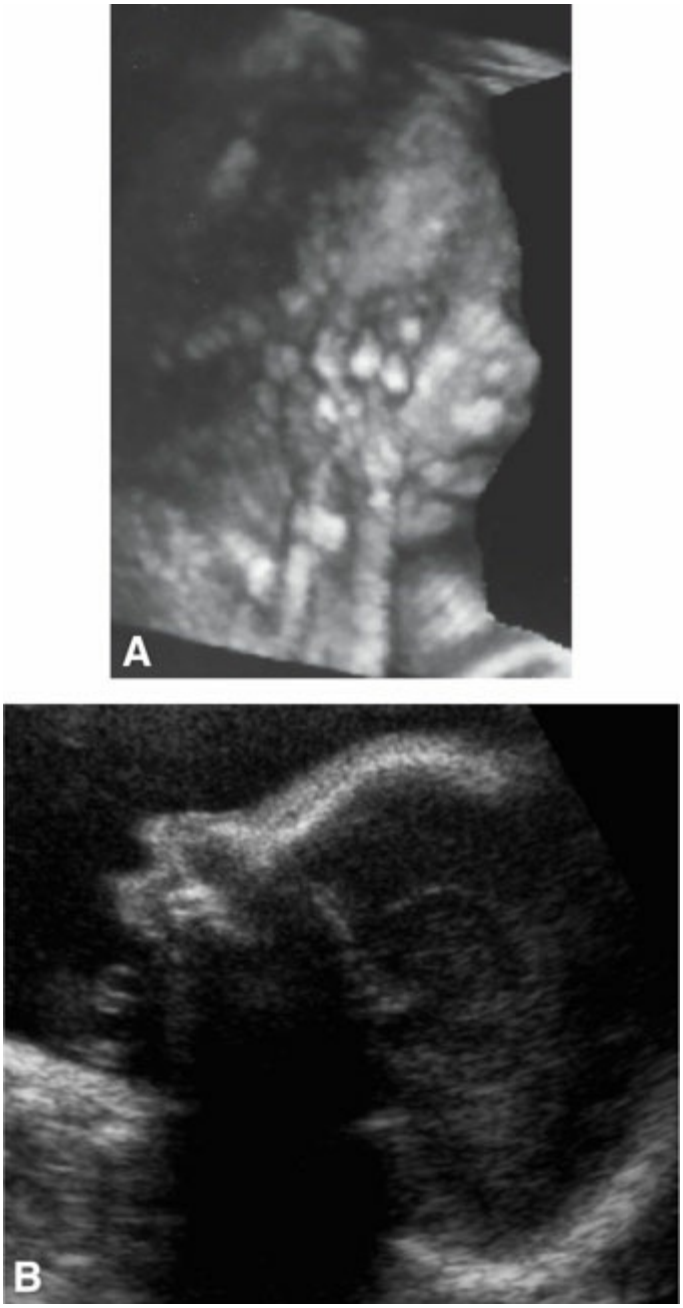


Figure 30-13 Micrognathia. **A.** Three-dimensional sonogram showing micrognathia in a fetus with trisomy 18. **B.** Sagittal profile image of the fetus revealing severe micrognathia.



Figure 30-14 Rockerbottom foot. Image of the lower leg and foot demonstrating downward curvature of the bottom of the foot (*arrows*).

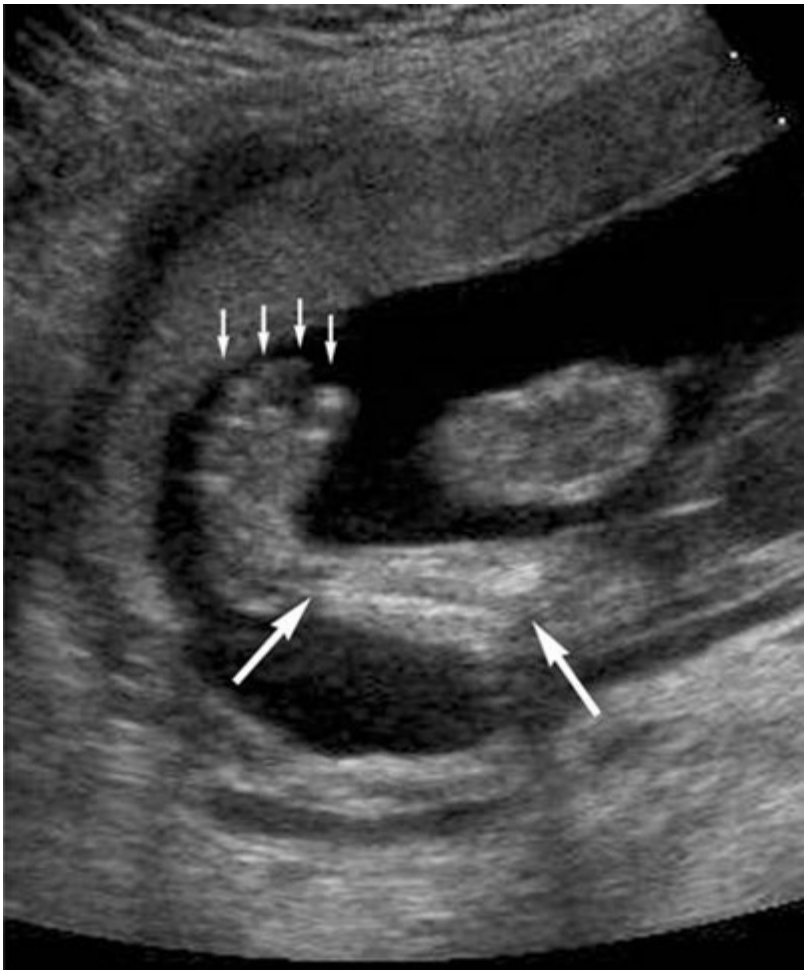


Figure 30-15 Clubfoot. Image of the lower leg and foot demonstrates the bones of the feet (*small arrows*) lying in the same plane as the tibia and fibula (*large arrows*).

Patau Syndrome (Trisomy 13)

Holoprosencephaly and abnormal facies are common findings with Patau syndrome or trisomy 13. The fetus with Patau syndrome has an extra chromosome 13. Unfortunately, this is almost a uniformly fatal condition because the fetus typically dies in the neonatal period. Various sonographic features of Patau syndrome include central nervous system aberrations, cyclopia, facial clefting, heart defects, and polydactyly (Fig. 30-16). Maternal serum screening is not always beneficial in the diagnosis of this condition.

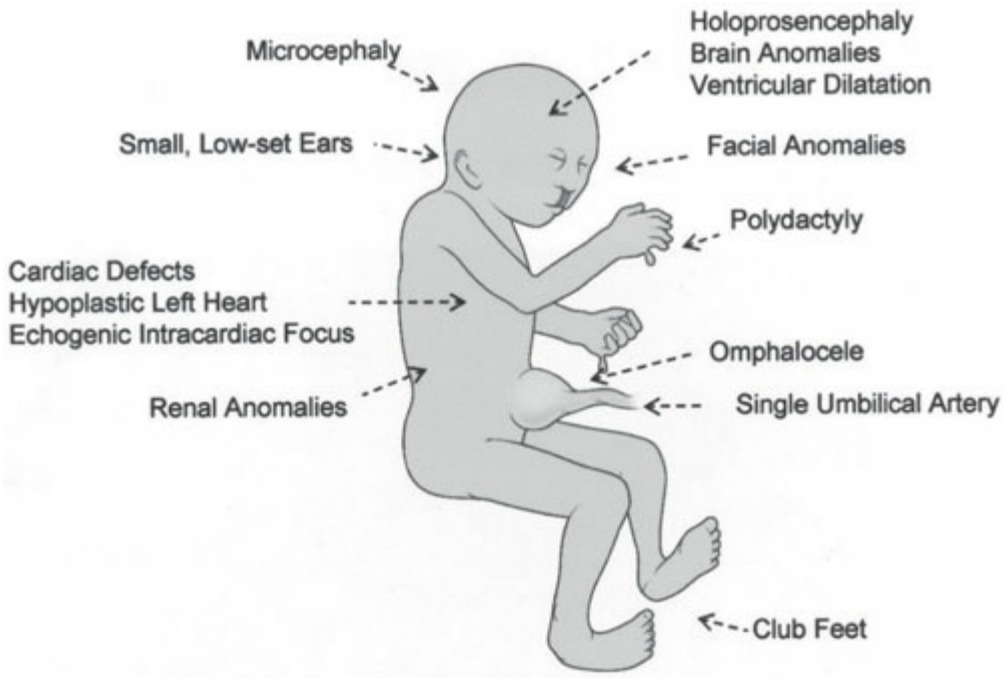


Figure 30-16 Common feature of trisomy 13.

MATERNAL SERUM SCREENING RESULTS OF PATAU SYNDROME

1. Not always beneficial and depends upon the anomaly present

SONOGRAPHIC FINDINGS OF PATAU SYNDROME

1. **Microcephaly**
2. Polydactyly (Fig. 30-17)
3. Holoprosencephaly (Fig. 30-18)
4. Ventriculomegaly
5. Hydrocephalus
6. Agenesis of the corpus callosum
7. Small, low-set ears
8. Facial anomalies (cyclopia, **cleft lip**, **cleft palate**, **microphthalmia**, **hypotelorism**)
9. Cardiac defects (**hypoplastic left heart** and echogenic intracardiac focus)
10. Omphalocele
11. Nonimmune hydrops
12. Renal anomalies (**hydronephrosis**, echogenic enlarged kidneys)
13. Single umbilical artery
14. Clubfeet

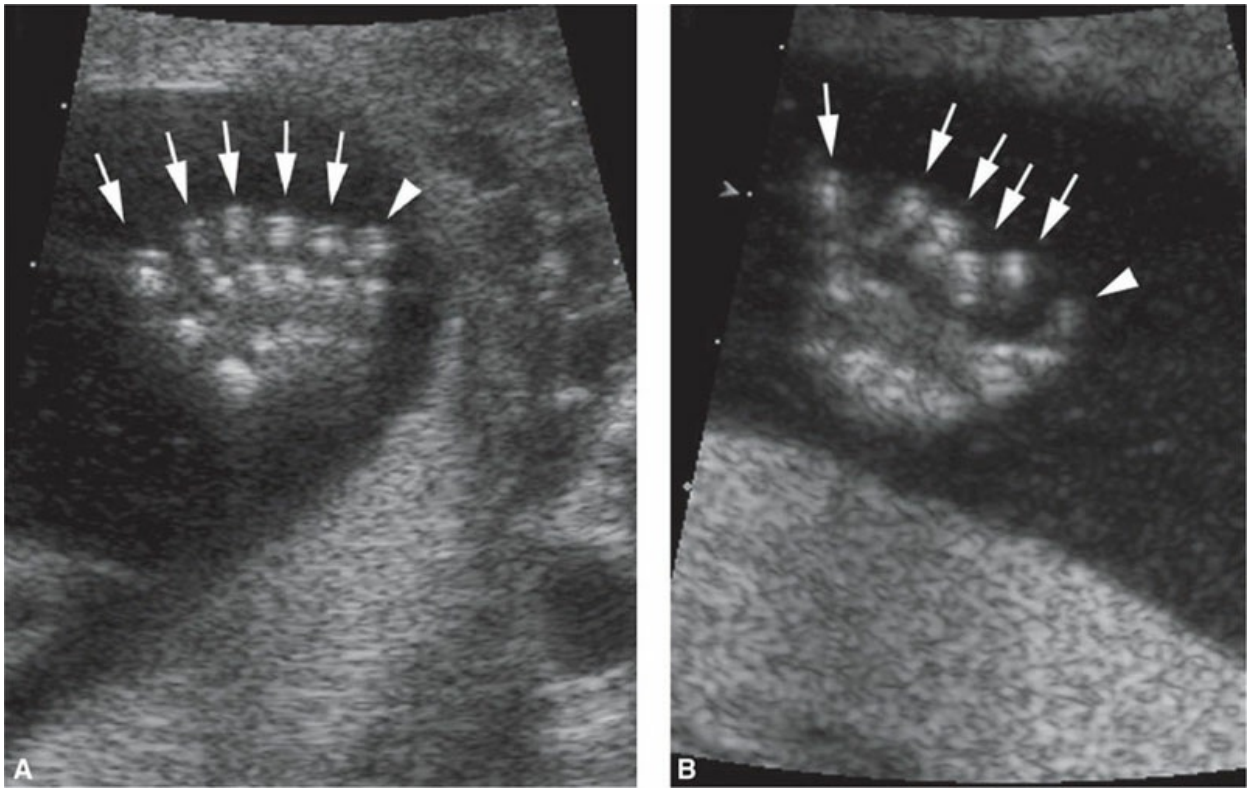


Figure 30-17 Polydactyly. Image of the foot **(A)** and of the hand **(B)** revealing six toes and fingers, respectively.

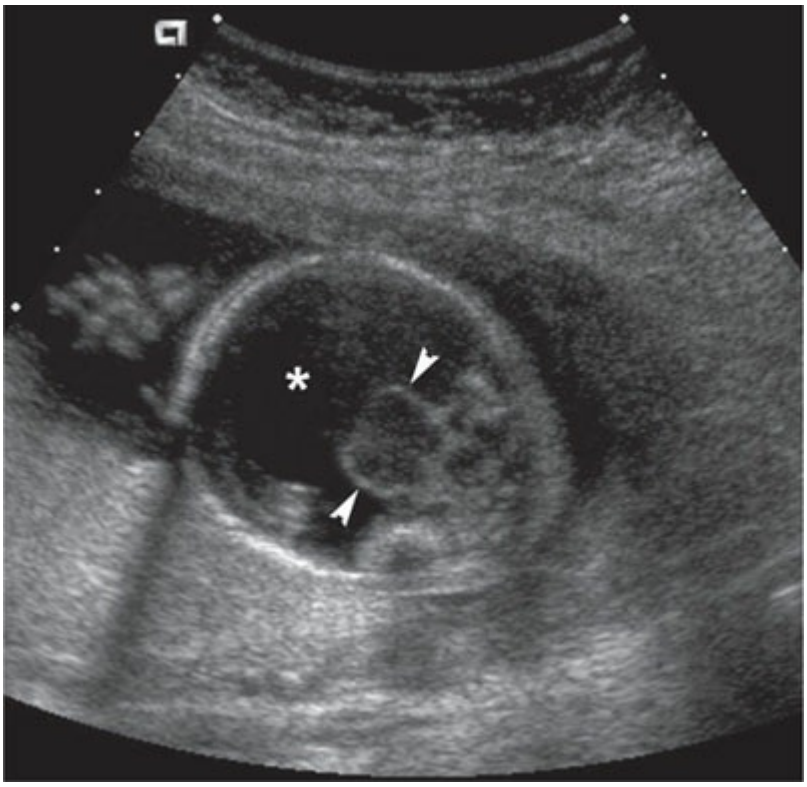


Figure 30-18 Holoprosencephaly. Coronal image of fetus with holoprosencephaly demonstrating a large monoventricle (*asterisk*) and fusion of the thalami (*arrowheads*).

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Holoprosencephaly and abnormal facies are common findings with Patau syndrome or trisomy 13.

Triploidy

Triploidy is a chromosomal abnormality in which the fetus has 69 chromosomes instead of the normal 46. Specifically, the fetus has three sets of chromosomes instead of the normal two. Because there are multiple major structural anomalies associated with triploidy, most of the fetuses with triploidy die in the first trimester or early second trimester. There are two types of triploidy (Type I and Type II). Often, a partial molar pregnancy is found with a triploid fetus, thus resulting in a markedly elevated hCG level and bilateral ovarian theca lutein cysts. Sonographic features of triploidy include small, low-set ears, cardiac defects, syndactyly, and intrauterine growth restriction (Fig. 30-19).

MATERNAL SERUM SCREENING RESULTS OF TRIPLOIDY

1. Elevated hCG in the presence of a molar pregnancy

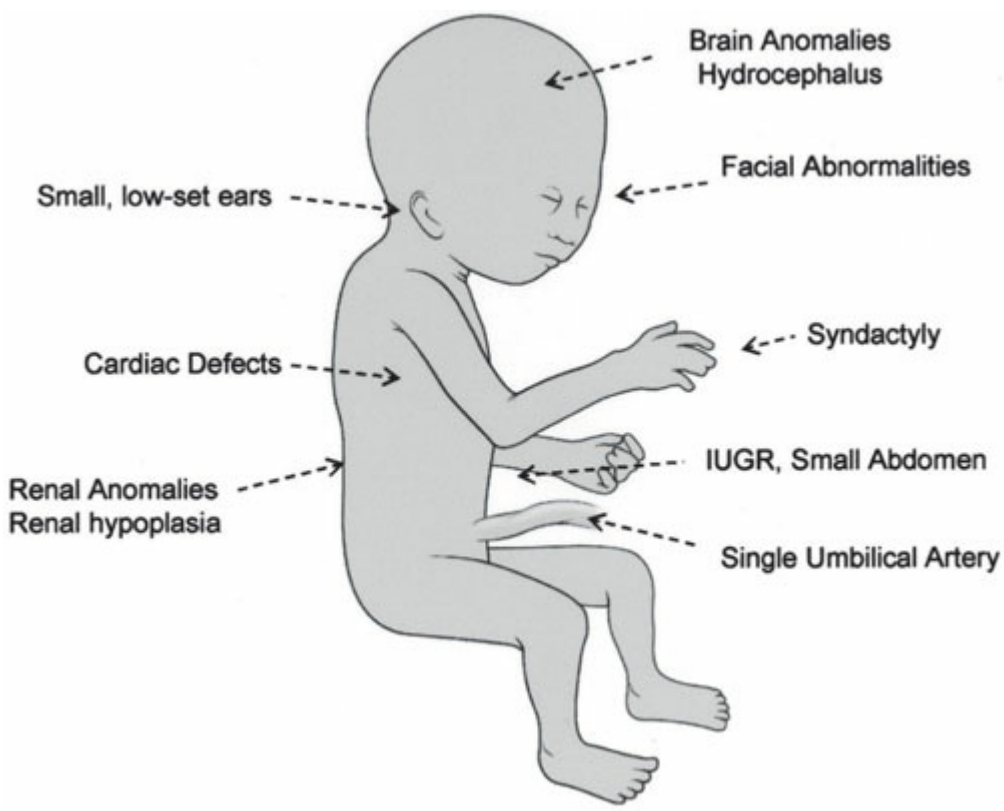


Figure 30-19 Common features of triploidy.

FIRST-TRIMESTER SONOGRAPHIC FINDINGS OF TRIPLOIDY

1. Cystic spaces seen within an enlarged placenta (molar pregnancy)
2. Fetal demise
3. Bilateral ovarian theca lutein cysts

SECOND- AND THIRD-TRIMESTER SONOGRAPHIC FINDINGS OF TRIPLOIDY

1. Holoprosencephaly
2. Dandy–Walker malformation
3. Agenesis of the corpus callosum
4. Hydrocephalus
5. Facial abnormalities (microphthalmia and micrognathia)
6. Small, low-set ears
7. Cardiac defects
8. Renal anomalies
9. Intrauterine growth restriction (small abdomen)
10. Omphalocele
11. Syndactyly (third and fourth fingers)
12. Single umbilical artery
13. Clubfeet



SOUND OFF

Often, a partial molar pregnancy is found with a triploid fetus, thus resulting in a markedly elevated hCG level and bilateral ovarian theca lutein cysts.

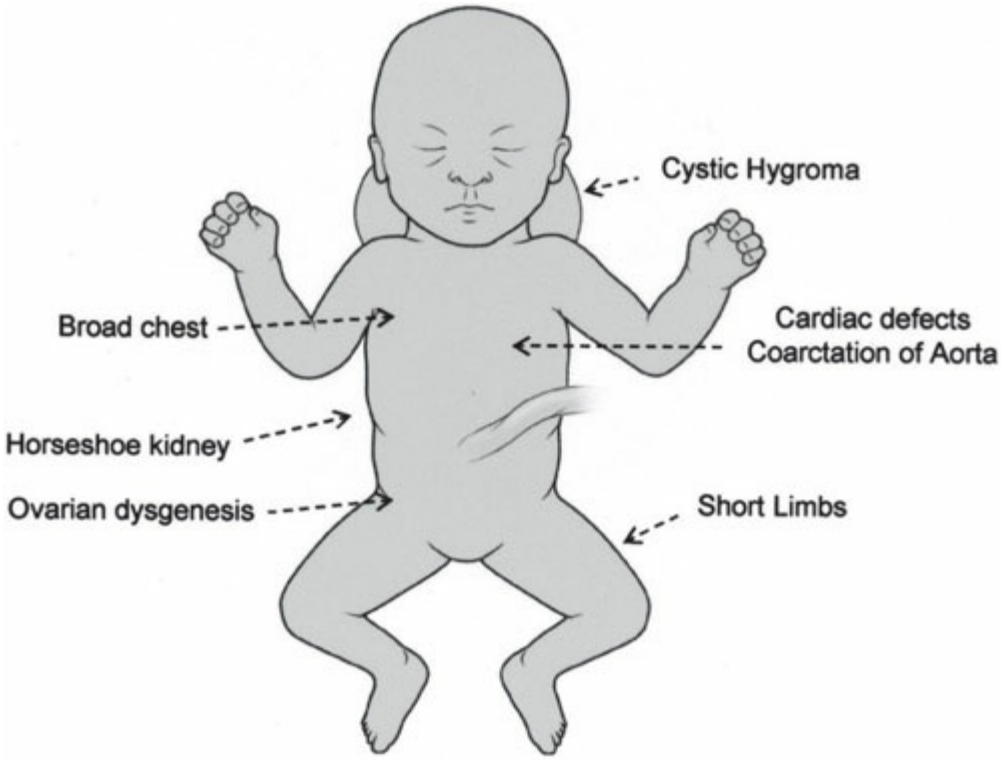


Figure 30-20 Common features of Turner syndrome.

Turner Syndrome

Turner syndrome is a disorder found in females. It may also referred to as 45,X or monosomy X because most often the paternal sex chromosome is missing. A fetus with this chromosomal anomaly classically presents with a nuchal cystic hygroma and nonimmune hydrops (Fig. 30-20).Nonimmune hydrops is the buildup of fluid within at least two fetal body cavities. Therefore, ascites, pleural effusions, pericardial effusion, and subcutaneous edema are all common findings with Turner syndrome (Fig. 30-21).

Turner syndrome is an often-fatal condition that leads to spontaneous abortion in the first or second trimester. It does, however, have a reported incidence of 1 in 2,500 to 5,000 live female births. The sonographic diagnosis is initially suspected when there is visualization of a large, septated cystic hygroma located in the neck. Maternal serum screening reveals decreased levels of all laboratory findings when hydrops is present. Ovarian dysgenesis, webbed neck, short stature, motor deficits, hearing loss, and renal anomalies are common in those persons who do survive birth and progress into adulthood.

MATERNAL SERUM SCREENING RESULTS OF TURNER SYNDROME

1. Low estriol
2. Low AFP
3. Low hCG (with hydrops)

4. Low inhibin A (with hydrops)
5. Low PAPP-A

SONOGRAPHIC FINDINGS OF TURNER SYNDROME

1. Increased nuchal translucency
2. Cystic hygroma
3. Renal anomalies (**horseshoe kidneys** and **renal agenesis**)
4. Cardiac defects (**coarctation of the aorta**)
5. Nonimmune hydrops

SOUND OFF

Turner syndrome is a disorder found in females. It may also referred to as 45,X or monosomy X because most often the paternal sex chromosome is missing.

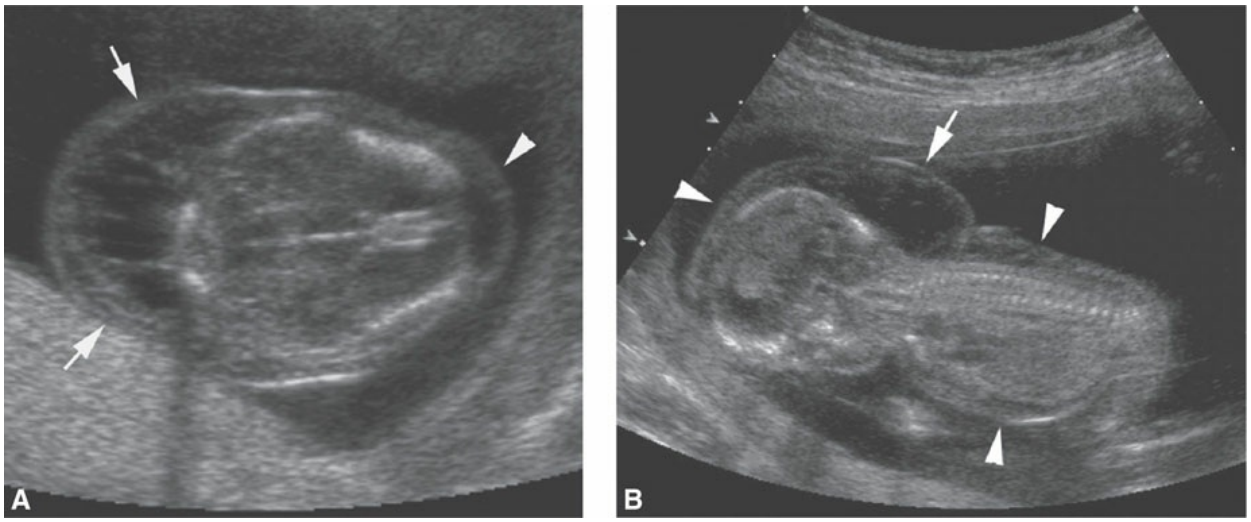


Figure 30-21 Cystic hygroma and subcutaneous edema. **A.** Sonogram of a 15-week fetus with a cystic hygroma *(arrows)* and subcutaneous edema *(arrowhead)*. **B.** Sagittal image of fetus with large posterior neck cystic hygroma *(arrow)* and extensive subcutaneous edema *(arrowheads)* posteriorly, anteriorly, and over the top of the head.

Klinefelter Syndrome

Klinefelter syndrome, or 47,XXY, is a male chromosomal anomaly that can result in hypogonadism, small testis, tall stature, long legs and arms, and gynecomastia. These individuals also tend to suffer from subnormal intelligence. Although genetic testing may reveal this anomaly, prenatal sonographic imaging may not yield any signs of structural birth defects.

REVIEW QUESTIONS

1. Normal diploid cells have:
   a. 46 chromosomes
   b. 23 chromosomes
   c. 21 chromosomes
   d. 69 chromosomes

2. A 38-year-old pregnant woman presents to the sonography department for an obstetrical sonogram with abnormal maternal serum screening. Her alpha-fetoprotein and estriol are low, whereas her hCG is elevated. These laboratory findings are most consistent with:
   a. Edwards syndrome
   b. Patau syndrome
   c. Triploidy
   d. Down syndrome

3. The triple screen typically includes:
   a. Alpha-Fetoprotein, estriol, and hCG
   b. Alpha-Fetoprotein, amniotic fluid index, and hCG
   c. Alpha-Fetoprotein, estriol, and PAPP-A
   d. PAPP-A, inhibin A, and hCG

4. Another name for Patau syndrome is:
   a. Trisomy 21
   b. Trisomy 16
   c. Trisomy 18
   d. Trisomy 13

5. Rounded head shape is referred to as:
   a. Dolichocephaly
   b. Brachycephaly
   c. Cebocephaly
   d. Craniosynostosis

6. Theca lutein cysts would most likely be linked with a molar pregnancy and:
   a. Down syndrome
   b. Intrauterine growth restriction
   c. Triploidy
   d. Monosomy X

7. With which of the following syndromes is brachycephaly associated most often?
   a. Edwards syndrome
   b. Patau syndrome
   c. Down syndrome
   d. Turner syndrome

8. Advanced maternal age is considered to be:
   a. >25 years of age
   b. >30 years of age
   c. >35 years of age
   d. >32 years of age

9. Which of the following is a sex chromosome anomaly?
   a. Edwards syndrome
   b. Trisomy 13
   c. Down syndrome
   d. 45,X

10. A molar pregnancy, omphalocele, and small, low-set ears are found most often with:
    a. Trisomy 21
    b. Trisomy 18
    c. Trisomy 13
    d. Triploidy

11. With what procedure is placental tissue obtained?
    a. Amniocentesis
    b. Cordocentesis
    c. CVS
    d. Trophoblastic resection technique

12. The bending of the fifth digit toward the fourth digit is called:
    a. Syndactyly
    b. Clinodactyly
    c. Polydactyly
    d. Stabodactyly

13. Webbing of the neck and short stature is found in infertile female patients with a history of:
    a. Trisomy 21
    b. Triploidy
    c. Trisomy 13

d. Turner syndrome

14. Pelvocaliectasis refers to:
    a. Dilation of the renal pelvis and calices
    b. Enlargement of the fetal pelvis
    c. Ectopic location of the kidney within the pelvis
    d. Dilation of the ureter within the pelvis

15. The earliest invasive fetal karyotyping technique that can be performed is:
    a. Amniocentesis
    b. Cordocentesis
    c. CVS
    d. PUBS

16. A strawberry-shaped skull is associated with:
    a. Edwards syndrome
    b. Turner syndrome
    c. Down syndrome
    d. Patau syndrome

17. Cleft lip, hypotelorism, and microphthalmia are all sonographic features of:
    a. Trisomy 21
    b. Trisomy 18
    c. Trisomy 13
    d. Turner syndrome

18. Monosomy X refers to:
    a. Edwards syndrome
    b. Patau syndrome
    c. Down syndrome
    d. Turner syndrome

19. What are the fingerlike projections of gestational tissue that attach to the decidualized endometrium?
    a. Decidua capsularis
    b. Decidua vera
    c. Chorionic villi
    d. Placental substance

20. A 22-week fetus with clinodactyly, an echogenic intracardiac focus, and hyperechoic bowel is noted during a screening obstetrical sonogram.

These findings are most consistent with:
a. Trisomy 21
b. Trisomy 13
c. Monosomy X
d. Trisomy 18

21. The term for small eyes is:
a. Microphthalmia
b. Micrognathia
c. Microcephaly
d. Microglossia

22. The maternal serum screening of a mother with a fetus with trisomy 18 will reveal:
a. Decreased hCG, elevated alpha-fetoprotein, and normal estriol
b. Increased hCG, alpha-fetoprotein, and estriol
c. Increased alpha-fetoprotein, increased hCG, and decreased estriol
d. Decreased hCG, alpha-fetoprotein, and estriol

23. Fusion of the orbits and holoprosencephaly are associated with:
a. Edwards syndrome
b. Turner syndrome
c. Down syndrome
d. Patau syndrome

24. A structural abnormality that results from an abnormal development describes:
a. Syndrome
b. Chromosomal deviation
c. Malformation
d. Congenital misrepresentation

25. Absent nasal bones and an increased nuchal fold measurement are most consistent with the sonographic markers for:
a. Trisomy 21
b. Trisomy 13
c. Triploidy
d. Trisomy 18

26. A large space between the first and second toes is termed:
a. Polydactyly
b. Clubfoot
c. Ulnaration

d. Sandal gap

27. Bilateral choroid plexus cysts, micrognathia, and rockerbottom feet are sonographic findings of a 27-week fetus with an omphalocele. These findings are most consistent with:
    a. Trisomy 21
    b. Trisomy 13
    c. Trisomy 18
    d. Triploidy

28. Nonimmune hydrops and ovarian dysgenesis are found in fetuses affected by:
    a. Trisomy 21
    b. Trisomy 18
    c. Trisomy 13
    d. Turner syndrome

29. What is macroglossia most often associated with?
    a. Trisomy 21
    b. Trisomy 18
    c. Triploidy
    d. Turner syndrome

30. A fetus with a karyotype revealing it has 69 chromosomes and sonographic findings of webbed fingers and intrauterine growth restriction most likely has:
    a. Trisomy 21
    b. Trisomy 18
    c. Triploidy
    d. Turner syndrome

31. What is another name for the most common chromosomal abnormality?
    a. Edwards syndrome
    b. Triploidy
    c. Down syndrome
    d. Turner syndrome

32. Widened pelvic angles and duodenal atresia are most consistent with the sonographic markers for:
    a. Triploidy
    b. Patau syndrome
    c. Down syndrome
    d. Edwards syndrome

33. Sonographically, you identify a fetus with fusion of the thalami and a monoventricle. Which chromosomal abnormality would be most likely?
    a. Trisomy 8
    b. Trisomy 21
    c. Trisomy 18
    d. Trisomy 13

34. Which protein is not produced by the developing placenta?
    a. Alpha-Fetoprotein
    b. hCG
    c. Estriol
    d. PAPP-A

35. Which of the following laboratory findings would not be consistent with trisomy 21?
    a. High AFP
    b. Low estriol
    c. High hCG
    d. Low PAPP-A

36. Cyclopia would most likely be associated with:
    a. Trisomy 8
    b. Trisomy 21
    c. Trisomy 18
    d. Trisomy 13

37. Webbed fingers or toes are termed:
    a. Clinodactyly
    b. Syndactyly
    c. Polydactyly
    d. Whren syndrome

38. Which of the following is a sex chromosome anomaly associated with hypogonadism and subnormal intelligence in males?
    a. Down syndrome
    b. Edwards syndrome
    c. Klinefelter syndrome
    d. Turner syndrome

39. Which of the following is not consistent with the diagnosis of nonimmune hydrops?
    a. Hypoplastic mandible

b. Pleural effusion
c. Ascites
d. Subcutaneous edema

40. Echogenic small bowel is most often associated with:
a. Down syndrome
b. Edwards syndrome
c. Patau syndrome
d. Turner syndrome

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31

Multiple Gestations

Introduction

Sonography plays a vital role in the early recognition and follow-up care of multiple gestations. Clinical findings such as large-for-dates or elevated levels of human chorionic gonadotropin may exist as the only clinical indicator at the time of the early sonogram. In the circumstance in which laboratory values and patient history are limited, the sonographer must be capable of evaluating and understanding the distinctiveness of multiple gestations. This chapter provides an overview of the embryology of twinning and other multiple gestations, and several complications that are unique to twins that a sonographer must be aware of.

Key Terms

acardiac twin—an abnormally developed twin that has an absent upper body and no heart

advanced maternal age—a maternal age of 35 years or older

amnion—the inner sac that contains the embryo and amniotic fluid; echogenic curvilinear structure that may be seen during the first trimester within the gestational sac

amnionicity—relates to the number of amnions in a multiple gestation

amniotic sac—fluid-filled space, created by the amnion, surrounding the developing embryo or fetus

anastomoses—vascular connections

anemia—the condition of having a deficient number of red blood cells

assisted reproductive therapy—techniques used to treat infertility

chorion—the outer membrane of a gestation that surrounds the amnion and developing embryo

chorionicity—relates to the number of chorions and the type of placentation in a multiple gestation

cleavage—the division of a cell

conjoined twins—monoamniotic, monochorionic twins that are attached at the head, thorax, abdomen, or lower body

craniopagus—twins joined at the cranium

delta sign—see key term lambda sign

diamniotic—having two amniotic sacs

dichorionic—having two placentas

dichorionic diamniotic—having two placentas and two amniotic sacs

discordant fetal growth—asymmetric fetal weight between twins

dizygotic—two ova are fertilized by two sperms

endoscopic-guided laser photocoagulation—a treatment that uses lasers to separate abnormal placental vascular connections between twins that are suffering from twin–twin transfusion syndrome

fetus papyraceus—the death of one fetus in a twin pregnancy that is maintained throughout the pregnancy; actually means paperlike fetus

fraternal twins—twins that result from the fertilization of two separate ova and have dissimilar characteristics

heterotopic pregnancy—coexisting ectopic and intrauterine pregnancies

hydrops (fetal)—an abnormal accumulation of fluid in at least two fetal body cavities

hypoxia—a shortage of oxygen or decreased oxygen in the blood

identical twins—twins that result from the split of a single zygote and share the same genetic structure

lambda sign—a triangular extension of the placenta at the base of the membrane is indicative of a dichorionic diamniotic pregnancy; also referred to as the delta sign or twin peak sign

monoamniotic—having one amniotic sac

monochorionic—having one chorion

monochorionic diamniotic—having one placenta and two amniotic sacs

monochorionic monoamniotic—having one placenta and one amniotic sac

monozygotic—coming from one fertilized ovum or zygote

morbidity—the relative frequency of occurrence of a disease

mortality—the rate of actual deaths

omphalopagus—conjoined twins attached at the abdomen

ovum—an unfertilized egg

parasitic twin—see key term acardiac twin

placentation—formation or structure of a placenta, structural organization, and mode of attachment of fetal to maternal tissues during placental formation

porencephaly—the development of a cystic cavity within the cerebrum; may be the result of an intraparenchymal hemorrhage

preeclampsia—pregnancy-induced maternal high blood pressure and excess protein in the urine after 20 weeks' gestation

pulmonary hypoplasia—underdevelopment of the lungs

pyopagus—conjoined twins joined back-to-back in the sacral region

singleton pregnancy—a single developing fetus

stillborn—dead at birth

stuck twin—when a twin fetus, suffering from twin–twin transfusion syndrome, experiences severe oligohydramnios and is closely adhered to the uterine wall

therapeutic amniocentesis—type of amniocentesis used to remove a large amount of amniotic fluid around a fetus suffering from polyhydramnios

thoracopagus—conjoined twins attached at the chest

twin embolization syndrome—when vascular products travel from a demised twin to the surviving twin by means of the common vascular channels within the shared placenta

twin peak sign—see key term lambda sign

twin–twin transfusion syndrome—shunting of venous or arterial blood from one twin to another through placental circulation

twin-reversed arterial perfusion sequence—another name for acardiac twinning

vanishing twin—the death and reabsorption of a twin

zygosity—relates to the number of zygotes (fertilized ova)

zygote—the cell formed by the union of two gametes; the first stage of a fertilized ovum

FACTORS THAT INCREASE THE LIKELIHOOD OF MULTIPLE GESTATIONS

Patients with multiple gestations may present with the clinical indication of large for dates and also an elevated human chorionic gonadotropin blood level compared to a singleton pregnancy. When compared with singleton pregnancies, twins have a four times higher risk of fetal mortality and a six times higher neonatal morbidity rate. There are several factors that influence the frequency of twins and other multiple gestations. A maternal history of multiple gestations, assisted reproductive therapy (ART), ovulation induction drugs, advanced maternal age, and maternal obesity have all been shown to increase the probability of multiple gestations. It has been reported that as many as 43% of triplets and higher order pregnancies are linked with ART. Thus, patients with a history of ovulation induction drugs or ART should be evaluated systematically, because they are more likely to have not only multiple gestations but also heterotopic pregnancies.

SOUND OFF

A maternal history of multiple gestations, ART, ovulation induction drugs, advanced maternal age, and maternal obesity have all been shown to increase the probability of multiple gestations.

TWINS

Zygosity, Chorionicity, and Amnionicity of Twins

The fertilization of a single ovum that eventually divides, or the fertilization of several ova, can produce multiple gestations. A fertilized egg is referred to as a zygote. In multiple gestations, the term zygosity refers to the number of eggs that are fertilized. Twins can be either monozygotic or dizygotic. Monozygotic twins arise from a single zygote, whereas dizygotic twins form from two separate zygotes (Fig. 31-1).

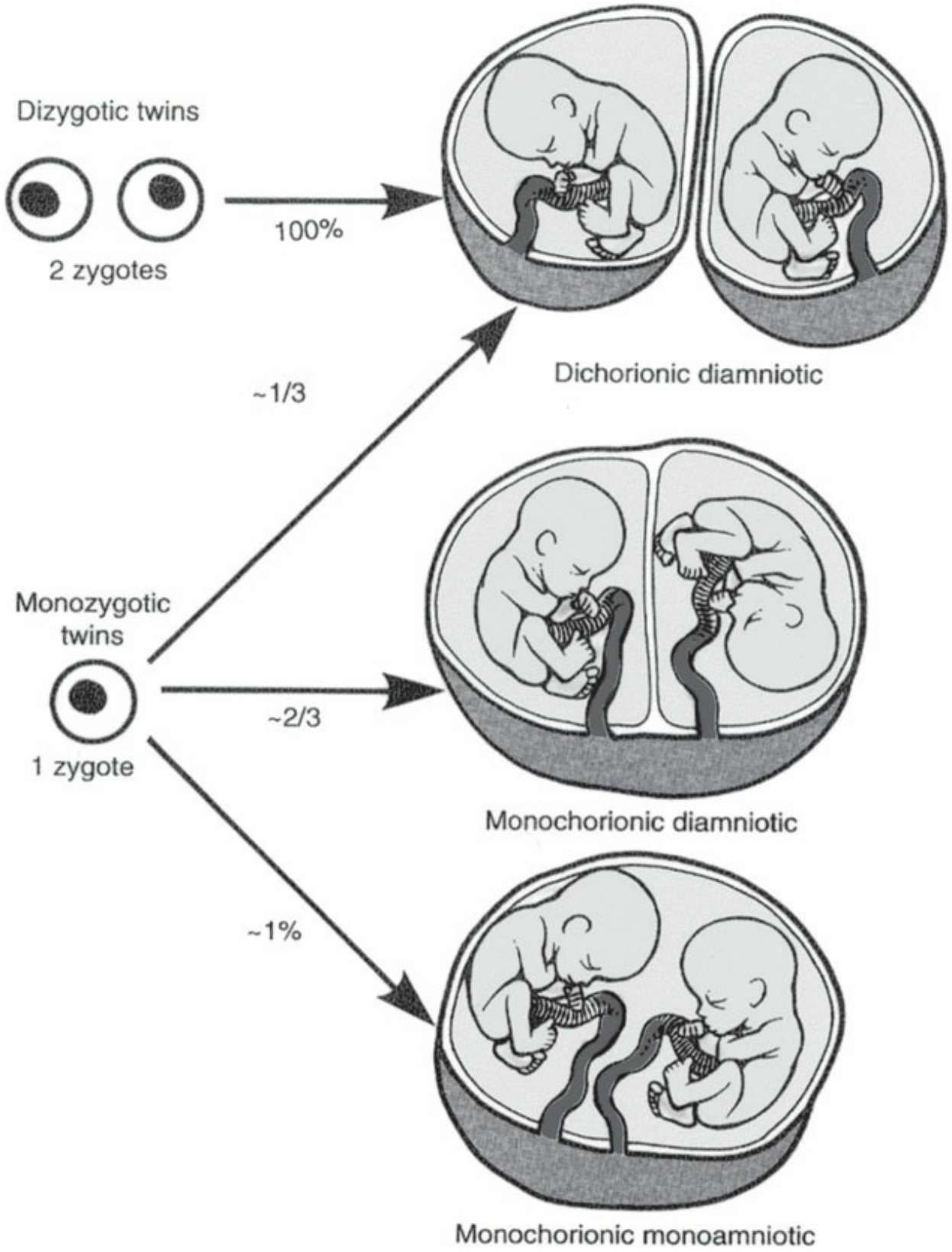


Figure 31-1 Monozygotic versus dizygotic twins. All dizygotic twins have dichorionic diamniotic placentation. Monozygotic twins may form dichorionic diamniotic, monochorionic diamniotic, or monochorionic monoamniotic placentation.

SOUND OFF
Monozygotic twins arise from a single zygote, whereas dizygotic

twins form from two separate zygotes.

The chorion, the structure that forms the placenta, develops before the amnion, the fluid-filled sac containing the embryo. Chorionicity, often referred to as placentation, relates to how many placentas are present. Twins who have one shared placenta are referred to as monochorionic, whereas twins who have two separate placentas are called dichorionic. Amnionicity refers to how many amnions or amniotic sacs are present. Twins who share the same amniotic sac are referred to as monoamniotic, whereas twins who have their own individual amniotic sac are diamniotic.

Dizygotic Twinning

Dizygotic twins, the most common form of twinning, arise from two separate fertilized ova. Dizygotic twins are referred to as fraternal twins because they have their own genetic structure and can differ from each other in many ways. Dizygotic twinning always results in dichorionic diamniotic twins (Table 31-1). That means, if there are two placentas, there must be two amnions. However, in early gestation, the placentas may fuse and appear as one large placenta with sonography.



SOUND OFF
Dizygotic twinning, or fraternal twins, is the most common form of twinning.

TABLE 31-1 Dizygotic twinning

Zygosity	Description	Result	Appearance
Dizygotic	Two separate fertilized ova	Dichorionic diamniotic	Fraternal

TABLE 31-2 Monozygotic twinning

Zygosity	Description	Result	Appearance
Monozygotic	One zygote splits between 4 and 8 d	Monochorionic diamniotic	Identical
Monozygotic	One zygote splits prior to day 4	Dichorionic diamniotic	Identical
Monozygotic	One zygote splits late	Monochorionic monoamniotic	Identical

Monozygotic Twinning

Monozygotic twins arise from a single zygote that splits. Thus, monozygotic twins are always identical twins because they share their design from only one fertilized egg. It depends on the time at which this division, or cleavage, takes place as to how many placentas and amnions may be present with monozygotic twins (see Fig. 31-1). There are three categories of monozygotic twins: (i) monochorionic diamniotic, (ii) dichorionic diamniotic, and (iii) monochorionic monoamniotic (Table 31-2).

Monochorionic diamniotic twins are the most common form of monozygotic twins. Division of the inner cell mass between 4 and 8 days will result in monochorionic diamniotic twinning. In this situation, both twins share a placenta and are positioned within separate amniotic sacs. It is important to note that when two fetuses share the same placenta, complications are more likely to occur. These complications are discussed later in this chapter.



SOUND OFF

Monochorionic diamniotic twins are the most common form of monozygotic twins.

An even earlier division, before day 4, leads to dichorionic diamniotic twins. This means that there are two separate placentas and two separate amnions. However, fusion of the placentas can occur with dichorionic diamniotic twins. The least probable monozygotic twinning to occur is monochorionic monoamniotic twins. A late split, beyond day 8 postconception, will result in monochorionic monoamniotic twins. Because of the shared amniotic sac, monochorionic monoamniotic carries the additional risk of conjoined twins.

Sonographic Assessment of Chorionicity and Amnionicity

Sonography can identify the presence of multiple gestations in the first trimester consistently. Determining the number of placentas in a multiple gestation is vital (Fig. 31-2). During the first trimester, dichorionic twins will have a thick membrane separating the two amniotic sacs, whereas monochorionic twins will have a thin membrane or no membrane at all between them (Fig. 31-3).

With monochorionic twins in the first trimester, before 7 weeks, it is helpful to identify the number of yolk sacs. The presence of one yolk sac and

two fetuses is indicative of a monoamniotic gestation, whereas the presence of two yolk sacs is indicative of a diamniotic gestation. After this point, the amniotic sacs are readily visualized and can be counted (Fig. 31-4). If no dividing membrane is seen, the diagnosis of monoamnionicity cannot be ruled out.

SOUND OFF
The presence of one yolk sac and two fetuses is indicative of a monoamniotic gestation, whereas the presence of two yolk sacs is indicative of a diamniotic gestation.

Chorionicity can be difficult to establish in the second and third trimesters. The membrane separating the twins is not always helpful. If separate placentas are noted, then the pregnancy must be dichorionic diamniotic. Additionally, noting a triangular extension of the placenta at the base of the dividing membrane is indicative of a dichorionic diamniotic pregnancy. This is referred to as the twin peak sign, lambda sign, or delta sign (Figs. 31-5 and 31-6). With a monochorionic diamniotic pregnancy, the membrane will be thin and seen separating at the junction point with the placenta, a sonographic sign referred to as the "T sign" (see Figs. 31-5 and 31-7). Determining the sex of the fetuses can be valuable as well. If the twins are different sexes, then one can assume that the twins are dichorionic (Fig. 31-8). Same-sex fetuses that have a single placenta and a thin membrane separating them are almost certainly monochorionic.

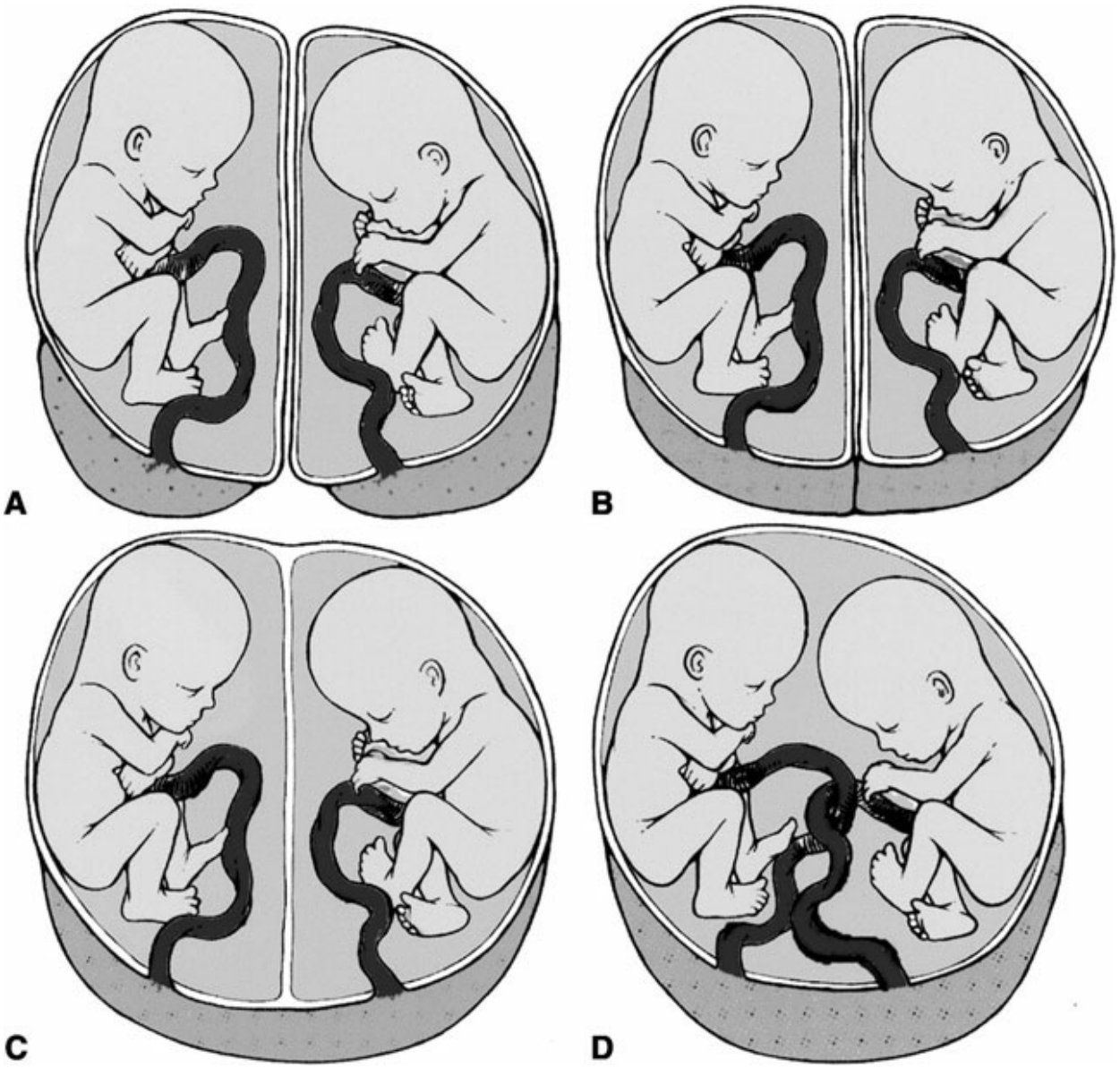


Figure 31-2 Schematic illustrating the position of the placenta with twins. **A.** Dichorionic diamniotic placentation with two separate placentas. **B.** Dichorionic diamniotic placentation with fused placentas. **C.** Monochorionic diamniotic placentation with a shared placenta. **D.** Monochorionic monoamniotic placentation with a single placenta.

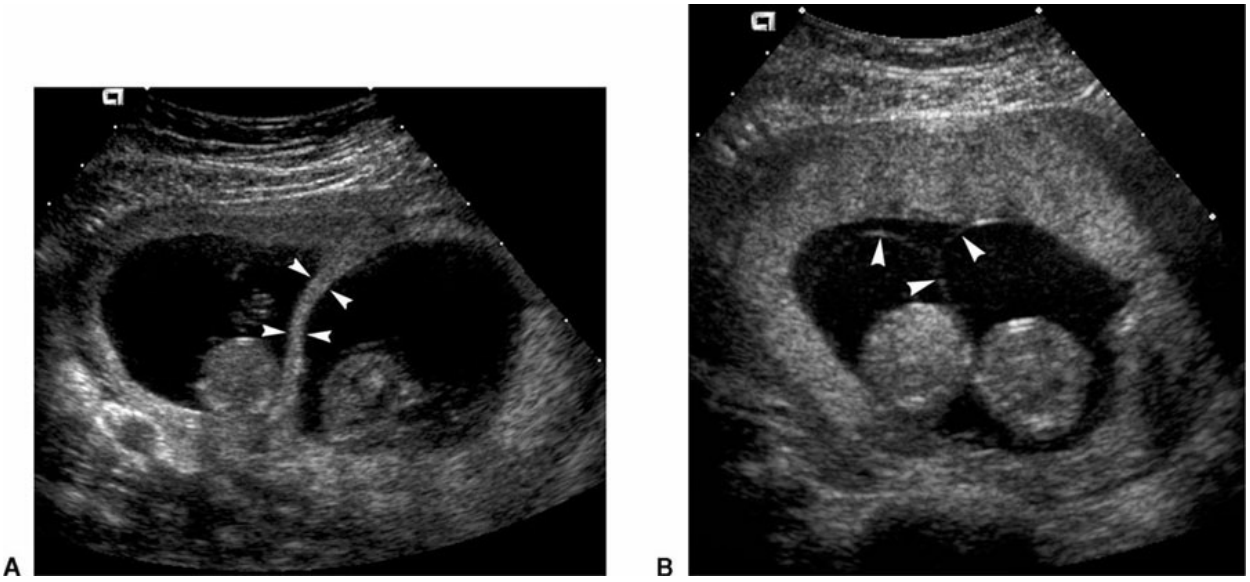


Figure 31-3 Determining chorionicity in the first trimester. **A.** Dichorionicity: sonogram of a twin gestation in which the fetuses are separated by a thick membrane (*arrowheads*), indicating that the twins are dichorionic. **B.** Monochorionicity: sonogram of a twin gestation in which both fetuses lie within a single gestational sac, with no thick band of tissue separating them, indicating that the twins are monochorionic. Each fetus is located within its own separate amnion (*arrowheads*).

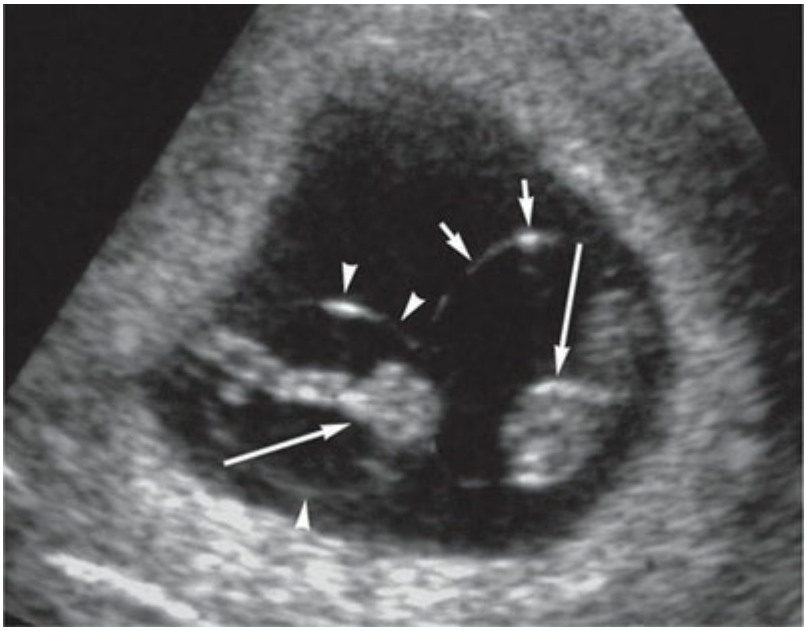


Figure 31-4 Diamniotic twins based on two amniotic sacs at 8 weeks' gestation. There are embryos (*long arrows*), each surrounded by its own amnion (*arrowheads* and *short arrows*).

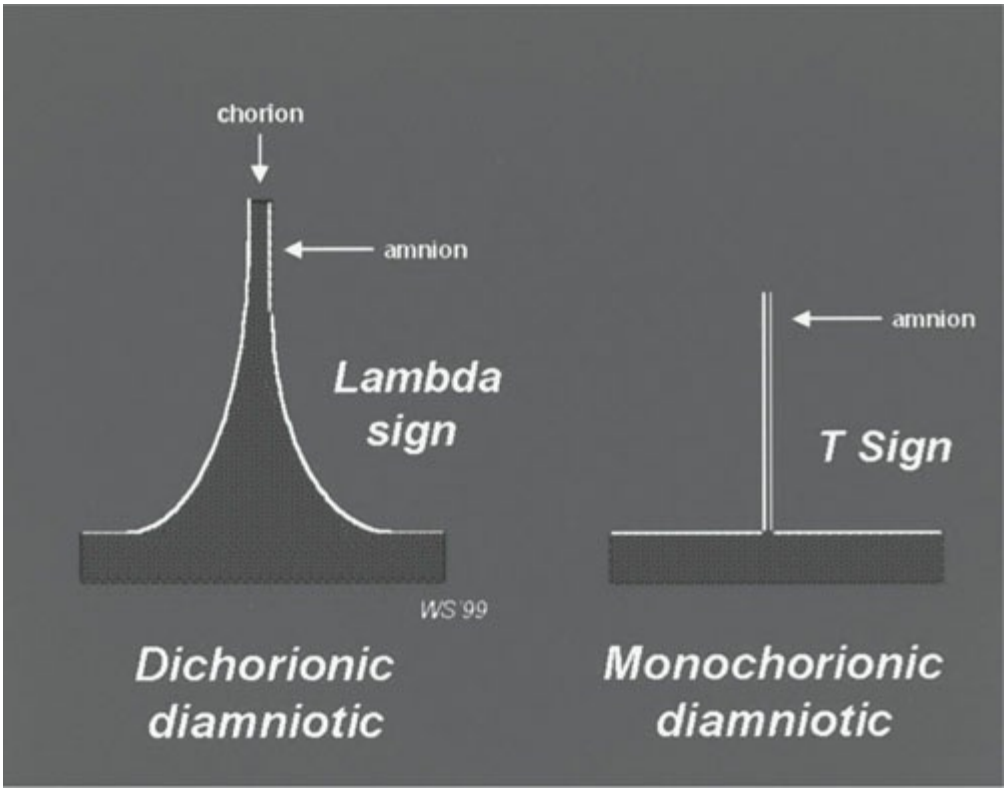


Figure 31-5 Schematic of the lambda, or twin peak, and the T signs. The lambda sign is indicative of a dichorionic diamniotic gestation, whereas the T sign is indicative of a monochorionic diamniotic gestation.



Figure 31-6 Diagnosis of dichorionicity based on the lambda sign. There is a triangular wedge of placental tissue extending into the intertwine membrane (*arrowheads*). This is highly indicative of dichorionicity.



Figure 31-7 Diagnosis of monochorionicity based on the T sign. Transabdominal sonogram of a 12-week monochorionic twin gestation showing the absence of the lambda sign and the presence of the T sign.

SOUND OFF

With a monochorionic diamniotic pregnancy, the membrane will be thin and seen separating at the junction point with the placenta, a sonographic sign referred to as the "T sign."



Figure 31-8 Dichorionicity based on different genders. Sonography of the genitalia in the twin gestation revealing a male (*long arrow*) and female (*short arrow*), thus confirming dichorionicity.

TWIN COMPLICATIONS

Twin–Twin Transfusion Syndrome

A complication that carries a high mortality rate for monochorionic twins is twin–twin transfusion syndrome (TTTS). With TTTS, shunting occurs from one twin to the other (Fig. 31-9). The twin that shunts blood to the other is called the "donor" twin and is often smaller than the twin receiving extra blood, the "recipient" twin. The donor twin often suffers from anemia and growth restriction, whereas the recipient experiences hydrops and congestive heart failure. The resulting sonogram will reveal discordant growth, which is described as a 15% to 25% reduction in the estimated fetal weight of the smaller fetus compared to the larger. Treatment options include therapeutic amniocentesis and endoscopic-guided laser photocoagulation of the communicating placental vessels. The sonographic findings of TTTS include decreased amniotic fluid around the donor twin (Fig. 31-10). Stuck twin refers to severe oligohydramnios surrounding a twin that appears to be closely associated with the uterine wall (Fig. 31-11).

SONOGRAPHIC FINDINGS OF TWIN–TWIN SYNDROME

1. Monochorionic twinning
2. Discordant fetal growth
3. Oligohydramnios around donor twin
4. Polyhydramnios around recipient twin
5. Recipient may be hydropic



Figure 31-9 Diagram illustrating monochorionic gestation with twin–twin transfusion syndrome. The recipient twin is larger and has polyhydramnios, whereas the donor twin is smaller and has oligohydramnios.

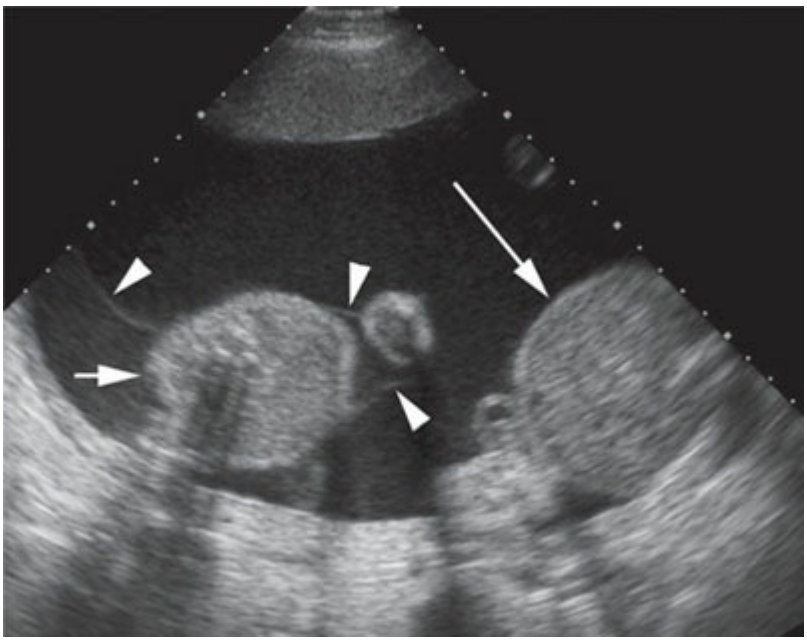


Figure 31-10 Twin–twin transfusion syndrome. Two fetal abdomen are pictured, with one that is smaller (*short arrow*) than the other (*long arrow*). The thin membrane (*arrowheads*) separating the twins is noted in this image as well.

SOUND OFF
With TTTS, the twin that shunts blood to the other is called the "donor" twin and is often smaller than the twin receiving extra blood, the "recipient" twin.

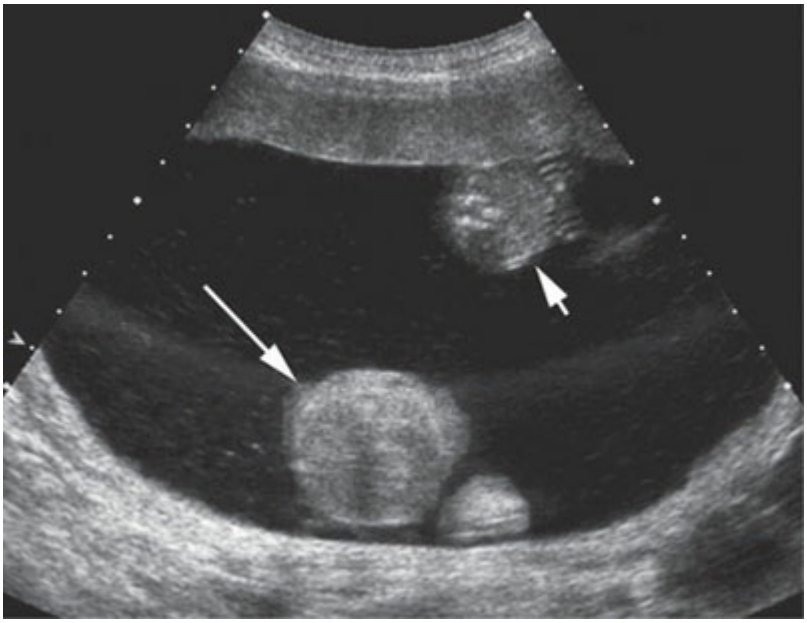


Figure 31-11 Stuck twin. Two fetal abdomen are pictured, with one (*short arrow*) appearing to be "stuck" against the uterine wall and smaller than the other (*large arrow*), indicating twin–twin transfusion.

Acardiac Twinning

Abnormal anastomoses of placental vessels may result in a parasitic twin or acardiac twin. This is considered to be a severe form of TTTS. Acardiac twinning may also be referred to as twin-reversed arterial perfusion (TRAP) sequence or acardiac parabiotic twinning. With acardiac twinning, there is one normal fetus, the "pump twin," and an abnormally developed fetus containing no heart. The normal fetus maintains the growth of the parasitic twin, albeit the growth is considerably irregular, typically resulting in an absence of the head, cervical spine, and upper limbs in the acardiac twin. Movement of the parasitic twin occurs, so differentiation is achieved through the recognition of other sonographic findings such as the absence of the heart, severe hydrops, and the absence of the upper body in the acardiac twin (Fig. 31-12). The pump twin has a perinatal mortality of 50% to 55%, secondary to polyhydramnios and prematurity.

SONOGRAPHIC FINDINGS OF ACARDIAC TWIN

1. Normal pump twin
2. Acardiac twin—absent upper body, absent heart, and hydrops

SOUND OFF

Acardiac twinning may also be referred to as TRAP syndrome or acardiac parabiotic twinning.

Conjoined Twins

Conjoined twins can result from monochorionic monoamniotic twinning. Conjoined twins can be attached at the head, thorax, abdomen, and the lower part of the body (Fig. 31-13; Table 31-3). The most common forms of conjoined twinning are thoracopagus and omphalopagus, which is the attachment at the chest and abdomen, respectively. Conjoined twins may also be joined at the cranium (craniopagus) or back-to-back in the sacral region, which is termed pyopagus. The prognosis is poor for conjoined twins. They have a 40% chance for being stillborn, with many dying within the first 24 hours.

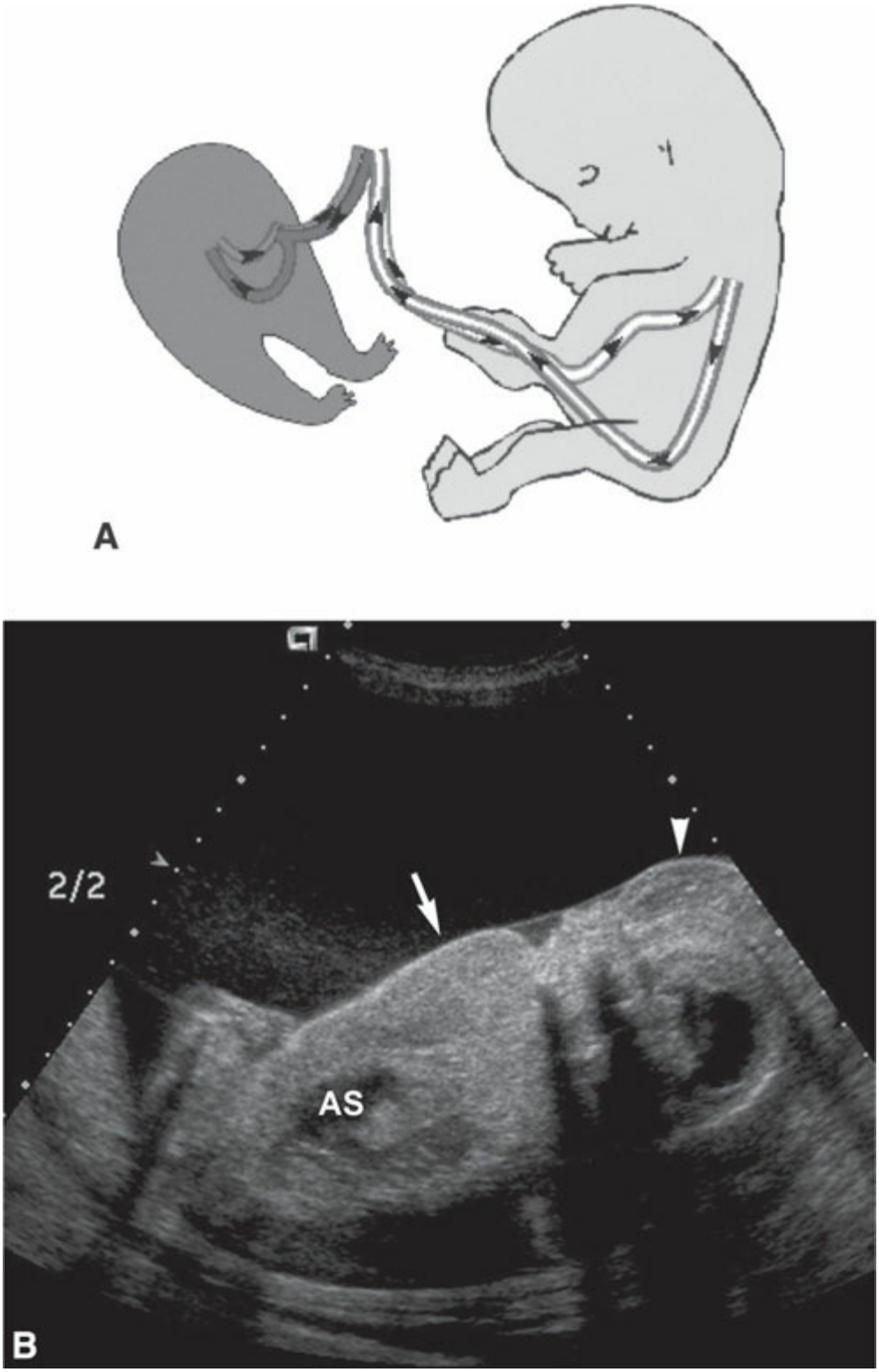


Figure 31-12 Acardiac twin. **A.** In twin-reversed arterial perfusion syndrome, the acardiac twin receives retrograde perfusion with poorly oxygenated blood. **B.** Sagittal image of an acardiac twin showing marked skin thickening over the thorax (*arrow*) and an abnormally formed head (*arrowhead*). Ascites (*AS*) is also noted within the abdomen.

SOUND OFF
Conjoined twins can result from monochorionic monoamniotic

twinning.

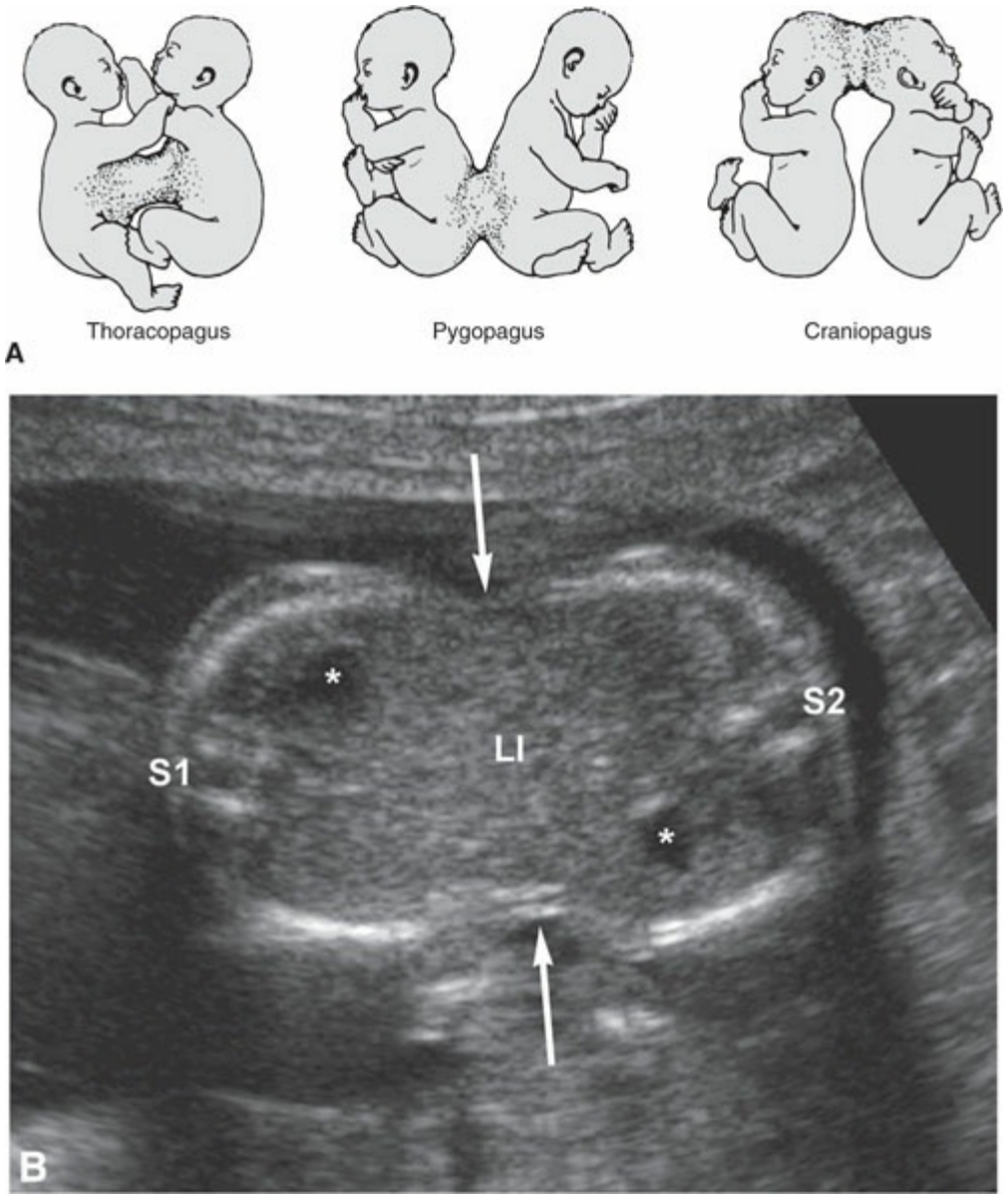


Figure 31-13 Conjoined twins. **A.** Several types of conjoined twinning. **B.** Transverse view of twin abdomens demonstrating that they are joined anteriorly (*arrows*) and share a liver (*Ll*). *S1*, spine of twin 1; *S2*, spine of twin 2; *asterisk*, stomachs.

TABLE 31-3 Terminology associated with conjoined twins

Conjoined Terminology	Area of Union
Craniopagus	Joined at the head
Thoracopagus	Joined at the thorax (chest)
Omphalopagus	Joined at the abdomen
Ischiopagus	Joined at the pelvis
Pyopagus	Joined at the sacral region or back-to-

Vanishing Twin and Twin Embolization Syndrome

It is important to note that follow-up sonograms of twin pregnancies could reveal a decrease in the number of gestational sacs and/or embryos. The death of a twin, and subsequent reabsorption of the embryo during the first trimester, is termed a vanishing twin (Fig. 31-14). If the fetus dies in the first trimester and is maintained throughout the pregnancy, it is referred to as fetus papyraceus. With dichorionic twins, the surviving twin is rarely affected by the death of the other. However, the death of a monochorionic twin during the first trimester frequently leads to the death of the other twin.

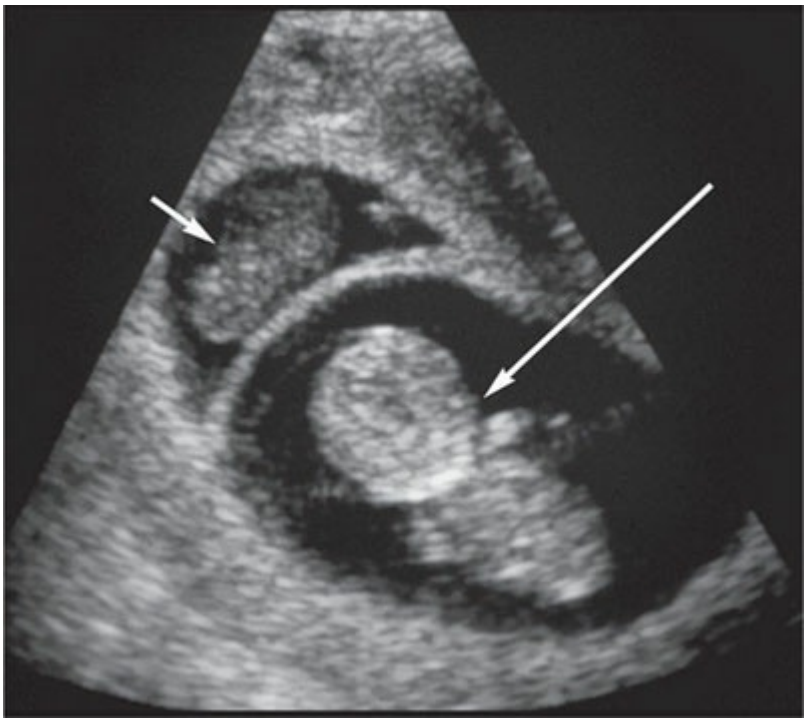


Figure 31-14 Vanishing twin. In this twin gestation, the fetuses (*arrows*) and gestational sacs differ in size. The larger fetus (*long arrow*) was alive at the time of the sonogram. The smaller fetus (*short arrow*) had demised. One month later on a follow-up sonogram, the live fetus had grown normally, and the second sac was not seen.

The death of a monochorionic twin during the second or third trimester can lead to life-threatening problems in the surviving twin. Potential troubles exist as a consequence of the breakdown of the demised twin. Vascular products travel from the demised twin to the surviving twin by means of the common vascular channels within the shared placenta, a complication known as twin embolization syndrome. Particularly, the central nervous system and

the kidneys are affected in the surviving twin, with a documented 25% risk of death or neurologic damage for the survivor. Intracranial abnormalities such as hydrocephalus and porencephaly are common in the survivor as well (Fig. 31-15).

SOUND OFF
Twin embolization syndrome can result from the death of a monochorionic twin.

BEYOND TWINS

Triplet pregnancies can manifest with different combinations of chorionicity and amnionicity. For example, triplets can be trichorionic triamniotic and dichorionic triamniotic (Fig. 31-16). Most triplet and quadruplet pregnancies result from the use of ovulation induction or in vitro fertilization (Fig. 31-17). Although the sonographic challenge is greatly amplified for the sonographer, the role of sonography remains the same with multiple pregnancies beyond twins. Amniocity and chorionicity should be determined sonographically so that adequate care can be accessible for the mother and all of her offspring.

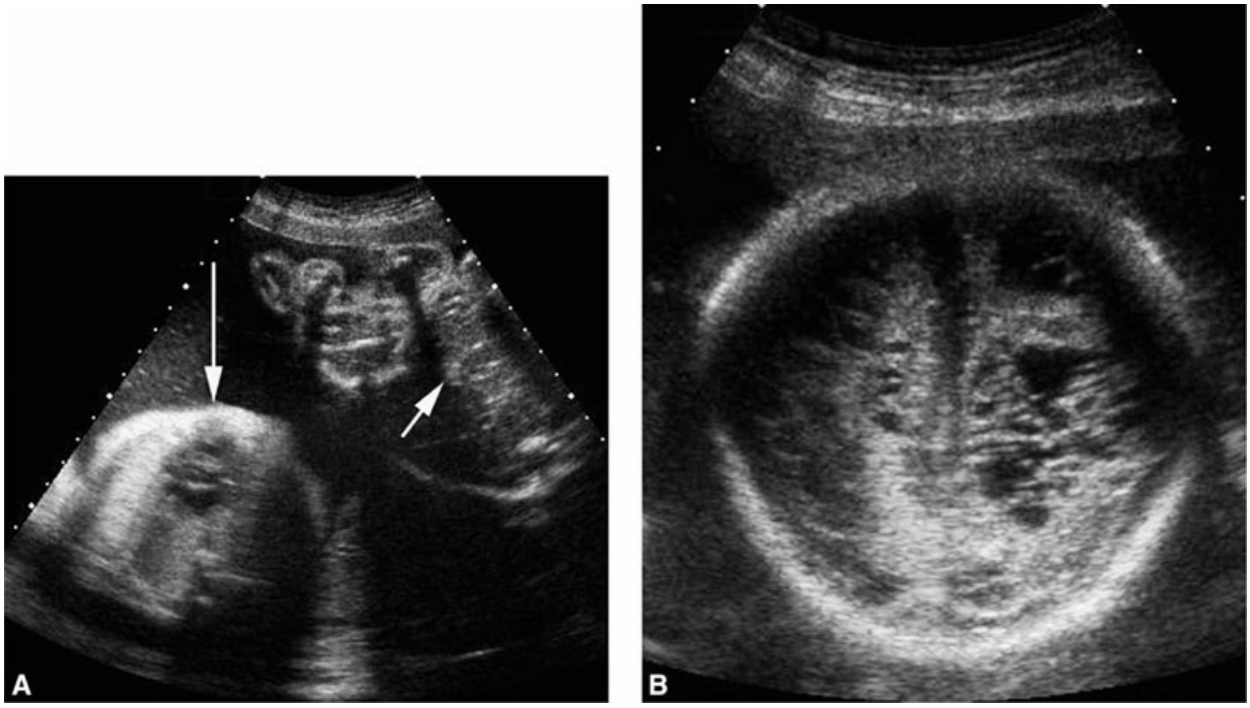


Figure 31-15 Twin embolization syndrome. **A.** A 32-week sonogram revealing a live twin (*long arrow*) and a demised twin (*short arrow*). **B.** One month later, the live twin is suffering from intracranial ischemic damage as a result of twin embolization syndrome.



Figure 31-16 Trichorionic triamniotic triplets. Sonogram at 6 weeks' gestation demonstrating three gestational sacs (*1*, *2*, and *3*) separated by thick bands of tissue.



Figure 31-17 Quadruplets. Four fetuses (*arrowheads*) are noted during this 10-week sonogram.

Unfortunately, multiple gestations beyond twins have an increased likelihood of discordant growth, miscarriage, and perinatal death. When assisted reproduction is used, resulting in a high number of multifetal pregnancies, multifetal reduction may be used. With ultrasound guidance, a needle punctures the fetal heart and potassium chloride is injected.

MATERNAL AND POSTNATAL COMPLICATIONS OF MULTIPLE GESTATIONS

Mothers expecting multiple gestations have an increased risk of developing preeclampsia and anemia. The risk for preterm delivery is increased 7 to 10 times more compared to a singleton pregnancy, with an associated low birth weight. The median gestational age of delivery for twins is 35 weeks, and for triplets and beyond, the gestational age of delivery is even earlier. Infants born with low birth weight, and specifically before 32 weeks' gestation, often suffer from pulmonary hypoplasia with episodes of hypoxia. Hypoxia at the time of birth can cause tiny, fragile blood vessels within the immature brain to rupture, leading to intracranial hemorrhage and possible irreversible neurologic complications or death.

REVIEW QUESTIONS

1. Which of the following is not a sonographic sign of a dichorionic diamniotic gestation?
   a. Twin peak sign
   b. Lambda Sign
   c. Delta Sign
   d. T sign

2. Twins that have the threat of being conjoined are:
   a. Monochorionic monoamniotic
   b. Monochorionic diamniotic
   c. Dizygotic
   d. Dichorionic diamniotic

3. Which of the following would a newborn most likely suffer from if he or she were born prior to 32 weeks as a result of multiple gestation complications?
   a. Ascites
   b. Pulmonary hypoplasia
   c. Amnionitis
   d. Preeclampsia

4. The inner membrane surrounding the fetus is referred to as the:
   a. Placenta
   b. Chorion
   c. Amnion

d. Yolk sac

5. Twins that result from the fertilization of two separate ova are called:
   a. Diamniotic
   b. Dizygotic
   c. Monozygotic
   d. Monochorionic

6. What condition is pregnancy-induced maternal high blood pressure and excess protein in the urine after 20 weeks' gestation?
   a. Gestational diabetes
   b. Preeclampsia
   c. Porencephaly
   d. Maternal mirror syndrome

7. The outer membrane of the gestation is referred to as the:
   a. Placenta
   b. Chorion
   c. Amnion
   d. Yolk sac

8. Which of the following would not increase the likelihood of multiple gestations?
   a. Gestational diabetes
   b. Maternal age of >40 years
   c. Maternal history of twins
   d. ART

9. Twins whose bodies are connected at some point are said to be:
   a. Fraternal
   b. Conjoined
   c. Identical
   d. Stuck

10. The term that indicates the presence of two separate amniotic sacs is:
    a. Dichorionic
    b. Bichorionic
    c. Monoamniotic
    d. Diamniotic

11. Twins having two placentas and one amniotic sac are referred to as:
    a. Monochorionic diamniotic
    b. Monoamniotic dichorionic

c. Dichorionic monoamniotic
d. This does not occur

12. What is it called when a twin fetus, suffering from TTTS, experiences severe oligohydramnios and becomes closely adhered to the uterine wall?
a. Acardiac monster
b. Vanishing twin
c. Acardiac twin
d. Stuck twin

13. Which term relates the number of amniotic sacs?
a. Chorionicity
b. Placentation
c. Amnionicity
d. Embryology

14. Twins having one placenta and one amniotic sac are referred to as:
a. Dichorionic monoamniotic
b. Dichorionic diamniotic
c. Monochorionic diamniotic
d. Monochorionic monoamniotic

15. Which term relates the number of placentas?
a. Chorionicity
b. Zygocity
c. Amnionicity
d. Cleavage

16. Identical twins result from:
a. Monozygotic twinning
b. Dizygotic twinning
c. Heterotopic pregnancies
d. Monochorionic pregnancies

17. The sonographic examination of twins reveals a triangular extension of the placenta at the base of the membrane. This finding is indicative of:
a. Monochorionic monoamniotic twins
b. Monochorionic diamniotic twins
c. Dichorionic diamniotic twins
d. Monochorionic diamniotic twins

18. Asymmetry in fetal weight between twins is indicative of:
a. Discordant growth

b. Preeclampsia
c. Dichorionic diamniotic twinning
d. Intrauterine infections

19. Twins having two placentas and two amniotic sacs are referred to as:
a. Monochorionic diamniotic
b. Biamniotic dichorionic
c. Dichorionic diamniotic
d. Dichorionic biamniotic

20. Typically, the first sonographic manifestation of TTTS is:
a. Oligohydramnios
b. Polyhydramnios
c. Dichorionic twinning
d. Discordant fetal growth

21. Conjoined twins that are attached at the abdomen are referred to as:
a. Omphalopagus
b. Thoracopagus
c. Ileopagus
d. Craniopagus

22. Monozygotic twins result from:
a. A single zygote that splits
b. Two zygotes that are fertilized by the same sperm
c. Two morulla
d. A single zygote that is fertilized by two sperm

23. The demise of a twin during the second or third trimester can lead to:
a. TTTS
b. Twin embolization syndrome
c. Twin peak sign
d. Acardiac twinning

24. The term that indicates the presence of two separate placentas is:
a. Dichorionic
b. Bichorionic
c. Monoamniotic
d. Diamniotic

25. What is a treatment that separates abnormal placental vascular connections between twins that are suffering from TTTS?
a. Cleavage-laser resection treatment

b. Endoscopic-guided laser photocoagulation
c. Endemic translocation of placental vessels
d. Circumvallate resection of shared placental vasculature

26. The shunting of blood from one twin to the other is termed:
a. TTTS
b. Twin embolization syndrome
c. Twin peak sign
d. Conjoined twins

27. Factors that increase the likelihood of having multiple gestations include all of the following except:
a. Advanced maternal age
b. Ovulation induction drugs
c. Poor nutritional state
d. Maternal predisposition for twins

28. TRAP syndrome may also be referred to as:
a. TTRS
b. Vanishing twin syndrome
c. Twin embolization syndrome
d. Acardiac twinning

29. Which of the following can occur as a result of dizygotic twinning?
a. Monochorionic diamniotic twins
b. Monochorionic monoamniotic twins
c. Dichorionic diamniotic twins
d. All of the above

30. The abnormal twin in acardiac twinning is also referred to as the:
a. Pump twin
b. Parasitic twin
c. Stuck twin
d. Vanishing twin

31. The twin that will appear larger in TTTS is the:
a. Donor
b. Recipient
c. Both will be the same
d. Both will be demised

32. Fraternal twins result from:
a. Monozygotic twinning

b. Dizygotic twinning
c. Heterotopic pregnancies
d. Monochorionic pregnancies

33. What is the term for conjoined twins attached at the sacral region?
a. Sacralpagus
b. Omphalopagus
c. Pyopagus
d. Thoracopagus

34. Which of the following can occur as a result of monozygotic twinning?
a. Monochorionic diamniotic twins
b. Monochorionic monoamniotic twins
c. Dichorionic diamniotic twins
d. All of the above

35. The most common form of monozygotic twins is:
a. Monochorionic diamniotic
b. Dichorionic monoamniotic
c. Monochorionic monoamniotic
d. None of the above

36. All of the following complications are associated with multiple gestations except:
a. Preterm delivery
b. High birth weight
c. Maternal anemia
d. Maternal preeclampsia

37. Acardiac twinning results from:
a. Poor maternal nutrition
b. Dizygotic gestations
c. Abnormal links between the placental vessels
d. Twin embolization syndrome

38. Ovulation induction drugs not only increase the likelihood of multiple gestations, but also increase the likelihood of:
a. Maternal diabetes
b. Ovarian prolapse
c. Heterotopic pregnancies
d. Choriocarcinoma

39. Which form of monozygotic twinning is least common?

a. Monochorionic diamniotic
b. Monochorionic monoamniotic
c. Dichorionic diamniotic
d. Dichorionic biamniotic

40. The demise of a twin can lead to the development of neurologic complications in the living twin as a result of:
a. Twin embolization syndrome
b. TTTS
c. TRAP syndrome
d. Dichorionicity

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32

Fetal Environment and Maternal Complications

Introduction

This chapter offers a review of the placenta, amniotic fluid, umbilical cord, and cervix. An appraisal of intrauterine growth restriction and maternal complications is also provided.

Key Terms

abruptio placentae—placental abruption

allantoic cyst—cyst found within the umbilical cord

amniotic fluid index—the amount of amniotic fluid surrounding the fetus; the sum of four quadrant measurements of amniotic fluid

anasarca—diffuse edema

anemia—the condition of having a deficient number of red blood cells

bilateral renal agenesis—the failure of both kidneys to develop in the fetus

bilobed placenta—placenta that consists of two separate discs of equal size

biophysical profile—method of fetal monitoring with sonography to produce a numerical scoring system that predicts fetal well-being

blastocyst—the stage of the conceptus that implants within the decidualized endometrium

cerclage—the placement of sutures within the cervix to keep it closed

cervical incompetence—the painless dilation of the cervix in the second or early third trimester

cesarean section—form of childbirth in which a surgical incision is made through the maternal abdomen to deliver the fetus

chorioangioma—a benign placental tumor

chorion frondosum—the part of the chorion, covered by chorionic villi, that is the fetal contribution of the placenta

chorionic villi—fingerlike projections of gestational tissue that attach to the decidualized endometrium and allow the transfer of nutrients from the mother to the fetus

circumvallate placenta—an abnormally shaped placenta caused by the membranes inserting inward from the edge of the placenta, producing a curled-up placental shape

cotyledons—groups or lobes of chorionic villi

cystic adenomatoid malformation—a mass consisting of abnormal bronchial and lung tissue that develops within the fetal chest

decidua basalis—the endometrial tissue at the implantation site, and the maternal contribution of the placenta

diaphragmatic hernia—the herniation of the abdominal contents into the chest cavity through a defect in the diaphragm

diethylstilbestrol—a drug administered to pregnant women from the 1940s to the 1970s to treat threatened abortions and premature labor that has been linked with uterine malformation in the exposed fetus

duodenal atresia—congenital maldevelopment or absence of the duodenum

erythroblastosis fetalis—condition in which there is an incompatibility between the fetal and maternal red blood cells

estimated fetal weight—the fetal weight based on sonographic measurements

esophageal atresia—congenital absence of part of the esophagus

exsanguination—total blood loss; to bleed out

fetal hydrops—an abnormal accumulation of fluid in at least two fetal body cavities

funneling (cervical)—the result of the premature opening of the internal os and the subsequent bulging of the membranes into the dilated cervix

gastroschisis—herniation of abdominal contents through a right-sided, periumbilical abdominal wall defect

gestational diabetes—diabetes acquired as a result of pregnancy

gestational trophoblastic disease—a disease associated with an abnormal proliferation of the trophoblastic cells during pregnancy; may also be referred to as molar pregnancy

hemangioma—a benign tumor composed of blood vessels

hydronephrosis—the dilation of the renal collecting system resulting from the obstruction of the flow of urine from the kidney(s) to the bladder; also referred to as pelvocaliectasis or pelvicaliectasis

hypoxia—a shortage of oxygen or decreased oxygen in the blood

idiopathic—from an unknown origin

immune hydrops—fetal hydrops caused by Rh incompatibility

infantile polycystic kidney disease—an inherited renal disease that results in bilateral enlargement of the fetal kidneys and microscopic renal cysts; also referred to as autosomal recessive polycystic kidney disease

intrauterine growth restriction—a fetus that is below the 10th percentile for gestational age (small for gestational age) and whose growth is impeded for some reason

leiomyoma (uterine)—a benign, smooth muscle tumor of the uterus; may also be referred to as a fibroid or uterine myoma

lower uterine segment—the term used for the isthmus during pregnancy

macrosomia—an estimated fetal weight of greater than the 90th percentile or the neonate that measures more than 4,500 g

marginal cord insertion—abnormal cord insertion at the edge of the placenta

meconium—fetal stool that is composed of fetal skin, hair, amniotic fluid, and bile

microcephaly—small head

mirror syndrome—a rare disorder in which the mother suffers from edema and fluid buildup similar to her hydropic fetus

multicystic dysplastic kidney disease—a fetal renal disease thought to be caused by an early renal obstruction; leads to the development of multiple noncommunicating cysts of varying sizes in the renal fossa

multiparity—having had several pregnancies

neonatal period—the first 28 days of life

neural tube defects—a group of developmental abnormalities that involve the brain and spine

nongravid—not pregnant

nonimmune hydrops—fetal hydrops caused by congenital fetal anomalies and infections

nuchal cord—condition of having the umbilical cord wrapped completely around the fetal neck

oligohydramnios—a lower-than-normal amount of amniotic fluid for the

gestational age

omphalocele—an anterior abdominal wall defect where there is herniation of the fetal bowel and other abdominal organ into the base of the umbilical cord

philtrum—the vertical groove seen between the upper lip and the nasal septum

placenta accreta—the abnormal adherence of the placenta to the myometrium in an area where the decidua is either absent or minimal

placenta increta—invasion of the placenta within the myometrium

placenta percreta—penetration of the placenta through the uterine serosa and possibly into adjacent pelvic organs

placenta previa—when the placenta covers or nearly covers the internal os of the cervix

placentomegaly—enlargement of the placenta

polyhydramnios—an excessive amount of amniotic fluid for the gestational age

posterior urethral valves—irregular thin membranes of tissue located within the male posterior urethra that does not allow urine to exit the urethra

postpartum—time directly after giving birth and extending to about 6 weeks

preeclampsia—pregnancy-induced maternal high blood pressure and excess protein in the urine after 20 weeks' gestation

premature rupture of membranes—the rupture of the amniotic sac prior to the onset of labor

proteinuria—protein in the urine

retained products of conception—when additional placental tissue remains within the uterus after the bulk of the placenta has been delivered

shoulder dystocia—when the shoulder of the fetus cannot pass through the birth canal during pregnancy

succenturiate lobe—an accessory lobe of the placenta

TORCH—acronym that stands for toxoplasmosis, other infections, rubella, cytomegalovirus, and herpes simplex virus

twin–twin transfusion syndrome—shunting of venous or arterial blood from one twin to another through placental circulation

two-vessel cord—an umbilical cord with one artery and one vein; could possibly be associated with other fetal abnormalities and intrauterine growth restriction

umbilical arteries—two vessels of the umbilical cord that carry deoxygenated blood from the fetus to the placenta

umbilical vein—the vessel of the umbilical cord that carries oxygenated

blood from the placenta to the fetus

umbilical vein varix—focal dilatation of the intra-abdominal portion of the umbilical vein

vasa previa—fetal vessels resting over the internal os of the cervix

velamentous cord insertion—the abnormal insertion of the umbilical cord into the membranes beyond the placental edge

venous lakes—pools of maternal blood within the placental substance

vernix—protective fetal skin covering

vitelline duct—the structure that connects the developing embryo to the secondary yolk sac

Wharton jelly—gelatinous material that is located within the umbilical cord around the umbilical vessels

FETAL ENVIRONMENT

The Placenta

The placenta is a vital organ to the fetus during pregnancy (Table 32-1). It normally weighs between 450 and 550 g and has a diameter of 16 to 20 cm. The placenta is derived from both fetal and maternal cells. The decidua basalis, the maternal contribution of the placenta, is the endometrium beneath the developing placenta. The chorion frondosum, the portion derived from the blastocyst and containing the chorionic villi, is the fetal contribution to the placenta. The placenta consists of approximately 10 to 30 cotyledons, which are groups or lobes of chorionic villi.



SOUND OFF

The decidua basalis is the maternal contribution of the placenta, and the chorion frondosum is the fetal contribution of the placenta.

The placenta produces human chorionic gonadotropin, which maintains the corpus luteum of the ovary. In later pregnancy, the placenta also produces estrogen and progesterone, taking over that function from the corpus luteum. One major function of the placenta is to act as an excretory organ for the fetus, performing imperative exchanges of waste products and gases with valuable nutrients and oxygen from the mother. The placenta effectively becomes the means of respiration for the fetus.

A definitive placenta may not be identified sonographically until after 10 to 12 weeks. It will appear as an echogenic thickening surrounding part of the gestational sac. As the pregnancy progresses, the placenta becomes more

defined (Fig. 32-1). The placenta consists of three parts: (i) the chorionic plate, (ii) the placental substance, and (iii) the basal layer or basal plate. The chorionic plate is the element of the placenta closest to the fetus. The basal layer is the area adjacent to the uterus. The placental substance contains the functional parts of the placenta and is located between the chorionic plate and the basal layer (Fig. 32-2).

TABLE 32-1 Functions of the placenta

Gas transfer
Excretory function
Water balance
pH maintenance
Hormone production
Defensive barrier

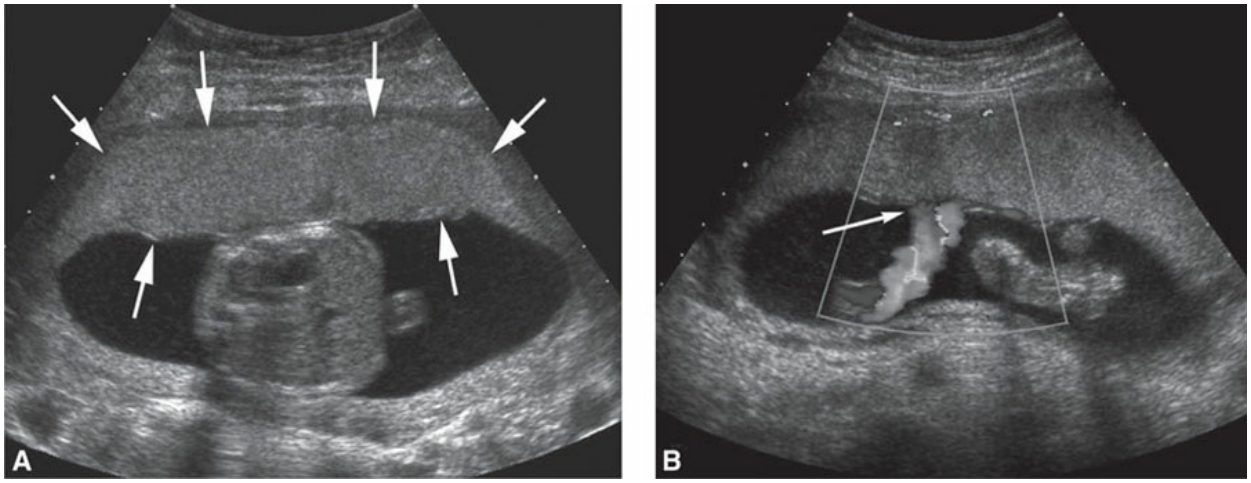


Figure 32-1 Normal placenta at 19 weeks. **A.** A normal-appearing anterior placenta (*between arrows*). **B.** The umbilical cord insertion into the placenta (*arrow*) is noted in this image. Color image provided online.

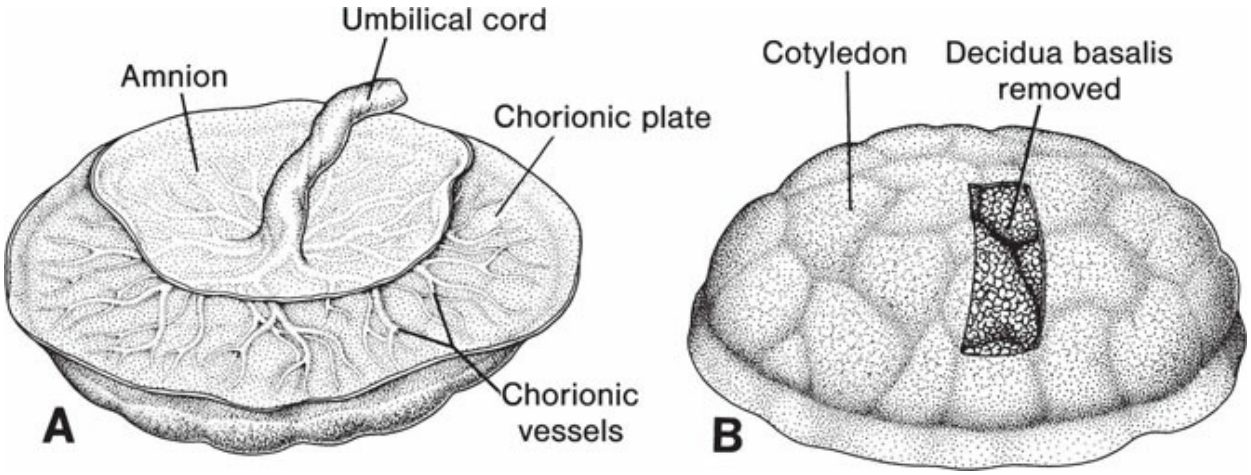


Figure 32-2 A full-term placenta. **A.** Fetal side. The chorionic plate and umbilical cord are covered by amnion. **B.** Maternal side showing the cotyledons. In one area, the decidua has been removed.

There are several normal variants seen within the placental substance that can distort the typical homogeneous appearance of this organ. Venous lakes, also referred to as maternal lakes or placental lakes, are pools of maternal blood within the placental substance. They appear as anechoic or hypoechoic areas, and may contain swirling blood. These are of little clinical significance.

SOUND OFF
Venous lakes, also referred to as maternal lakes or placental lakes, are pools of maternal blood within the placental substance.

The shape of the placenta may vary as well. A bilobed placenta consists of two separate discs of equal size. There may also be an accessory lobe or a succenturiate lobe of the placenta, which are additional smaller lobes located separate from the main segment of the placenta (Fig. 32-3). Also, a circumvallate placenta is an abnormally shaped placenta caused by the membranes inserting inward from the edge of the placenta, producing a curled-up placental contour (Fig. 32-4). A circumvallate placenta may lead to vaginal bleeding and placental abruption, among other complications.

Calcifications may be noted within the placenta, and indentations may be seen within the basal and chorionic plates with advancing gestation. Although it has fallen out of favor in some institutions, grading of the placenta has been performed in the past to predict fetal lung maturity by assessing these indentations and calcifications (Table 32-2; Fig. 32-5). The thickness of the placenta should be evaluated with sonography. It should not exceed 4 cm. Both a thick or large placenta, termed placentomegaly, and a thin placenta are associated with maternal and/or fetal abnormalities (Tables

32-3 and 32-4).

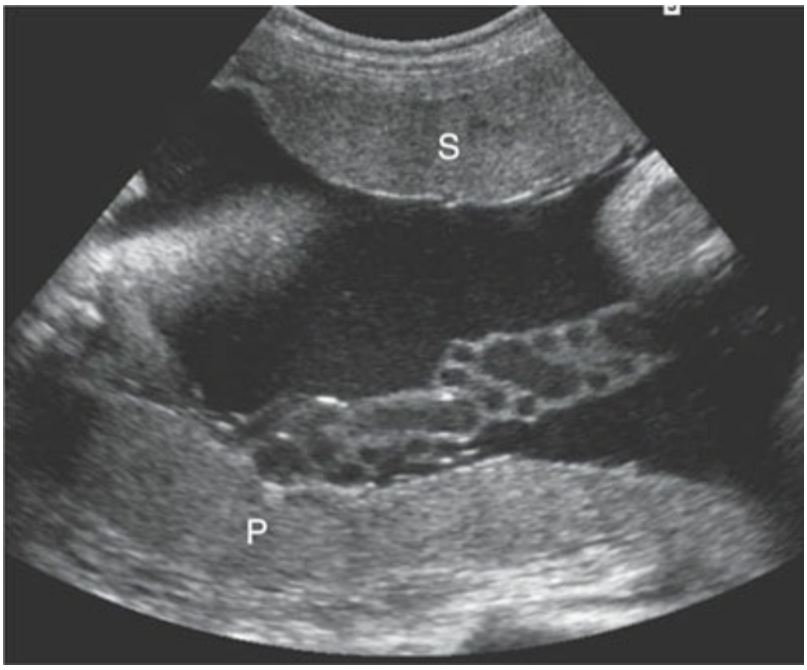


Figure 32-3 Succenturiate placenta. Image demonstrating a succenturiate lobe (*S*), or accessory lobe, separate from the posterior placenta (*P*).

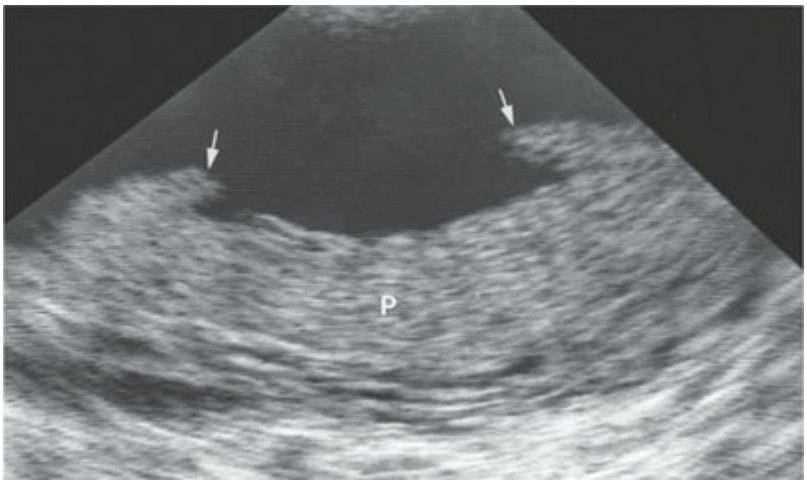


Figure 32-4 Circumvallate placenta. Scan showing infolding margin (*arrows*) of the placenta (*P*).

TABLE 32-2 Classic placental grading with associated sonographic findings

Placental Grade	Sonographic Findings
Grade 0	Uninterrupted chorionic plate and homogeneous placental substance
Grade I	Subtle indentations on the chorionic plate, with some small

	calcifications within the placental substance
Grade II	Moderate indentations in the chorionic plate with “comma-like” calcification in the placental substance
Grade III	Prominent indentation in the chorionic plate that extends to the basal layer with diffuse echogenic and anechoic areas noted within the placental substance

SOUND OFF
The thickness of the placenta should be evaluated with sonography. It should not exceed 4 cm.

Placenta Previa

Implantation of the placenta may occur within the lower uterine segment. This will often lead to placenta previa, which is evident when the placenta covers the internal os of the cervix. Placenta previa is a common cause of painless vaginal bleeding in the second and third trimesters. It is discovered more often in women with a history of multiparity, advanced maternal age, previous abortion, and prior cesarean section (C section). The correlation with C section is theorized to be the result of uterine scar formation from surgery, with the subsequent implantation of the next placenta in that area.

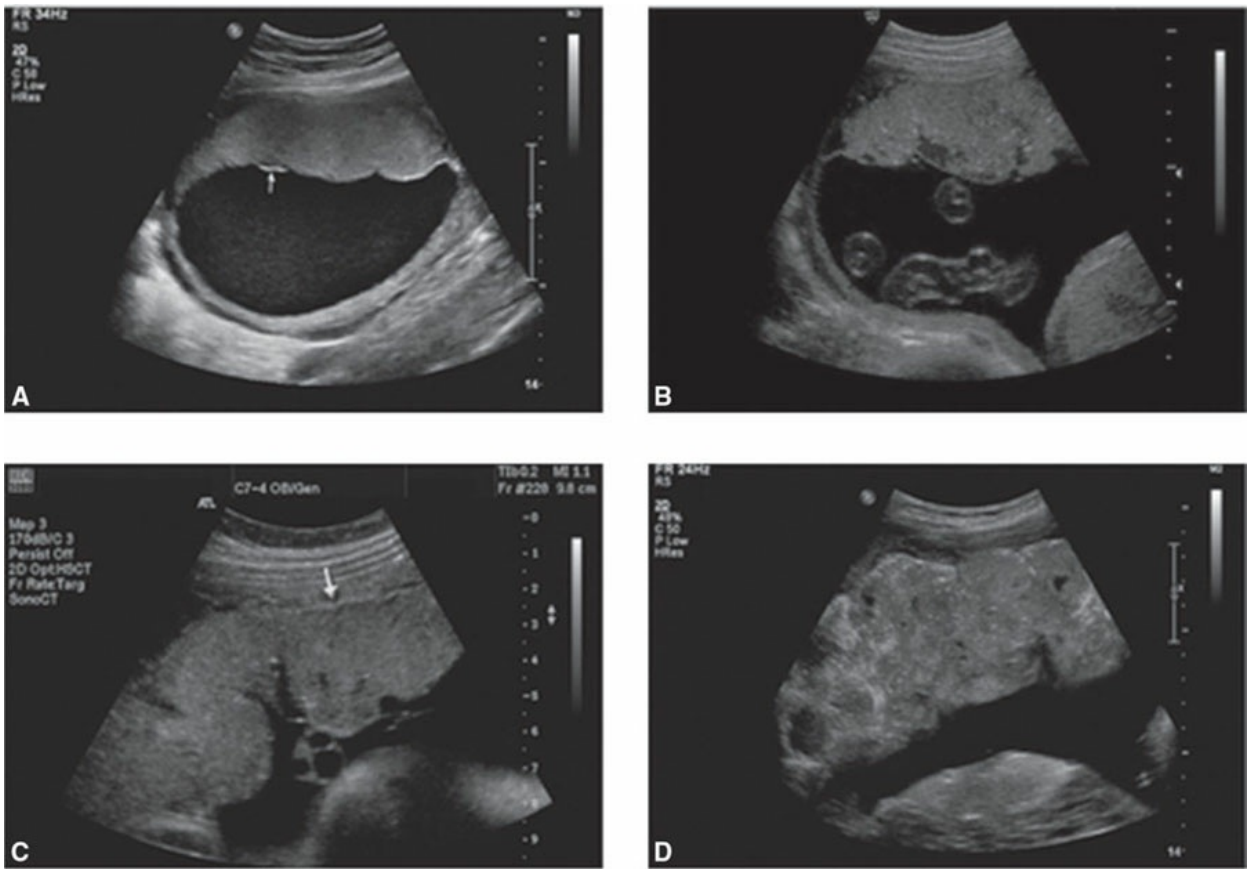


Figure 32-5 Placental grading. **A.** Anterior grade 0 placenta demonstrating the characteristic smooth, homogeneous texture. The perpendicular angle of incidence allows for imaging of the chorionic plate (*arrow*). **B.** Grade I placenta containing scattered calcifications with the beginning of lobulations developing on the fetal side. **C.** In the Grade II placenta, lobulations increase with the basal layer (*arrow*) appearing irregular because of small calcifications. **D:** Grade III placenta demonstrating interlobar and septal calcifications.

TABLE 32-3 Possible causes of a thick placenta

Diabetes mellitus
Maternal **anemia**
Infection
Fetal hydrops
Rh isoimmunization
Multiple gestation

TABLE 32-4 Possible causes of a thin placenta

Diabetes mellitus (long-standing)
Intrauterine growth restriction
Placental insufficiency
Polyhydramnios
Preeclampsia
Small-for-dates fetus

SOUND OFF
Placenta previa is a common cause of painless vaginal bleeding in the second and third trimesters.

Placenta previa is not routinely diagnosed until the late second or third trimester. This is secondary to the fact that because of the growth of the uterus, the placenta has the potential to migrate away from the cervix with advancing gestation. The term migration may be misleading, because the placenta does not actually travel but rather the uterine growth shifts the placenta away from the cervix. There are several terms associated with placenta previa that are specific to the location of the placenta in relation to the internal os of the cervix (Table 32-5; Figs. 32-6 and 32-7). Although

marginal placenta previa and partial placenta previa are defined separately, they are often difficult to distinguish sonographically.

The placenta should be evaluated for placenta previa after 20 weeks with an empty maternal bladder using a transabdominal approach, because the fully distended bladder may lead to a false-positive diagnosis of placenta previa. Another cause of false-positive placenta previa is painless myometrial contractions that occur in the lower uterine segment. However, these should resolve as the sonographic examination continues.

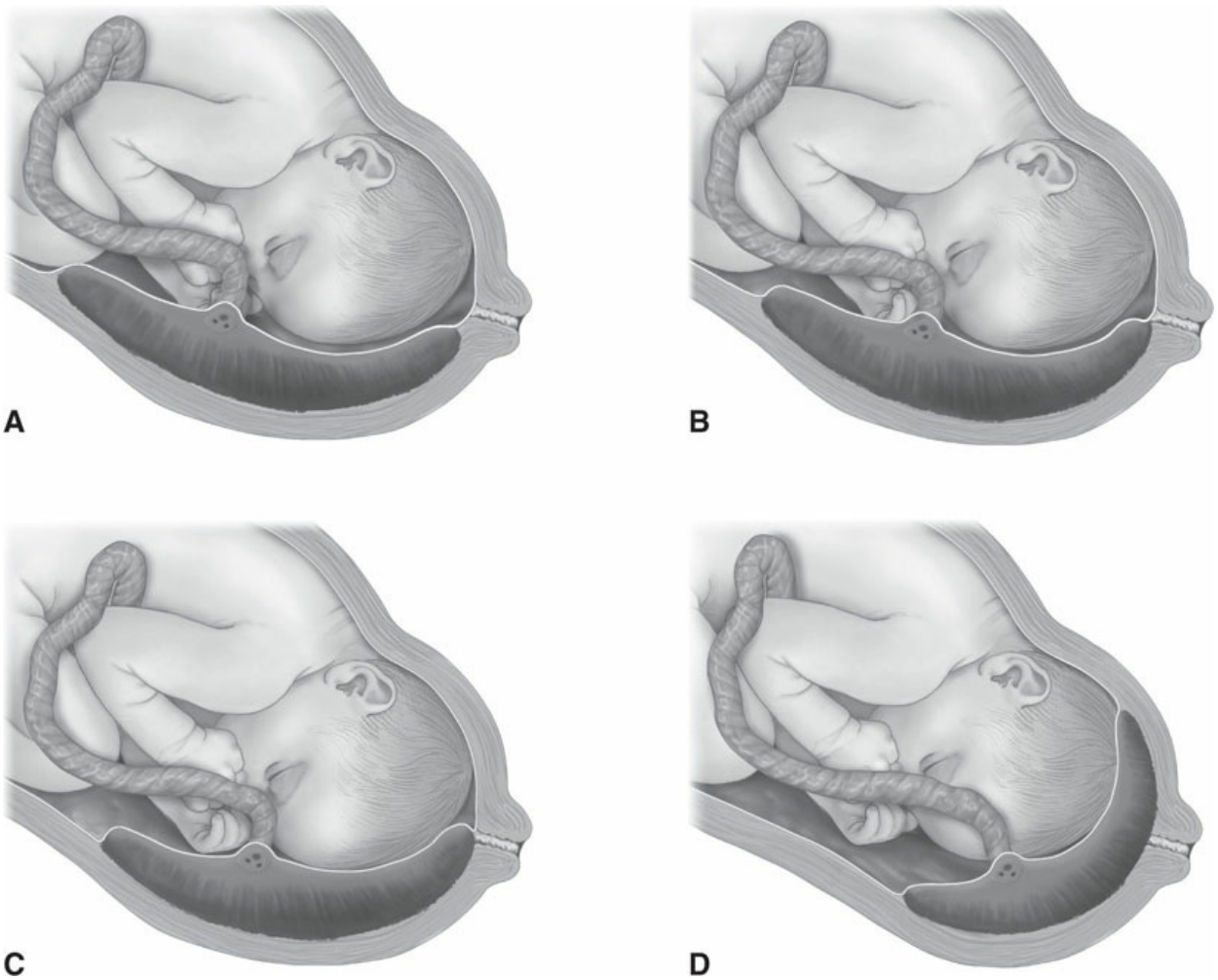


Figure 32-6 Classification of placental location. **A.** Low-lying previa. **B.** Marginal previa. **C.** Partial previa. **D.** Complete previa.

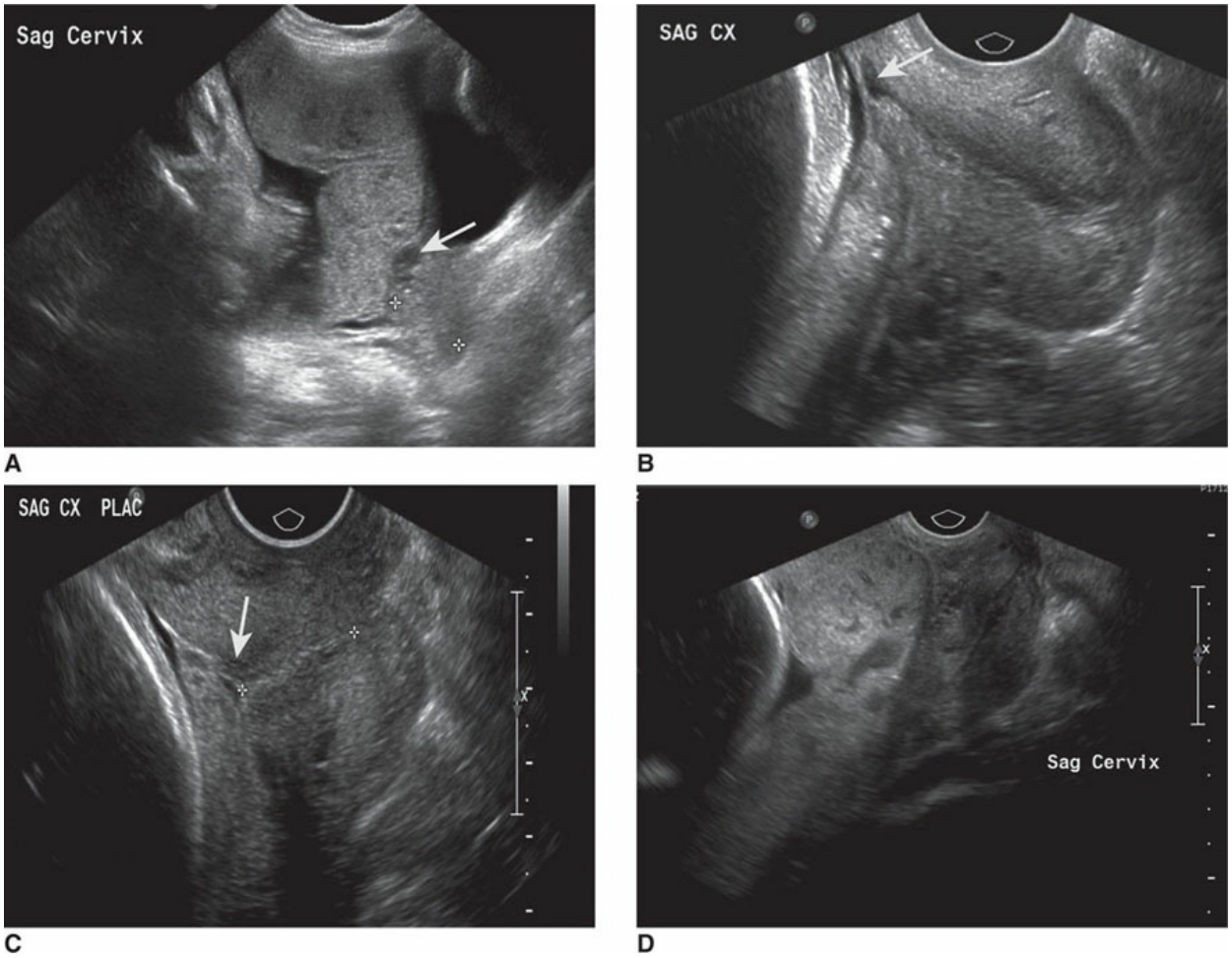


Figure 32-7 Complete placenta previa. **A.** Sagittal transabdominal image demonstrating the placental tissue covering the internal cervical os. **B.** Endovaginal image demonstrating marginal placenta previa. The *arrow* points to the internal cervical os. **C.** Endovaginal image demonstrating partial placenta. The *arrow* points to the internal cervical os. **D.** Complete central placenta previa with accreta on an endovaginal image.

TABLE 32-5 Terms associated with placenta previa

Term Associated with Placenta Previa	Sonographic Description
Complete (total) previa	Placenta covers the internal os completely
Partial previa	Placenta partially covers the internal os
Marginal previa	Placenta lies at the edge of the internal os
Low-lying previa	Placental edge extends into the lower uterine segment but ends more than 2 cm away from the internal os

Transvaginal and translabial or transperineal scanning can be extremely

beneficial, especially with advanced gestation when the fetal head or fetal parts obscure the internal os. Translabial scanning is discussed later in this chapter. Because both the patient and the fetus have an increased risk of death with placenta previa, a C section is the preferred method of delivery.

CLINICAL FINDINGS OF PLACENTA PREVIA

1. Previous C section or uterine surgery
2. Painless vaginal bleeding
3. Possibly asymptomatic

Vasa Previa

The complication of fetal vessels resting over the internal os of the cervix is referred to as vasa previa. These vessels are prone to rupture as the cervix dilates. This, in turn, can lead to exsanguination of the fetus. Vasa previa is often associated with velamentous cord insertion and possibly a succenturiate lobe. The sonographic findings of color Doppler signals over the internal os are sonographically indicative of vasa previa.

SONOGRAPHIC FINDINGS OF VASA PREVIA

1. Identification of vessels over the internal os of the cervix with the use of color Doppler
2. Velamentous cord insertion

Placental Abruption

Placental abruption, also referred to as abruptio placentae, is the premature separation of the placenta from the uterine wall before the birth of the fetus, thus causing hemorrhage. It may be further described as complete abruption, partial abruption, marginal abruption, or be defined by its location (Fig. 32-8). A complete abruption, which is the most severe, often results in the development of a retroplacental hematoma, which is located between the placenta and the myometrium (Fig. 32-9). Partial abruption often results in only a few centimeters of separation. Marginal abruption, often referred to as a subchorionic hemorrhage, lies at the edge of the placenta and is the most common placental hemorrhage identified with sonography.

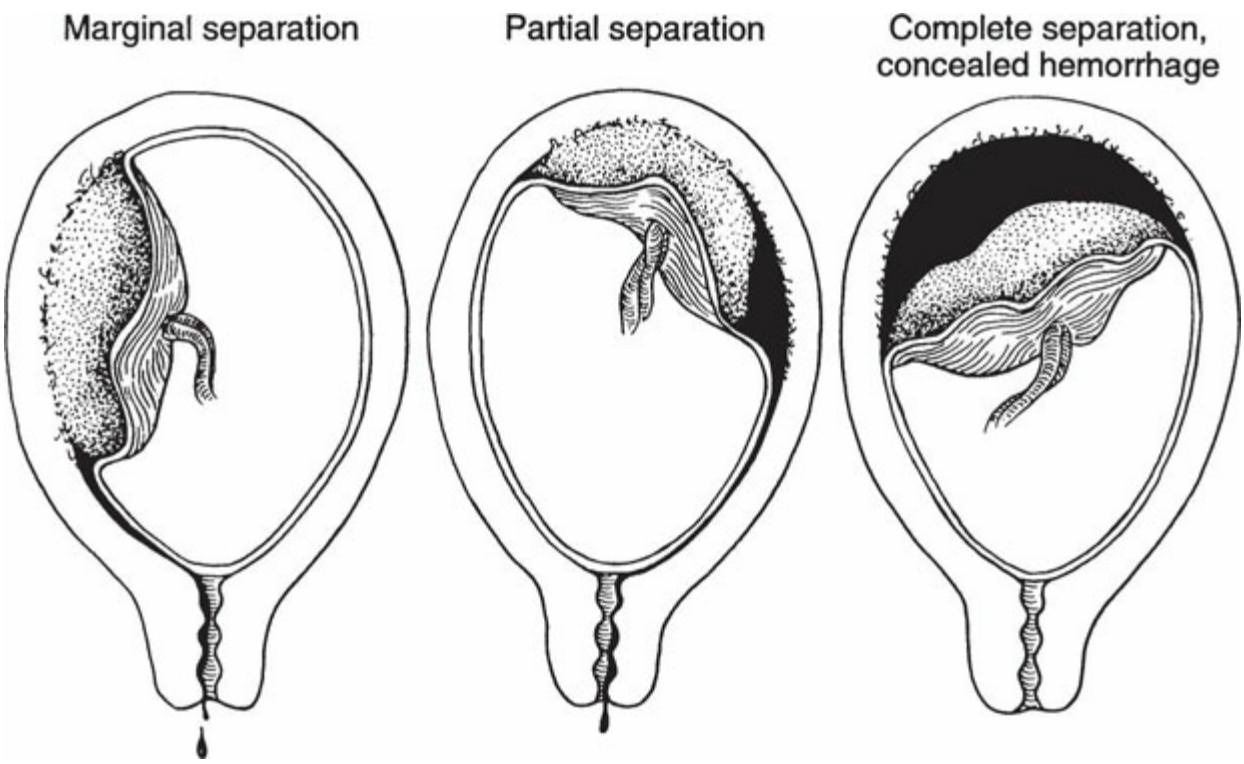


Figure 32-8 Classification of placental abruption.

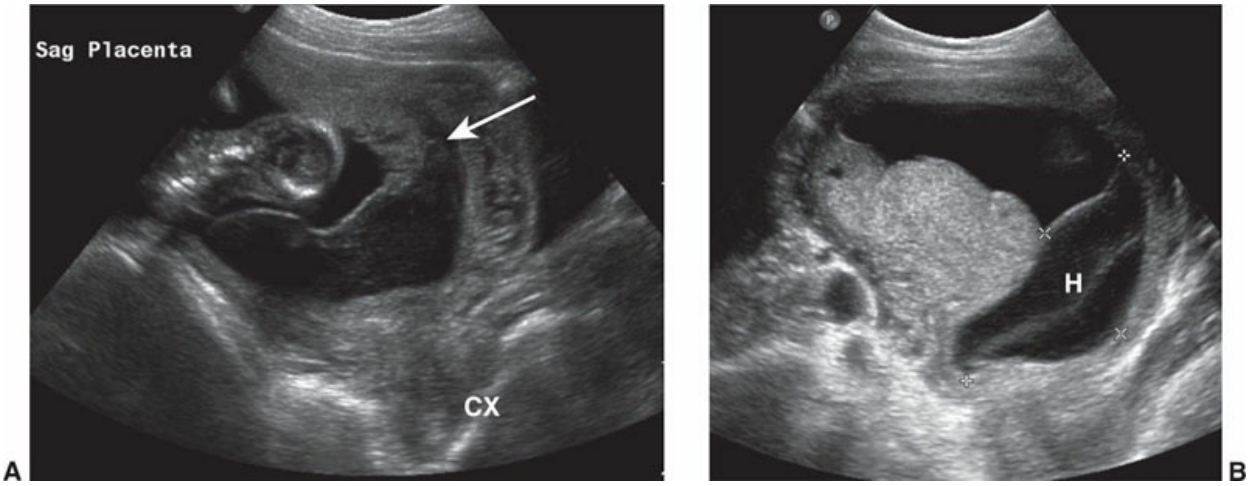


Figure 32-9 Placental abruption with retroplacental hematoma. **A.** Sagittal sonographic image demonstrating partial separation of the placenta from the uterine wall. Note the raised placental edge (*arrow*) with a large accumulation of blood adjacent to the cervix (*CX*). **B.** Sagittal sonographic image of a subchorionic hemorrhage demonstrating the layering of blood products within the clot formation (*H*).

Maternal conditions that are linked to the development of placental abruption include hypertension, preeclampsia, cocaine use, cigarette smoking, poor nutrition, and trauma. Sonography is not always effective in identifying placental abruption. A retroplacental hematoma can be identified either between the placenta and myometrium or under the chorionic membrane. Clinically, patients may present with vaginal bleeding, abdominal

pain, uterine contractions, and uterine tenderness. Placental abruption is an understandably urgent situation that can lead to fetal death from hypoxia and possibly the death of the mother.

SOUND OFF

Maternal conditions that are linked to the development of placental abruption include hypertension, preeclampsia, cocaine use, cigarette smoking, poor nutrition, and trauma.

CLINICAL FINDINGS OF PLACENTAL ABRUPTION

1. Abdominal pain (often sudden onset)
2. Possible vaginal bleeding
3. Uterine contraction
4. Uterine tenderness

SONOGRAPHIC FINDINGS OF PLACENTAL ABRUPTION

1. Hematoma located either at the edge of the placenta or between the placenta and the myometrium.

Placenta Accreta, Increta, and Percreta

Placenta accreta is frequently used as a universal term to describe the condition that is defined as the abnormal adherence of the placenta to the myometrium in an area where the decidua is either absent or minimal (Fig. 32-10). The placenta may attach to a uterine scar following a previous C section and/or after uterine surgery. This explains the association between anterior placenta previa and placenta accreta. As a result of this abnormal adherence, the placenta does not detach at birth. There are three different terms associated with this abnormality: (i) placenta accrete, (ii) placenta increta, and (iii) placenta percreta (Table 32-6).

Depending on the amount of invasion or penetration of the placenta into the myometrium, the patient could suffer from heavy bleeding at delivery and possibly uterine rupture. Therefore, an emergency hysterectomy may be warranted. The sonographic appearance of placenta accreta is the loss of the normal hypoechoic interface between the placenta and the myometrium (Fig. 32-11). Increta and percreta can be diagnosed based on the amount of invasion and if there is a breach of the serosal layer of the uterus. With placenta percreta, the placenta can even invade the urinary bladder, thus causing urinary complications.

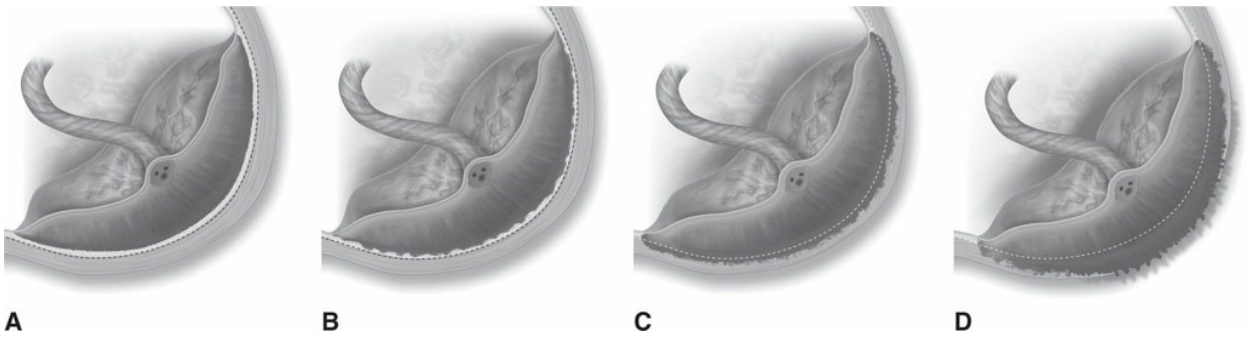


Figure 32-10 Classification of the placenta accreta spectrum. **A.** Normal placentation. **B.** Placenta accreta. **C.** Placenta increta. **D.** Placenta percreta.

TABLE 32-6 Terms associated with placenta accreta

Term Associated with Placenta Accreta	Definition	Sonographic Finding
Placenta *a*ccreta	*A*dherence of the placenta to the myometrium	Loss of normal hypoechoic interface between the placenta and the myometrium
Placenta *i*ncreta	*I*nvasion of the placenta within the myometrium	Loss of normal hypoechoic interface between the placenta and myometrium with invasion into the myometrium
Placenta *p*ercreta	*P*enetration of the placenta through the serosa and possibly into adjacent organs	Loss of normal hypoechoic interface between the placenta and the myometrium with penetration beyond the serosa

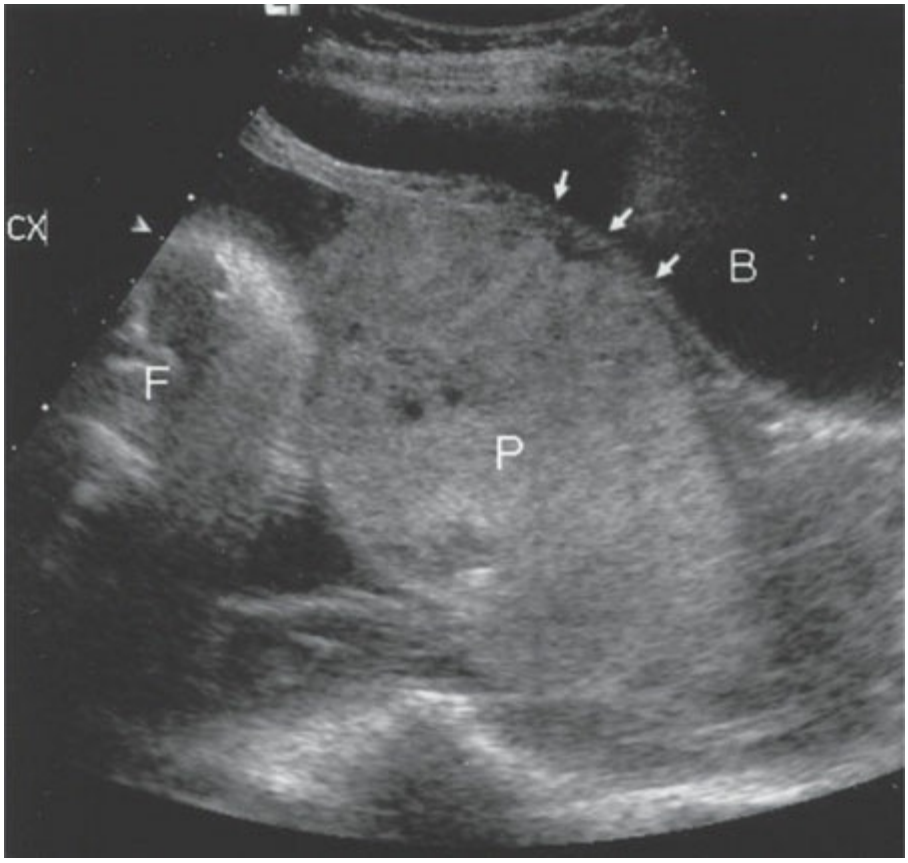


Figure 32-11 Placenta increta. Longitudinal image of a gravid patient with a history of two previous cesarean sections demonstrating a complete previa and the loss of the normal hypoechoic boundary (*arrows*) between the placenta (*P*) and the urinary bladder (*B*).

CLINICAL FINDINGS OF PLACENTA ACCRETA, INCRETA, AND PERCRETA

1. Previous C section or uterine surgery
2. Painless vaginal bleeding if placenta previa is present
3. Possibly asymptomatic

SONOGRAPHIC FINDINGS OF PLACENTA ACCRETA, INCRETA, AND PERCRETA

1. Placenta previa (frequent associated finding)
2. Loss of the normal hypoechoic interface between the placenta and the myometrium

SOUND OFF

Note in Table 32-6 that *a*ccrete is associated with *a*dherence, *i*ncreta is associated with *i*nvasion, and *p*ercreta is associated with *p*enetration of the placenta.

Chorioangioma

Chorioangioma is the most common placental tumor. Clinically, chorioangiomas are commonly asymptomatic but may produce an elevation in maternal serum alpha-fetoprotein. The most common location of this mass is adjacent to the umbilical cord insertion site at the placenta. They typically do not carry any risks to the fetus or mother, although larger chorioangiomas have been associated with polyhydramnios, intrauterine growth restriction (IUGR), and fetal hydrops. Sonographically, a chorioangioma will appear as a well-circumscribed hypoechoic or hyperechoic mass within the placental substance. Differentials for the chorioangioma include other solid-appearing focal hypoechoic areas within the placenta is the placental infarct and placental fibrin deposits.

CLINICAL FINDINGS OF A CHORIOANGIOMA

1. Possible elevation in maternal serum alpha-fetoprotein

SONOGRAPHIC FINDINGS OF A CHORIOANGIOMA

1. Solid hypoechoic or hyperechoic mass within the placenta

Uterine Synechia(e)

Uterine synechiae, also referred to as amniotic sheets, are linear bands of scar tissue within the uterus. These synechiae are the result of intrauterine adhesions, as seen with Asherman syndrome. They can result from uterine surgery. Sonographically, a uterine synechia appears as a linear, echogenic band traversing the uterine cavity. The fetus will be seen to move freely. Although typically isolated, uterine synechiae have been associated with premature rupture of membranes, premature delivery, and placental abruption. Amniotic bands are typically thinner, or may not be seen, and are associated with fetal anomalies.

SONOGRAPHIC FINDINGS OF UTERINE SYNECHIA(E)

1. Linear, echogenic band of tissue traversing the uterine cavity
2. The band does not involve fetal parts, and the normal fetus appears to move freely

The Umbilical Cord

The umbilical cord, which normally inserts into the middle of the placenta, has two arteries and one vein. These vessels are surrounded by a gelatinous material called Wharton jelly, all of which is covered by a single layer of

amnion. The cord develops from the fusion of the yolk stalk and the vitelline duct (omphalomesenteric duct) early in gestation.

The umbilical vein, which carries oxygenated blood from the placenta to the fetus, enters the fetal abdomen and proceeds cephalad to connect to the left portal vein within the liver. The umbilical arteries enter the fetal abdomen and carry deoxygenated blood from the fetus to the placenta. The arteries, once they enter the abdomen, proceed caudal around the bladder to connect to the fetal internal iliac arteries. Therefore, color Doppler can establish that there is a three-vessel cord (3VC), by placing the color Doppler box over the fetal bladder and identifying both arteries adjacent to the bladder. A 3VC may also be obtainable in the transverse view of the umbilical cord. A single umbilical artery, or two-vessel cord (2VC), has been cited as the most common abnormality of the umbilical cord. It has been reported in association with abnormalities of all major organ systems and IUGR. Fetuses with a 2VC have an approximate 20% chance of having additional abnormalities, and thus a thorough examination of the fetus for other findings is warranted.



SOUND OFF

Fetuses with a 2VC have an approximate 20% chance of having additional abnormalities, and thus a thorough examination of the fetus for other findings is warranted.

The umbilical cord normally inserts into the central portion of the placenta. Abnormal cord insertion sites are described as either marginal or velamentous. Marginal cord insertion is at the edge of the placenta. This is also referred to as a battledore placenta. Velamentous cord insertion denotes the insertion of the umbilical cord into the membranes beyond the placental edge. This type of abnormal insertion is often seen in association with vasa previa (Fig. 32-12).

Occasionally, the umbilical cord may be seen encircling the fetal neck. This is termed nuchal cord. A nuchal cord can be confirmed with color Doppler. It does not always indicate fetal distress, even though on occasion multiple loops of cord may be noted around the neck. Nonetheless, this abnormality should be documented particularly if additional signs of fetal distress are evident.



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Velamentous cord insertion denotes the insertion of the umbilical cord into the membranes beyond the placental edge.

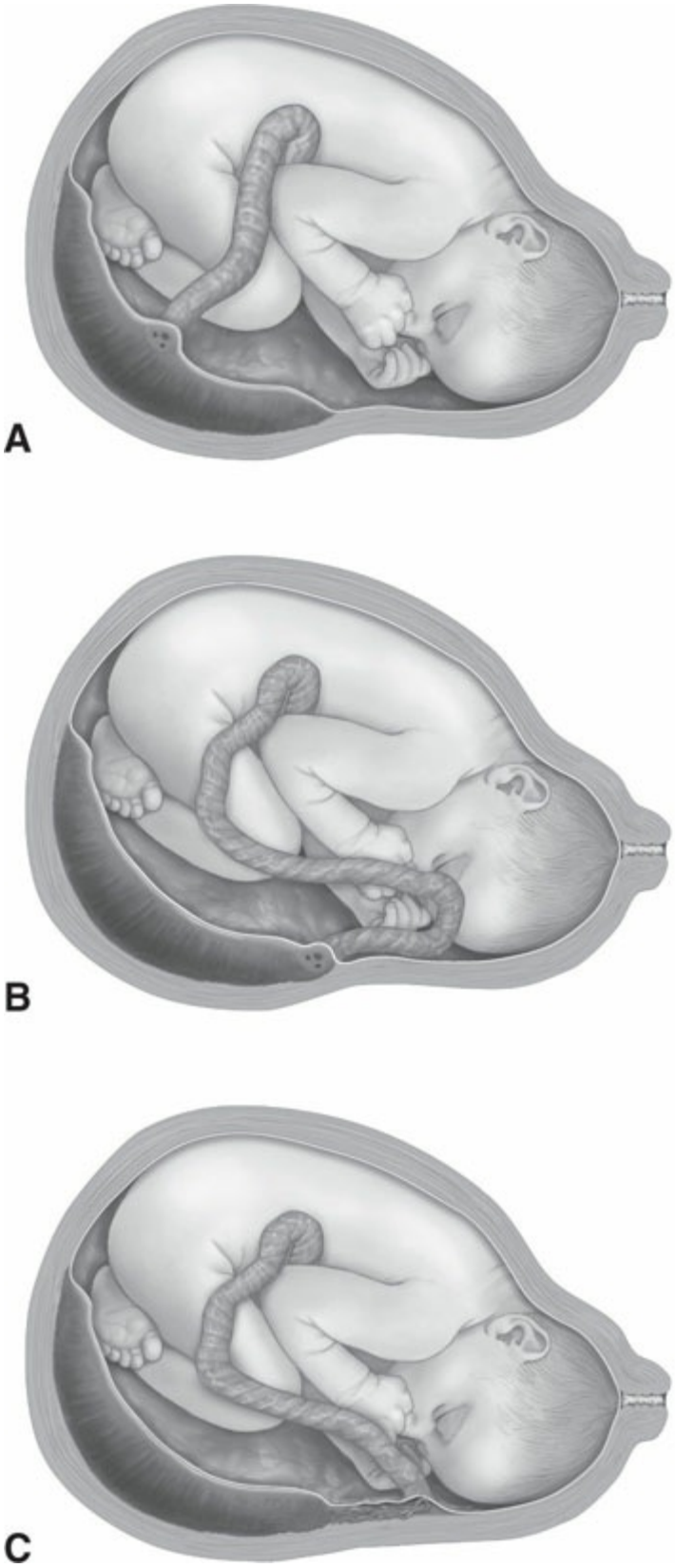


Figure 32-12 Umbilical cord insertions. **A.** Central insertion of cord into placenta. **B.** Battledore insertion. Cord is inserted near the margin or edge of the placenta. **C.** Velamentous insertion.

Cystic masses of the umbilical cord may be seen with sonography. An allantoic cyst is a mass that may be noted in the umbilical cord adjacent to

the umbilical vessels. Umbilical cord cysts are most often found near the fetal abdomen and have been seen in connection with omphalocele and aneuploidy, especially if noted in the second or the third trimester. Another cystic-appearing mass that may be noted within the abdomen of the fetus, appearing to be adjacent to the umbilical cord, is an umbilical vein varix, which is essentially the focal dilatation of the abdominal portion of the umbilical vein. It has been associated with fetal aneuploidy, growth restriction, hydrops, and demise. Color Doppler can be used to prove the vascularity of this abnormality.

The hemangioma is the most common tumor of the umbilical cord, although it is exceedingly rare. These masses, unlike allantoic cysts, appear as solid hyperechoic masses and are more often located near the cord insertion site into the placenta.

SONOGRAPHIC FINDINGS OF ALLANTOIC CYSTS

1. Cystic mass within the umbilical cord
2. Most often noted close to the fetal abdomen

SONOGRAPHIC FINDINGS OF HEMANGIOMAS OF THE UMBILICAL CORD

1. Solid hyperechoic mass within the umbilical cord
2. Most often noted close to the cord insertion into the placenta

Umbilical Cord Doppler

Fetal well-being can be evaluated using pulsed Doppler of the umbilical cord by measuring the systolic to diastolic ratio (S/D ratio). The S/D ratio assesses the vascular resistance in the placenta by taking a sample of the umbilical artery. It can be performed anywhere along the length of the cord, although a free loop of cord will tend to offer the most accurate measurement. Normally, the S/D ratio will decrease with advancing gestation. Therefore, an elevated S/D ratio is associated with increased placental resistance and an increase in the risk of perinatal mortality and morbidity. Absence or reversal of diastolic flow in the umbilical artery is considered irregular and is associated with an increased incidence of IUGR and oligohydramnios (Fig. 32-13).



SOUND OFF

Normally, the S/D ratio will decrease with advancing gestation. An elevated S/D ratio is associated with increased placental resistance and an increase in the risk of perinatal mortality and morbidity.

Amniotic Fluid

Amniotic fluid appears sonographically as anechoic fluid surrounding the fetus. Echogenic debris in the amniotic fluid may be vernix or meconium, with meconium being the least likely to be observed during an otherwise normal examination. Amniotic fluid has a number of important functions, including protecting the fetus from trauma, temperature regulation, musculoskeletal maturity, and normal lung and gastrointestinal development. The fluid that is seen in early gestation is thought to arise from water and various other materials passing freely through the membranes surrounding the embryo. In the second half of the pregnancy, the fetal kidneys and lungs produce the majority of amniotic fluid, with urine being the greatest contributor.

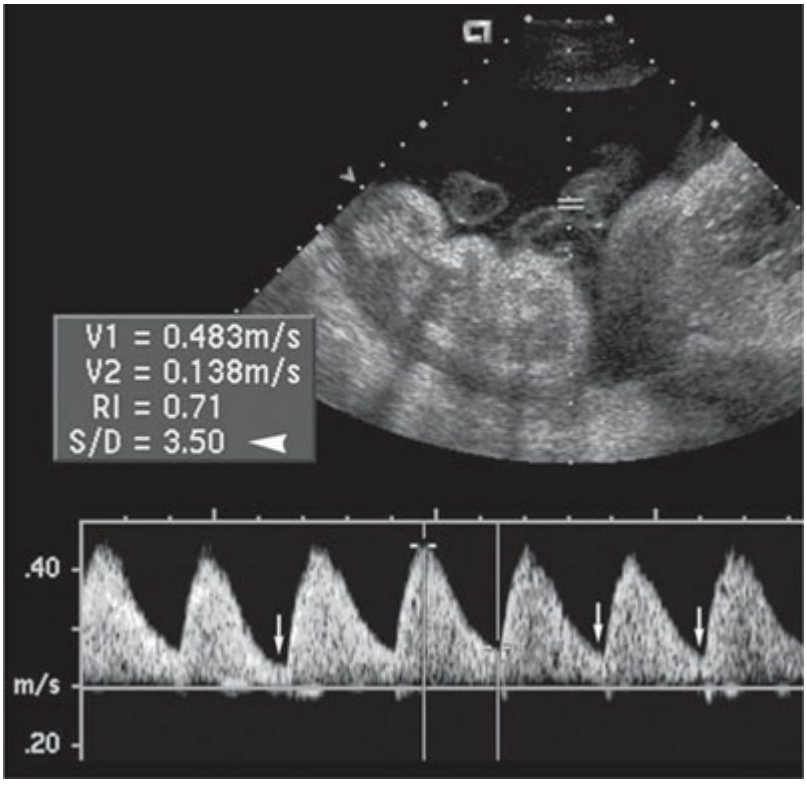


Figure 32-13 Diminished umbilical cord artery diastolic flow. Spectral Doppler of the umbilical artery in a 35-week fetus demonstrating diminished diastolic flow (*arrows*) with an elevated S/D ratio of 3.50 (*arrowhead* and *calipers*). S/D ratio, systolic to diastolic ratio.

The amount of amniotic fluid, or amniotic fluid volume, can be appraised using several sonographic techniques. The maximum vertical pocket, also referred to as the deepest vertical pocket, may be used. This pocket should contain no fetal parts or umbilical cord and measure at least 2 cm, with a normal range between 2 and 8 cm. The most widely accepted means of evaluating the volume of amniotic fluid is the amniotic fluid index (AFI).

The AFI is measured using the anteroposterior dimensions obtained from the four quadrants of the amniotic sac and adding them together. Once more, these measurements should not include fetal parts or umbilical cord. Color Doppler can be used to ensure that no cord is included. For the measurement, the transducer must be placed perpendicular to the floor. The "normal" amount of fluid varies with gestation.

SOUND OFF
The AFI is measured using the anteroposterior dimensions obtained from the four quadrants of the amniotic sac and adding them together. The measurements should not include fetal parts or umbilical cord.

An excessive amount of amniotic fluid is termed polyhydramnios, whereas a deficient amount is termed oligohydramnios. When an abnormality is noted in the amount of amniotic fluid, a thorough evaluation of the fetal genitourinary system and gastrointestinal system for abnormalities should be conducted, although other systems may be the reason for the imbalance (Tables 32-7 and 32-8). Because the fetal kidneys produce a significant amount of amniotic fluid, when oligohydramnios is observed, abnormalities of the urinary system should be initially suspected. Amniotic fluid is also constantly being swallowed by the developing fetus and absorbed by the gastrointestinal tract. Therefore, when polyhydramnios is present, abnormalities of the fetal gastrointestinal system should be primarily suspected. Chapters 28 and 29 further stress the significance of understanding these relationships.

Fetal Infections and TORCH

TORCH, an acronym that stands for toxoplasmosis, other infections, rubella, cytomegalovirus, and herpes simplex virus, is a group of infections that can cross the placenta and influence the development of the fetus. Among these, cytomegalovirus is listed as the most common congenital infection. Although additional abnormalities may be present, a common sonographic finding of fetal infections, especially with cytomegalovirus, is the presence of intracranial calcifications. Heart abnormalities, microphthalmia, microcephaly, ventriculomegaly, and hepatosplenomegaly may be noted as well (Fig. 32-14). Recently, the Zika virus has also been linked with microcephaly, decreased brain tissue, and limb abnormalities such as clubfoot.

TABLE 32-7 Fetal malformation and complications associated with

oligohydramnios
Bilateral **multicystic dysplastic kidney disease**
Bilateral renal agenesis
Infantile polycystic kidney disease
Intrauterine growth restriction
Posterior urethral valves
Premature rupture of membranes (PROM)

TABLE 32-8 Fetal malformations and complications associated with polyhydramnios

Cardiac and/or chest abnormalities
Chromosomal abnormalities
Duodenal atresia
Esophageal atresia
Gastroschisis
Neural tube defects
Omphalocele
Rh incompatibility
Twin–twin transfusion syndrome

SONOGRAPHIC FINDINGS OF TORCH

1. Intracranial calcifications
2. **Microcephaly**
3. Microphthalmia
4. Ventriculomegaly
5. Hepatosplenomegaly



SOUND OFF
Cytomegalovirus is listed as the most common congenital infection.

Fetal Alcohol Syndrome

Fetal alcohol syndrome (FAS) includes a wide variety of deleterious effects of alcohol exposure upon the fetus caused by the maternal consumption of alcohol. Children exposed to alcohol in utero have been shown to have an increase risk for growth restriction, mental impairment, physical

abnormalities, and immune dysfunction. FAS has been cited as the most common cause of intellectual disability in the United States. Alcohol, which is a teratogen, and its metabolites have been proven to cross the placenta and inflict irreversible damage on the fetal central nervous system. Sonographic findings include microcephaly, dysgenesis of the corpus callosum, long round philtrum, malformed ears, microphthalmia, heart defects such as ventricular septal defects, and cleft palate.

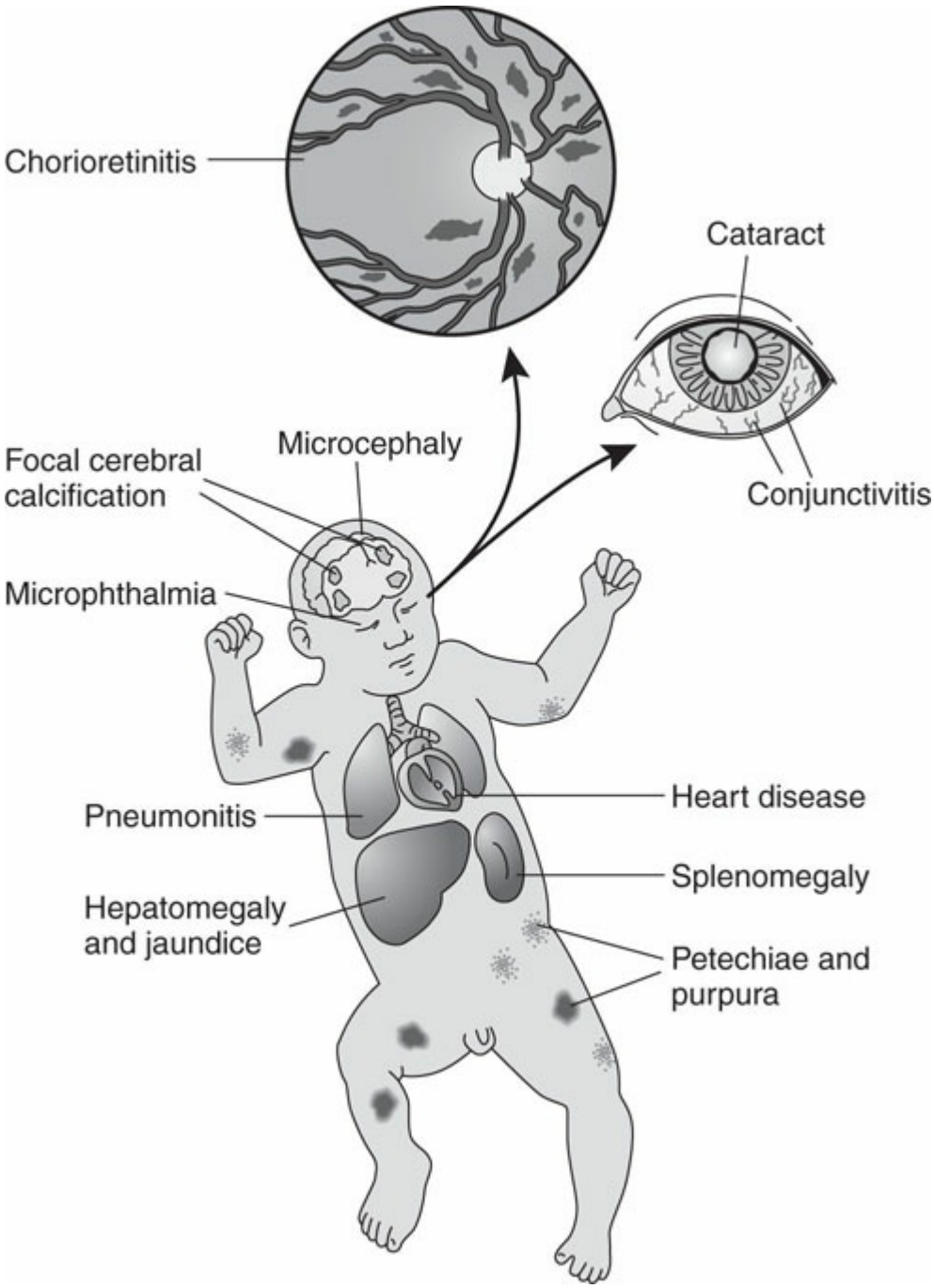


Figure 32-14 TORCH infection complications.

SONOGRAPHIC FINDINGS OF FETAL ALCOHOL SYNDROME

1. Microcephaly
2. Dysgenesis of the corpus callosum
3. Long round **philtrum**
4. Malformed ears
5. Microphthalmia
6. Cleft palate
7. Heart defects such as ventricular septal defects



SOUND OFF

Children exposed to alcohol in utero have been shown to have an increase risk of growth restriction, mental impairment, physical abnormalities, and immune dysfunction.

Sonographic Assessment of Intrauterine Growth Restriction

IUGR, or fetal growth restriction, is defined as an estimated fetal weight (EFW) that is below the 10th percentile at a given gestational age. IUGR typically results from the inadequate transfer of nutrients from the mother to the fetus, and thus is the dysfunction of the placenta. The fetus is at risk if the mother suffers from chronic disease, drinks alcohol, smokes cigarettes, has poor nutrition, is younger than 17 or older than 35 years, or has a history of previous pregnancies that were considered growth restricted. IUGR can be either symmetric, in which the entire fetus is small, or asymmetric, wherein the femur length typically is normal while all other measurements are small for gestation. The measurement that should be scrutinized closely in fetuses that are at risk for growth abnormalities is the abdominal circumference (AC), because it carries a sensitivity of greater than 95% for the diagnosis of IUGR. The discrepancy in the AC will yield an abnormal head circumference/AC ratio and a femur length/AC ratio.

The growth-restricted fetus has an increased risk of suffering from physical handicaps and neurodevelopmental delays after birth. Asymmetric and symmetric IUGR appear to have diverse causes (Tables 32-9 and 32-10). The fetus with IUGR can be monitored with sonography by evaluating the flow within the umbilical artery with the S/D ratio mentioned earlier in this chapter. The S/D ratio evaluates the sufficiency of the placenta by means of pulsed Doppler interrogation of the umbilical artery. An abnormally high S/D ratio, resulting from a reversal or absence of diastolic flow within the umbilical artery, is associated with a poor outcome.

TABLE 32-9 Suspected causes of symmetric intrauterine growth restriction

Genetic disorders
Fetal infections
Congenital malformations
Syndromes

TABLE 32-10 Suspected causes of asymmetric intrauterine growth restriction

Nutritional deficiency
Oxygen deficiency

SOUND OFF
IUGR, or fetal growth restriction, is defined as an EFW that is below the 10th percentile at a given gestational age.

When a fetus presents with measurements that lead to suspected small for gestational age, sonography can further assess the pregnancy for signs of IUGR by performing the biophysical profile. A biophysical profile combines several fetal monitoring factors to produce a numeric scoring system that predicts fetal well-being. Biophysical profile scoring is discussed further in Chapter 22 of this book.

Doppler assessment of the middle cerebral artery has also been shown effective at evaluating for hypoxia in a fetus that is measuring small for dates. The right and left middle cerebral arteries are branches of the anterior portion of the circle of Willis. Just like umbilical artery Doppler, the pulsatility index of the middle cerebral artery varies with gestational age but normally decreases as the pregnancy progresses toward term. When comparing the two Doppler signals, the middle cerebral artery should generate a higher resistance flow pattern than the umbilical artery.

Maternal uterine artery Doppler may be useful at anticipating the progression of IUGR in high-risk pregnancies. The portion of the main uterine artery as it crosses over the external iliac artery is the most common site utilized for this sample. The normal flow pattern is said to be low resistance. Therefore, an abnormal flow pattern will yield high resistance within the uterine artery when IUGR is present.

Large for Dates

The obese fetus is defined as a fetus that has an EFW of greater than the 90th

percentile. In the neonatal period, macrosomia is technically defined as the neonate that measures more than 4,500 g in nondiabetic mothers and 4,000 g in diabetic mothers. Mothers who are prone to have a macrosomic fetus are those who suffer from diabetes, whether pregestational or gestational. A macrosomic fetus is predisposed to shoulder dystocia secondary to fetal size, and have an increased risk of hypoglycemia and lifelong struggles with obesity. Therefore, they will most often be delivered by means of C section.



SOUND OFF

The obese fetus is defined as a fetus that has an EFW of greater than the 90th percentile.

MATERNAL COMPLICATIONS

Translabial Scanning

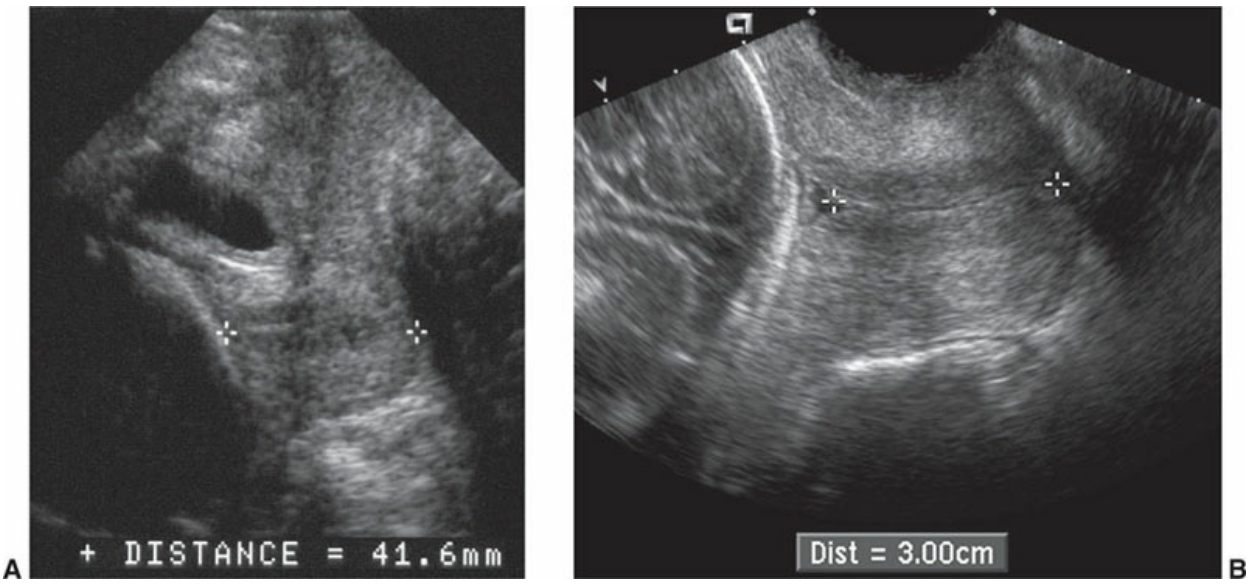
Occasionally, during the second half of pregnancy, the cervix can be difficult to image with a transabdominal approach. Translabial scanning, also referred to as tranperineal scanning, can offer a useful, noninvasive glimpse at the cervix. The sonographer can evaluate the length of the cervix and the proximity of the placenta to the internal os, and for signs of cervical incompetence using a translabial approach.

Translabial scanning should be performed with an empty maternal bladder. The covered transducer, whose size and frequency may vary with institution, is placed against the labia. The cervical length measurement can be obtained with a measurement from the internal os to the external os in the sagittal transducer position, or notch up (Fig. 32-15). The internal os should be observed several times throughout the examination when cervical incompetence is suspected, because the cervix is a dynamic structure whose shape and length can change over time. If the cervix is not seen because of shadowing from the pubic bone, the patient can slightly lift her hips off of the bed for an improved view of the external os. If translabial imaging does not provide optimal images, transvaginal imaging may be performed (see Fig. 32-15). It is again important to note that the cervix can undergo dynamic changes and thus cervical length may fluctuate slightly. Therefore, a judicious examination should be conducted and the shortest measurement of the cervix recorded. A cine loop recording may be helpful in this situation as well.

Cervical Incompetence

Cervical incompetence, or an incompetent cervix, is the painless dilation of

the cervix in the second or early third trimester. Funneling of the cervix is a result of the premature opening of the internal os and the subsequent bulging of the membranes into the dilated cervix. It is an early sign of an incompetent cervix. In cases of PROM, patients may have vaginal bleeding. Patients who are at risk for cervical incompetence include those with uterine malformations, previous pregnancy loss in the second trimester, and intrauterine exposure to diethylstilbestrol.



A B

Figure 32-15 Normal cervix. **A.** Translabial demonstrating the cervix (*between calipers*). **B.** Transvaginal cervix (*between calipers*).

SOUND OFF
Funneling of the cervix is a result of the premature opening of the internal os and the subsequent bulging of the membranes into the dilated cervix.

A sonographic assessment of the cervix can be performed with transvaginal or translabial imaging as mentioned earlier. There are two measurements of the cervix that can be obtained utilizing these techniques. The most often employed sonographic measurement for the assessment of cervical incompetence is the length measurement taken from the internal os to the external os (Fig. 32-16). The cervical length should measure at least 3 cm. Therefore, the shorter the cervical length, the more likely the patient will suffer from preterm delivery. An additional measurement can be taken of the width of the funnel. The funnel may take on a “U” or “V” shape (Fig. 32-17).

The treatment of an incompetent cervix is a cerclage. The two most commonly performed cerclage techniques are the Shirodkar and the McDonald. The suture of the cerclage may be seen during a follow-up

examination and will appear as echogenic structures within the cervix that may produce some posterior shadowing.

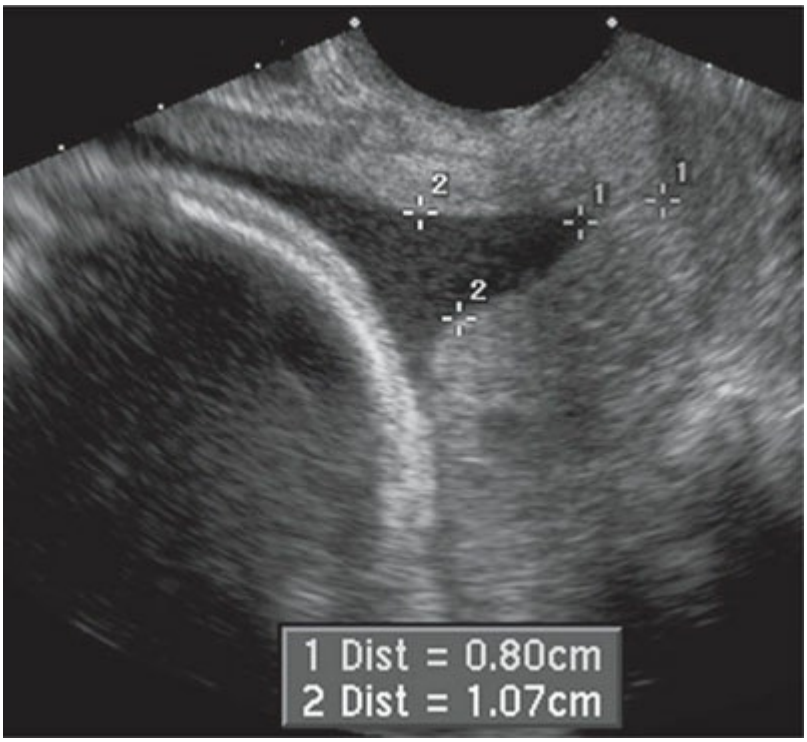


Figure 32-16 Short, funneled cervix. Transvaginal view of the cervix demonstrating that the cervix is 10.7 mm dilated (*#2 calipers*), with a residual cervix of only 8.0 mm (*#1 calipers*).

CLINICAL FINDINGS OF CERVICAL INCOMPETENCE

1. Painless dilation of the cervix
2. Premature rupture of membranes
3. Vaginal bleeding

SONOGRAPHIC FINDINGS OF CERVICAL INCOMPETENCE

1. Cervical length of less than 3 cm
2. Funneling of the cervix (can produce a “U” or “V” shape)

Fetal Hydrops and Rh Sensitization

Fetal hydrops, also referred to as hydrops fetalis, occurs when there is an accumulation of fluid within at least two fetal body cavities. Fluid can collect within the chest (pleural effusion), the abdomen (ascites), or around the heart (pericardial). Hydrops may also be defined as anasarca and fluid in at least one of the previously listed body cavities. Fetal hydrops can be categorized as either immune or nonimmune. Immune hydrops is caused by the absence of a detectable circulating fetal antibody against the red blood cells in the

mother. This results in incompatibility between the fetal and maternal red blood cells, a condition known as erythroblastosis fetalis (Fig. 32-18).

SOUND OFF
Immune hydrops is associated with erythroblastosis fetalis and Rh isoimmunization.

Maternal Rh sensitization, also referred to as Rh isoimmunization, occurs when the mother has Rh-negative blood and the fetus has Rh-positive blood. Cells from the Rh-positive fetus enter the mother's bloodstream during her first pregnancy. Although antibodies are created in the maternal circulation, this pregnancy will progress normally. With the mother's next pregnancy, the Rh-positive fetus is attacked as a result of the antibodies produced during the first pregnancy. These antibodies cross the placenta and begin to destroy the fetal red blood cells, resulting in fetal anemia, enlargement of the fetal liver and spleen, and the accumulation of fluid within the fetal body cavities.

The prevention of immune hydrops caused by Rh sensitization is the administration of RhoGAM, also referred to as Rh immune globulin, at approximately 28 weeks' gestation. Treatment for fetal hydrops may be conducted via intrauterine transfusion of donor red blood cells to treat the anemic fetus. This is typically performed under sonographic guidance. It is often difficult to determine the cause of fetal hydrops by sonographic findings. Immune and nonimmune hydrops may lead to the accumulation of fluid within the abdomen, chest, scrotum, and skin. Table 32-11 provides the causes of nonimmune hydrops.

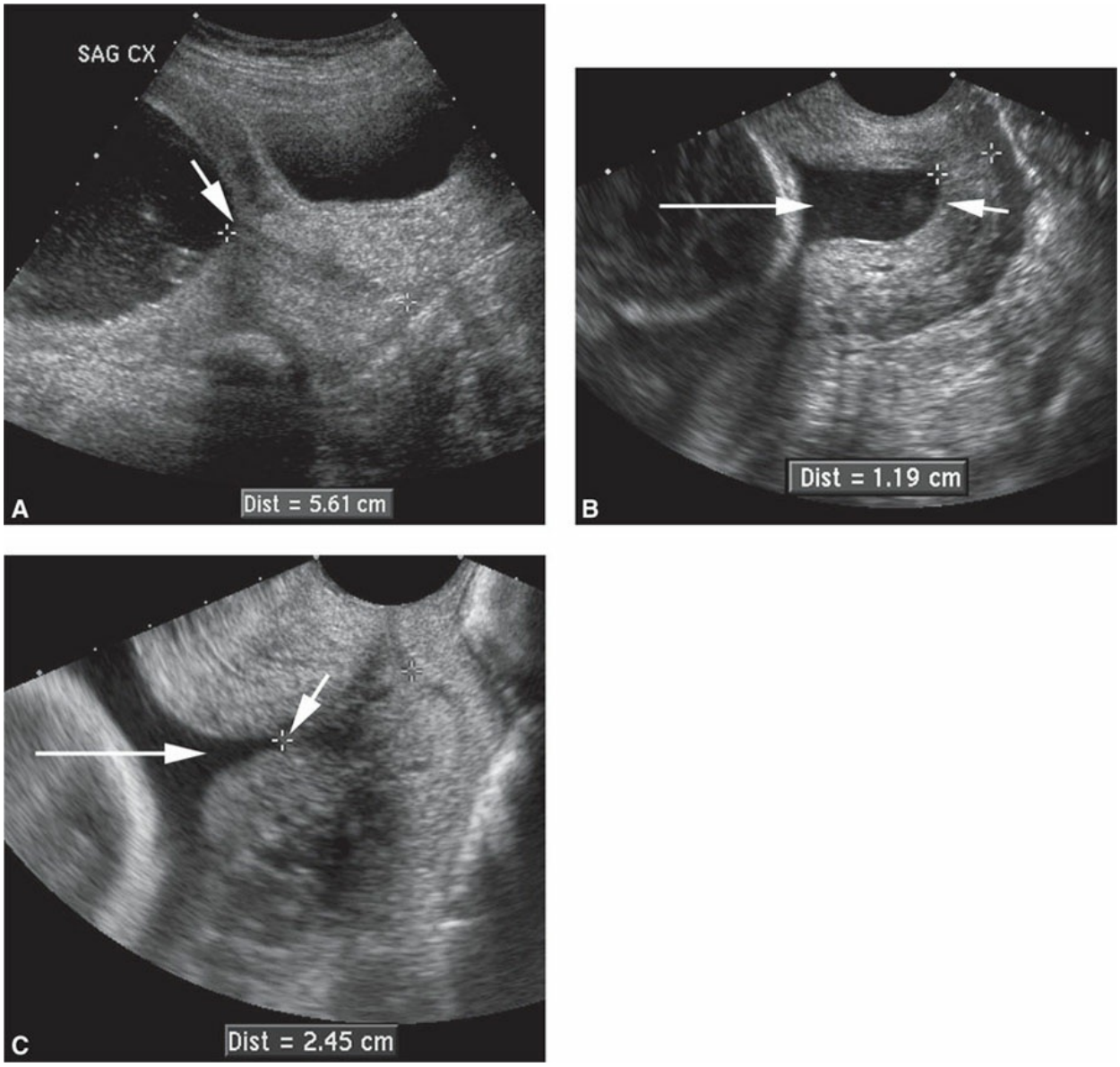


Figure 32-17 Normal cervix and incompetent cervix. **A.** Transabdominal measurement (*calipers*) when the internal os (*arrow*) is closed (i.e., no funneling). **B.** Transvaginal measurement (*calipers*) when the internal os (*long arrow*) is open and there is U-shaped funneling (*short arrow*). **C.** Transvaginal measurement (*calipers*) when the internal os (*long arrow*) is open and there is V-shaped funneling (*short arrow*).

Maternal mirror syndrome is a rare disorder in which the mother suffers from edema and fluid buildup similar to her hydropic fetus. The reason for this syndrome is unknown.

SONOGRAPHIC FINDINGS OF FETAL HYDROPS

1. Fluid accumulation within at least two fetal body cavities (pleural effusion, ascites, skin edema, pericardial effusion)
2. Fetal hepatosplenomegaly
3. Polyhydramnios

4. Thickened placenta

Preeclampsia and Eclampsia

Preeclampsia is defined as the presence of pregnancy-induced hypertension accompanied by proteinuria. The mother may also suffer from edema in the hands, face, and legs. Uncontrolled preeclampsia leads to eclampsia, which is potentially fatal. Patients with eclampsia will have headaches and often suffer from convulsions. Those with an increased risk of preeclampsia include advanced maternal age, diabetic patients, and those who have gestational trophoblastic disease. The sonographic findings may include oligohydramnios, IUGR, gestational trophoblastic disease, placental abruption, or an elevated S/D ratio.

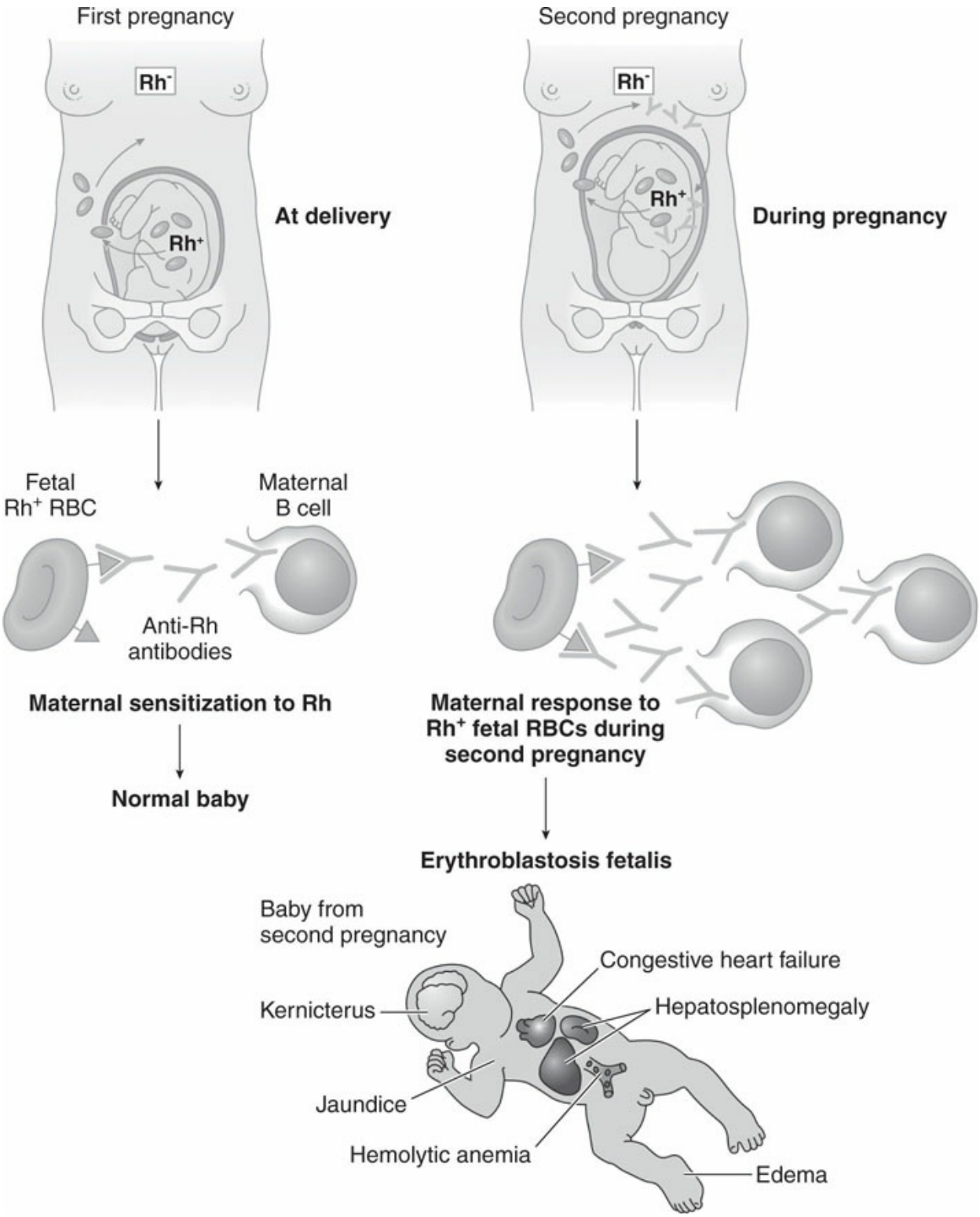


Figure 32-18 Erythroblastosis fetalis. Erythroblastosis fetalis is caused by maternal fetal Rh incompatibility. Sensitization of the Rh^- mother with Rh^+ RBCs in the first pregnancy leads to the formation of anti-Rh antibodies. These antibodies cross the placenta and damage the Rh^+ fetus in subsequent pregnancies. RBCs, red blood cells.

CLINICAL FINDINGS OF PREECLAMPSIA

1. Maternal hypertension
2. Maternal edema

3. Maternal proteinuria

CLINICAL FINDINGS OF ECLAMPSIA

1. Long-standing, uncontrolled preeclampsia
2. Headaches
3. Seizures

SONOGRAPHIC FINDINGS OF PREECLAMPSIA AND ECLAMPSIA

1. Oligohydramnios
2. IUGR
3. Gestational trophoblastic disease
4. Placental abruption
5. Elevated S/D ratio

Maternal Diabetes

Maternal diabetes can be described as either pregestational diabetes or gestational diabetes. With pregestational diabetes, the mother already has a history of diabetes. Gestational diabetes, which is the most common type of diabetes during pregnancy, is pregnancy induced. Women are screened for diabetes at the end of the second trimester, around 26 weeks' gestation. The major risk for the fetus of a mother with gestational diabetes is macrosomia. Sonographically, the placenta may appear enlarged (placentomegaly), measuring greater than 4 cm thick. There may also be polyhydramnios, and the AC typically measures significantly larger than the other measurements. Pregnancy-induced diabetes resolves shortly after birth.

TABLE 32-11 Causes of nonimmune hydrops

Chorioangioma
Cystic adenomatoid malformation
Diaphragmatic hernia
Fetal (nonimmune) anemia
Fetal infections
Idiopathic
Structural anomalies of the cardiac and lymphatic systems
Trisomy 13
Trisomy 18
Trisomy 21
Turner syndrome

Mothers with pregestational diabetes have a higher risk of miscarriage and toxemia, and the fetus has an increased risk of congenital anomalies, hypoglycemia, respiratory distress, perinatal mortality, and IUGR. The congenital anomalies most often encountered with pregestational diabetes include cardiac defects, neural tube defects, caudal regression syndrome, sirenomelia, and renal anomalies.



SOUND OFF

Mothers with pregestational diabetes have a higher risk of miscarriage and **toxemia**, and the fetus has an increased risk of congenital anomalies, hypoglycemia, respiratory distress, perinatal mortality, and IUGR.

Bladder Flap Hematoma

A bladder flap hematoma may result from a C section. This mass can appear anechoic, although it most likely will appear as a complex mass greater than 2 cm. It will be located adjacent to the scar between the lower uterine segment and the posterior bladder wall.

CLINICAL FINDINGS OF BLADDER FLAP HEMATOMA

1. Recent C section

SONOGRAPHIC FINDINGS OF BLADDER FLAP HEMATOMA

1. Anechoic or complex mass located between the lower uterine segment and the posterior bladder wall

Leiomyoma and Pregnancy

A leiomyoma, commonly referred to as a fibroid, is a common benign smooth muscle uterine tumor. They are often asymptomatic during pregnancy, although they may be associated with some pregnancy complications, such as an elevated pregnancy loss rate and increased risk of placental abruption. Occasionally, fibroids can grow during pregnancy secondary to estrogen stimulation, and may prevent vaginal delivery if located within the lower uterine segment. Fibroids should be differentiated from normal myometrial contractions. Myometrial contractions typically resolve within 15 to 30 minutes, whereas fibroids will not change in shape.

SONOGRAPHIC FINDINGS OF A LEIOMYOMA

1. Hypoechoic mass within the uterus
2. Posterior shadowing from mass
3. Degenerating fibroids may have calcifications or cystic components
4. Multiple fibroids appear as an enlarged, irregularly shaped, diffusely heterogeneous uterus

Maternal Hydronephrosis

Maternal hydronephrosis is common during pregnancy. Dilation of the renal collecting system is most often secondary to the large size of the uterus, with subsequent transient painless obstruction of the ureters. However, maternal hydronephrosis can also be caused by urinary calculi, in which case the patient will suffer from renal colic, flank pain, and hematuria.

Retained Products of Conception

The normal postpartum uterus returns to its nongravid size 6 to 8 weeks after delivery. Excessive and sustained postpartum vaginal bleeding may be the result of retained products of conception (RPOC). Most often, part of the placenta is left behind at the time of delivery. There are several predisposing factors, including adhesions, accessory lobes of the placenta, and placenta accreta.

Sonographically, RPOC may be seen as an echogenic intracavitary mass within the endometrium. Unfortunately, an echogenic blood clot can appear similar and may also be seen after pregnancy. No evidence of an endometrial fluid collection or mass within the endometrium, and an endometrial measurement of less than 10 mm, is less likely to be RPOC. Color Doppler can help prove that retained placental tissue is present, because flow will be noted within the retained placental segment. RPOC is typically treated with dilatation and curettage.

CLINICAL FINDINGS OF RETAINED PRODUCTS OF CONCEPTION

1. Postpartum vaginal bleeding

SONOGRAPHIC FINDINGS OF RETAINED PRODUCTS OF CONCEPTION

1. Echogenic intracavitary mass that may contain some calcifications
2. Color Doppler signals within the retained placental tissue

REVIEW QUESTIONS

1. Nonimmune hydrops is associated with all of the following except:
   a. RH isoimmunization
   b. Pleural effusion
   c. Turner syndrome
   d. Fetal infections

2. The maternal contribution to the placenta is the:
   a. Chorionic vera
   b. Decidua vera
   c. Decidua basalis
   d. Chorion frondosum

3. The placenta releases _____ to maintain the corpus luteum.
   a. human chorionic gonadotropin
   b. follicle-stimulating hormone
   c. luteinizing hormone
   d. gonadotropin-stimulating hormone

4. An anechoic mass is noted within the umbilical cord during a routine sonographic examination. What is the most likely diagnosis?
   a. Hemangioma
   b. Vasa previa
   c. Chorioangioma
   d. Allantoic cyst

5. With Rh isoimmunization, the maternal antibodies cross the placenta and destroy the fetal:
   a. Spleen
   b. Red blood cells
   c. Liver
   d. White blood cells

6. Mothers with pregestational diabetes, as opposed to gestational diabetes, have an increased risk of a fetus with:
   a. Neural tube defects
   b. Proteinuria
   c. TORCH
   d. Diethylstilbestrol

7. A succenturiate lobe of the placenta refers to a:
   a. Bilobed placental lobe
   b. Circumvallate placental lobe
   c. Accessory lobe

d. Circummarginate placental lobe

8. Pools of maternal blood noted within the placental substance are referred to as:
   a. Accessory lobes
   b. Decidual casts
   c. Chorioangiomas
   d. Maternal lakes

9. The fetal contribution of the placenta is the:
   a. Chorionic vera
   b. Decidua vera
   c. Decidua basalis
   d. Chorion frondosum

10. Which of the following would be least likely associated with immune hydrops?
    a. Fetal hepatomegaly
    b. Fetal splenomegaly
    c. Anasarca
    d. Leiomyoma

11. The placenta is considered too thick when it measures:
    a. >4 mm
    b. >4 cm
    c. >8 mm
    d. >3.5 cm

12. All of the following are associated with a thin placenta except:
    a. Preeclampsia
    b. IUGR
    c. Fetal hydrops
    d. Long-standing diabetes

13. What would be most likely confused for a uterine leiomyoma?
    a. Placental infarct
    b. Chorioangioma
    c. Myometrial contraction
    d. Placenta previa

14. When the placenta completely covers the internal os, it is referred to as:
    a. Low-lying previa
    b. Marginal previa

c. Partial previa
d. Total previa

15. One of the most common causes of painless vaginal bleeding in the second and third trimesters is:
    a. Spontaneous abortion
    b. Abruptio placentae
    c. Placenta previa
    d. Placenta accrete

16. All of the following are associated with a thick placenta except:
    a. Fetal infections
    b. Rh isoimmunization
    c. Placental insufficiency
    d. Multiple gestations

17. Placenta accrete denotes:
    a. The abnormal attachment of the placenta to the myometrium
    b. The premature separation of the placenta from the uterine wall
    c. The invasion of the placenta into the myometrium
    d. The condition of having the fetal vessels rest over the internal os

18. Doppler sonography reveals vascular structures coursing over the internal os of the cervix. This finding is indicative of:
    a. Vasa previa
    b. Placenta previa
    c. Placenta increta
    d. Abruptio placentae

19. All of the following are clinical features of placental abruption except:
    a. Vaginal bleeding
    b. Uterine tenderness
    c. Abdominal pain
    d. Funneling of the cervix

20. Penetration of the placenta beyond the uterine wall would be referred to as:
    a. Placenta accrete
    b. Placenta increta
    c. Placenta previa
    d. Placenta percreta

21. All of the following are associated with oligohydramnios except:

a. Bilateral renal agenesis
b. Infantile polycystic kidney disease
c. Premature rupture of membranes
d. Duodenal atresia

22. The most common placental tumor is the:
a. Choriocarcinoma
b. Maternal lake
c. Chorioangioma
d. Allantoic cyst

23. Pregnancy-induced maternal high blood pressure and excess protein in the urine after 20 weeks' gestation is termed:
a. Preeclampsia
b. Gestational diabetes
c. Eclampsia
d. Gestational trophoblastic disease

24. The normal umbilical cord has:
a. One vein and one artery
b. Two veins and two arteries
c. Two veins and one artery
d. Two arteries and one vein

25. Insertion of the umbilical cord at the edge of the placenta is referred to as:
a. Velamentous cord insertion
b. Partial cord insertion
c. Marginal cord insertion
d. Nuchal cord insertion

26. Increased S/D ratio is associated with all of the following except:
a. IUGR
b. Placental insufficiency
c. Allantoic cysts
d. Perinatal mortality

27. A velamentous cord insertion is associated with which of the following?
a. Placenta increta
b. Placental abruption
c. Vasa previa
d. Circumvallate placenta

28. The normal umbilical cord insertion point into the placenta is:
    a. Central
    b. Superior margin
    c. Inferior margin
    d. Lateral margin

29. Normally, the S/D ratio:
    a. Increases with advancing gestation
    b. Decreases with advancing gestation
    c. Reverses occasionally during a normal pregnancy
    d. Has an absent diastolic component

30. Fetal TORCH is frequently associated with:
    a. Maternal hypertension
    b. Twin–twin transfusion syndrome
    c. Intracranial calcifications
    d. Renal cystic disease

31. Evidence of polyhydramnios should warrant a careful investigation of the fetal:
    a. Genitourinary system
    b. Gastrointestinal system
    c. Extremities
    d. Cerebrovascular system

32. All of the following are associated with polyhydramnios except:
    a. Omphalocele
    b. Gastroschisis
    c. Esophageal atresia
    d. Bilateral multicystic dysplastic kidney disease

33. IUGR is evident when the EFW is:
    a. Above the 90th percentile
    b. Below the 90th percentile
    c. Above the 10th percentile
    d. Below the 10th percentile

34. The cervix should measure at least _____ in length.
    a. 4 cm
    b. 5 cm
    c. 3 cm
    d. 8 mm

35. The abnormal insertion of the umbilical cord into the membranes beyond the placental edge is termed:
    a. Placenta previa
    b. Placental abruption
    c. Marginal insertion
    d. Velamentous insertion

36. The measurement that should be carefully scrutinized in cases of IUGR is the:
    a. AC
    b. Femur length
    c. Biparietal diameter
    d. Head circumference

37. Doppler assessment of the middle cerebral artery:
    a. Helps to determine whether fetal anorexia is occurring
    b. Is valuable in diagnosing the extent of ventriculomegaly
    c. Can evaluate the fetus for hypoxia
    d. Is important to determine whether TORCH complications are present

38. Mothers with gestational diabetes run the risk of having fetuses that are considered:
    a. Nutritionally deficient
    b. Acromegalic
    c. Microsomic
    d. Macrosomic

39. Which of the following is described as the situation in which the placental edge extends into the lower uterine segment but ends more than 2 cm away from the internal os?
    a. Low-lying placenta
    b. Marginal previa
    c. Partial previa
    d. Total previa

40. Which of the following would increase the likelihood of developing placenta previa?
    a. Vaginal bleeding
    b. Previous cesarean section
    c. Corpus albicans
    d. Chorioangioma

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Answers to Review Questions

Chapter 1

1. A
2. B
3. D
4. B
5. C
6. C
7. B
8. D
9. A
10. D
11. C
12. A
13. B
14. D
15. C
16. B
17. A
18. C

19. D
20. B
21. A
22. D
23. C
24. B
25. A
26. B
27. A
28. C
29. D
30. D
31. B
32. D
33. A
34. C
35. A
36. B
37. D
38. B
39. A
40. C

Chapter 2

1. D

2. A
3. B
4. B
5. C
6. A
7. B
8. A
9. B
10. D
11. B
12. A
13. C
14. D
15. D
16. B
17. A
18. B
19. C
20. C
21. D
22. C
23. D
24. A
25. B
26. A

27. D
28. D
29. C
30. D
31. D
32. B
33. A
34. D
35. C
36. A
37. D
38. A
39. A
40. C

Chapter 3

1. C
2. C
3. B
4. D
5. C
6. A
7. A
8. C
9. B

10. D
11. A
12. D
13. C
14. A
15. C
16. A
17. B
18. B
19. A
20. A
21. B
22. B
23. D
24. A
25. C
26. D
27. B
28. C
29. A
30. D
31. C
32. C
33. A
34. C

35. A
36. A
37. C
38. B
39. A
40. C

Chapter 4

1. D
2. C
3. C
4. A
5. B
6. D
7. B
8. C
9. C
10. A
11. D
12. B
13. A
14. A
15. D
16. C
17. C

18. A
19. B
20. A
21. B
22. D
23. C
24. C
25. B
26. A
27. D
28. C
29. D
30. A
31. B
32. A
33. C
34. B
35. C
36. D
37. B
38. D
39. A
40. D

Chapter 5

1. A
2. B
3. A
4. B
5. B
6. D
7. C
8. D
9. A
10. C
11. A
12. D
13. B
14. C
15. B
16. A
17. D
18. B
19. C
20. A
21. C
22. C
23. B
24. D
25. D

26. A
27. D
28. C
29. A
30. C
31. A
32. C
33. C
34. D
35. B
36. B
37. A
38. D
39. C
40. A

Chapter 6

1. D
2. C
3. B
4. A
5. D
6. A
7. A
8. B

9. B
10. B
11. C
12. A
13. D
14. A
15. A
16. B
17. B
18. A
19. D
20. D
21. C
22. D
23. A
24. A
25. C
26. B
27. D
28. C
29. C
30. A
31. B
32. C
33. B

34. C
35. D
36. A
37. A
38. C
39. B
40. C

Chapter 7

1. A
2. A
3. B
4. B
5. C
6. D
7. C
8. D
9. C
10. B
11. D
12. B
13. D
14. C
15. B
16. C

17. D
18. A
19. C
20. C
21. D
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27. A
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29. D
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31. A
32. B
33. C
34. A
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37. D
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Chapter 8

1. A
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24. C
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26. A
27. D
28. C
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31. B
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34. C
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36. B
37. A
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Chapter 9

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27. D
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Chapter 10

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36. A
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Chapter 11

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Chapter 12

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Chapter 13

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15. D
16. C

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Chapter 14

1. A
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Chapter 15

1. A
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Chapter 16

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Chapter 17

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Chapter 18

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Chapter 19

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Chapter 20

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Chapter 21

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Chapter 22

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Chapter 23

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Chapter 24

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Chapter 25

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Chapter 26

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Chapter 27

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Chapter 28

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Chapter 29

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Chapter 30

1. A
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Chapter 31

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Chapter 32

1. A
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36. A
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Glossary

abdominal aorta—major abdominal artery responsible for supplying the abdomen, pelvis, and lower extremities with oxygenated blood

abdominal aortic aneurysm—enlargement of the diameter of the abdominal aorta to greater than 3 cm

abdominal circumference—fetal biometric measurement made of the abdomen in the second and third trimesters; used in conjunction with other measurements to date the pregnancy and size the fetus

abnormal uterine bleeding—a change in menstrual bleeding patterns caused by either endocrine abnormalities or lesions within the uterus

abortion—the complete expulsion or partial expulsion of the conceptus

abruptio placentae—placental abruption

acalculous cholecystitis—the inflammation of the gallbladder without associated gallstones

acardiac twin—an abnormally developed twin that has an absent upper body and no heart

accessory spleen—a small, round island of splenic tissue often located near the splenic hilum or near the tail of the pancreas also referred to as a splenule, a splenunculus, or a supernumerary spleen

acetabulum—the bowl-shaped surface of the pelvis where the head of femur normally rests

Achilles tendon—tendon located along the posterior ankle that connects the calf muscle to the posterior surface of the heel

achondrogenesis—rare, lethal condition resulting in abnormal development of the bones and cartilage

achondroplasia—a disorder that results in abnormal bone growth and dwarfism

acinar cells—the cells of the pancreas that carry out the exocrine function

and therefore produce amylase, lipase, sodium bicarbonate, and other digestive enzymes

acoustic shadowing—an area where sound has been prohibited to propagate resulting in a dark shadow projecting posterior to a structure

acquired renal cystic disease—a cystic disease of the kidney that is often the result of chronic hemodialysis

acrania—the absence of the cranial vault above the bony orbits

acute appendicitis—inflammation of the appendix

acute cholecystitis—the sudden onset of gallbladder inflammation

acute pancreatitis—inflammation of the pancreas secondary to the leakage of pancreatic enzymes from the acinar cells into the parenchyma of the organ

acute pyelonephritis—an inflammation of the kidney or kidneys

acute renal failure—a sudden decrease in renal function

acute respiratory distress syndrome—the buildup of fluid within the air sacs or alveoli within the lungs

acute tubular necrosis—damage to the tubule cells within the kidneys that results in renal failure

Addison disease—an endocrine disorder that results from hypofunction of the adrenal cortex

adenocarcinoma—cancer that originates in glandular tissue

adenomyoma—a focal mass of adenomyosis

adenomyomatosis—benign hyperplasia of the gallbladder wall

adenomyosis—the benign invasion of endometrial tissue into the myometrium of the uterus

adhesions—irregular bands of tissue

adnexal ring sign—the sonographic sign that describes the appearance of an ectopic pregnancy within the fallopian tube

adnexa—the area located posterior to the broad ligaments and adjacent to the uterus, which contains the ovaries and fallopian tubes

adrenal adenoma—benign solid mass located within the adrenal glands

adrenal cysts—benign simple cysts located within the adrenal glands

adrenal rest—mass of ectopic adrenal tissue within the testicle; are associated with congenital adrenal hyperplasia or Cushing syndrome

adrenocorticotropic hormone—hormone secreted by the anterior pituitary gland, which controls the release of hormones by the adrenal glands

advanced maternal age—a maternal age of 35 years or older

agenesis of the corpus callosum—the congenital absence of corpus callosum that may be partial or complete

agenesis—failure of an organ or structure to grow during embryologic development

allantoic cyst—cyst found within the umbilical cord

allantois—a membrane that is present during early embryonic development that contributes to urinary bladder formation and development

alobar holoprosencephaly—the most severe form of holoprosencephaly

alpha-Fetoprotein—a protein produced by the fetal yolk sac, fetal gastrointestinal tract, and the fetal liver; may also be produced by some malignant tumors

ambiguous genitalia—birth defect in which the external genitalia appear neither recognizably male nor female

amebic hepatic abscess—an abscess that develops from a parasite that grows in the colon and invades the liver via the portal vein

amenorrhea—absence of menstruation

amniocentesis—a surgical procedure in which amniotic fluid is extracted for genetic testing or removed when there is an accumulation of an excessive amount of fluid around the fetus

amnionicity—relates to the number of amnions in a multiple gestation

amnionitis—inflammation of the amniotic sac secondary to infection

amnion—the inner sac that contains the embryo and amniotic fluid; echogenic curvilinear structure that may be seen during the first trimester within the gestational sac

amniotic band syndrome—group of abnormalities associated with the entrapment of fetal parts in the amnion, often resulting in fetal amputations or clefting

amniotic cavity—the cavity that contains simple-appearing amniotic fluid and the developing embryo

amniotic fluid index—the amount of amniotic fluid surrounding the fetus; the sum of four quadrant measurements of amniotic fluid

amniotic sac—fluid-filled space, created by the amnion, surrounding the developing embryo or fetus

ampulla (fallopian tube)—the longest and most tortuous segment of the fallopian tube; area of the tube in which fertilization takes place and a common location for ectopic pregnancies to implant

ampulla of Vater—the merging point of the pancreatic duct and common bile duct just before the sphincter of Oddi; also referred to as the hepatopancreatic ampulla

ampulla—the longest and most tortuous segment of the fallopian tube

amyloidosis—the accumulation of the abnormal protein amyloid in the kidneys and other organs that can lead to organ damage, as well as renal failure

anasarca—diffuse edema

anastomoses—vascular connections

anastomosis—the surgical connection between two structures

androblastoma—see key term Sertoli-Leydig cell tumor

androgen—a hormone, such as testosterone, that is responsible for male characteristics

anembryonic gestation—an abnormal pregnancy in which there is no evidence of a fetal pole or yolk sac within the gestational sac; also referred to as a blighted ovum

anemia—a condition in which the red blood cell count or the hemoglobin is decreased

anencephaly—a neural tube defect that is described as the absence of the cranium and cerebral hemispheres

aneuploidy—a condition of having an abnormal number of chromosomes

aneurysm—any dilation of a blood vessel, whether focal or diffuse

angiomyolipoma—a common benign renal tumor that consists of a network of blood vessels, muscle, and fat

angiosarcoma—a rare malignant tumor of the spleen that is derived from blood vessels

anhydramnios—no amniotic fluid

annular pancreas—congenital anomaly of the pancreas that results in the maldevelopment of the pancreas in which the most ventral part of the

pancreas encases the duodenum and may consequently lead to duodenal obstruction

anomaly—a structural feature that differs from the norm

anophthalmia—absence of the eye(s)

anorectal atresia—congenital maldevelopment of the rectum and absence of the anal opening

anovulation—lack of ovulation

anovulatory—absence of ovulation

anoxia—lack of oxygen supply to the body, organ, or tissue

anteflexion—the uterine body tilts forward and comes in contact with the cervix, forming an acute angle between the body and the cervix

anterior cul-de-sac—peritoneal outpouching located between the bladder and the uterus; also referred to as the vesicouterine pouch

anterior pituitary gland—the anterior segment of the pituitary gland, which is responsible for releasing follicle-stimulating hormone and luteinizing hormone during the menstrual cycle

anteversion—the typical version of the uterus where the uterine body tilts forward, forming a 90-degree angle with the cervix

anticoagulation therapy—drug therapy in which anticoagulant medications are given to a patient to slow the rate at which the patient's blood clots

aortic atresia—abnormality in which there is a small or absent opening between the left ventricle and aorta

aortic stenosis—abnormal narrowing of the aortic valve

Apert syndrome—genetic disorder that includes craniosynostosis, midline facial hypoplasia, and syndactyly

aperture(s)—an opening in a structure

appendicolith—a dense, calcified stone within the appendix

appendicular skeleton—includes the bones of the upper extremities, lower extremities, and pelvic girdle

appendix epididymis—the testicular appendage located at the head of the epididymis

appendix testis—the testicular appendage located between the head of the epididymis and the superior pole of the testis

appendix vas—the testicular appendage located between the body and tail of the epididymis

aqueduct of Sylvius—see key term cerebral aqueduct

aqueductal stenosis—the abnormal narrowing of the cerebral aqueduct

arachnoid cyst(s)—benign cysts within the brain that do not communicate with the ventricular system

arachnoid granulations—nodular structures located along the falx cerebri that reabsorb cerebrospinal fluid into the venous system

arachnoid membrane—the middle layer of the meninges

arachnoid villi—see key term arachnoid granulations

arcuate arteries—peripheral arteries of the uterus that lie at the edge of the myometrium

Arnold–Chiari II malformation—a group of cranial abnormalities associated with spina bifida

arteriovenous fistula—an abnormal passageway between an artery and a vein

arthrogryposis—a congenital disorder associated with severe joint contractures

ascariasis—an infection of the small intestine that is caused by *Ascaris lumbricoides*, a parasitic roundworm

ascites—a collection of abdominal fluid within the peritoneal cavity

Asherman syndrome—a syndrome characterized by endometrial adhesions that typically occur as a result of scar formation after some types of uterine surgery

asplenia—the congenital absence of the spleen

assisted reproductive therapy—techniques used to treat infertility

atherosclerosis—a disease characterized by the accumulation of plaque within the walls of arteries

atresia (ovarian follicle)—degeneration of a follicle

atrioventricular defect—abnormal development of the central portion of the heart; also referred to as endocardial cushion defect

atrophy—wasting away of a part of the body

autoimmune disorders—disorders in which the body’s immune system

attacks and destroys health tissues and/or organs

autosomal dominant disorder—a way in which a disorder or trait can be inherited by a fetus; at least one of the parents has to be the carrier of the gene for the disease

autosomal dominant polycystic kidney disease—an inherited disease that results in the development of renal, liver, and pancreatic cysts late in life; also referred to as adult polycystic kidney disease

autosomal dominant—a way in which a disorder or trait can be inherited by a fetus; at least one of the parents has to be the carrier of the gene for the disease

autosomal recessive polycystic kidney disease—an inherited renal disease that results in bilateral enlargement of the fetal kidneys and microscopic renal cysts; also referred to as infantile polycystic kidney disease

autosomal recessive—a way in which a disorder or trait can be inherited by a fetus; both parents must be carriers of the gene for the disease

autosplenectomy—the gradual fibrosis and dysfunction of the spleen secondary to a disease

axial skeleton—includes the bones of cranium and spine

azotemia—an excess of urea or other nitrogenous compounds in the blood

bacterial endocarditis—an infection of the surface of the heart that can spread to other organs

bacteriuria—the presence of bacteria in the urine

Baker cyst—a synovial cyst located within the popliteal fossa; may also be referred to as a popliteal cyst

banana sign—the sonographic sign of the cerebellum being curved in the presence of spina bifida

bare area—the region of the liver not covered by peritoneum

Barlow test—clinical test for developmental hip dysplasia that is used to evaluate the hip for dislocation

basal ganglia—a group of nuclei within the brain that function in several ways, including information processing and emotional response

basal layer (endometrium)—the nonfunctional outer layer of the endometrium

bat-wing sign—the sonographic appearance of a fetal unilateral pleural

effusion

Beckwith–Weidemann syndrome—a growth disorder syndrome synonymous with enlargement of several organs including the skull, tongue, and liver

"bell-clapper" deformity—the condition in which the patient lacks the normal posterior fixation of the testis and epididymis to the scrotal wall

benign prostatic hypertrophy—the benign enlargement of the prostate gland

bezoars—masses of various ingested materials that may cause an intestinal obstruction

bicornuate uterus—a common uterine anomaly in which the endometrium divides into two horns; also referred to as bicornis unicollis

bilateral renal agenesis—the failure of both kidneys to develop in the fetus

bilateral salpingo-oophorectomy—the surgical removal of both ovaries and both fallopian tubes

biliary atresia—a congenital disease described as the narrowing or obliteration of all or a portion of the biliary tree

biliary colic—pain located in the right upper quadrant in the area of the gallbladder

biliary stasis—a condition in which bile is stagnant and allowed to develop into sludge or stones

bilirubin—a yellowish pigment found in bile that is produced by the breakdown of old red blood cells by the liver

biliverdin—a green pigment found in the bile

bilobed placenta—placenta that consists of two separate discs of equal size

binocular diameter—measurement from the lateral margin of one orbit to the lateral margin of the other orbit

biophysical profile—method of fetal monitoring with sonography to produce a numerical scoring system that predicts fetal well-being

biparietal diameter—a fetal head measurement obtained in the transverse plane at the level of the third ventricle and thalamus; this measurement is obtained from the outer table of the proximal parietal bone to inner table of the distal parietal bone

bladder diverticulum—an outpouching of the urinary bladder wall

bladder exstrophy—a birth defect in which the bladder is located outside of the abdomen

blastocyst—the stage of the conceptus that implants within the decidualized endometrium

blighted ovum—see key term anembryonic gestation

blood urea nitrogen—a measure of the amount of nitrogen in the blood in the form of urea

"blue dot" sign—the appearance of a torsed testicular appendage that can be observed as a blue dot just under the skin surface

blunt trauma—non-penetrating injury to the body

Bochdalek hernia—the herniation of abdominal contents into the chest cavity because of an opening in the left posterolateral portion of the diaphragm

boggy—limp

brachycephaly—round skull shape

bradycardia—a low heart rate

brain stem—the lower part of the brain composed of the pons, midbrain, and medulla oblongata

branchial cleft cysts—benign congenital neck cysts found most often near the angle of the mandible

Brenner tumors—small benign ovarian tumors

broad ligament—pelvic ligament that extends from the lateral aspect of the uterus to the side walls of the pelvis

Buck fascia—deep layer of fascia that covers the corpus cavernosa and corpus spongiosum of the penis

Budd–Chiari syndrome—a syndrome described as the occlusion of the hepatic veins, with possible coexisting occlusion of the inferior vena cava

buffalo hump—excessive amount of fat on the back between the shoulders

bulbourethral gland—gland that secretes pre-ejaculate fluid that lubricates the penile urethra prior to ejaculation; also referred to as the Cowper gland

CA 125—a protein that may be increased in the blood of women with ovarian cancer and other abnormalities

CA-125—a tumor marker in the blood that can indicate certain types of

cancer, such as cancer of the ovary, endometrium, breast, gastrointestinal tract, and lungs; stands for cancer antigen-125

caliectasis—dilation of the calices

caput medusa—recognizable dilation of the superficial veins of the abdomen

cardinal ligament—pelvic ligament that extends from the lateral surface of the cervix to the lateral fornix of vagina and houses the uterine vasculature

Caroli disease—a congenital disorder characterized by segmental dilatation of the intrahepatic ducts

caudal regression syndrome—syndrome associated with the absence of the sacrum and coccyx; also referred to as sacral agenesis

cavernous hemangioma—the most common benign liver tumor

cavum septum pellucidum—a normal midline brain structure identified in the anterior portion of the brain between the frontal horns of the lateral ventricles

cebocephaly—close-set eyes (hypotelorism) and a nose with a single nostril

cellulitis—inflammation and infection of the skin and subcutaneous tissues

central dot sign—the presence of echogenic dots in the nondependent part of the dilated duct representing small fibrovascular bundles; seen with Caroli disease

cephalic index—the ratio used for assessing fetal head shape

cephalocele(s)—protrusions of intracranial contents through a defect in the skull

cerclage—the placement of sutures within the cervix to keep it closed

cerebellar vermis—the portion of the cerebellum, located within the midline of the brain, that connects its two hemispheres

cerebellum—the portion of the brain located in the inferior posterior part of the skull that is responsible for motor output, sensory perception, and equilibrium

cerebral aqueduct—the duct that connects the third ventricle of the brain to the fourth ventricle; also referred to as the aqueduct of Sylvius

cerebral peduncles—paired structures located anterior to the cerebral aqueduct

cerebrospinal fluid—the protective and nourishing fluid of the brain and

spinal cord produced by the cells of the choroid plexus

cervical incompetence—the painless dilation of the cervix in the second or early third trimester

cervical lymphadenopathy—enlargement of the cervical lymph nodes

cervicitis—inflammation of the cervix

cervix sign—a sonographic sign associated with pyloric stenosis in the long axis

cervix—the rigid region of the uterus located between the isthmus and the vagina

cesarean section—form of childbirth in which a surgical incision is made through the maternal abdomen to deliver the fetus

champagne sign—the effect of dirty shadowing, reverberation, or ring down artifact caused by gas or gas bubbles produced by bacteria within the nondepedent gallbladder wall

Charcot triad—fever, right upper quadrant pain, and jaundice associated with cholangitis

chlamydia—a sexually transmitted disease that can lead to an infection of the genital tract in both sexes

chocolate cysts—another name for endometriomas

cholangiocarcinoma—primary bile duct cancer

cholangiography—a radiographic procedure in which contrast is injected into the bile ducts to assess for the presence of disease

cholangitis—inflammation of the bile ducts

cholecystectomy—the surgical removal of the gallbladder

cholecystitis—inflammation of the gallbladder

cholecystokinin—the hormone produced by the duodenum that causes the gallbladder to contract

choledochal cyst—the cystic dilatation of the common bile duct

choledocholithiasis—the presence of a gallstone or gallstones within the biliary tree

cholelithiasis—gallstone(s)

cholesterolosis—a condition that results from the disturbance in cholesterol metabolism and accumulation of cholesterol typically within a focal region

of the gallbladder wall; may be diffuse and referred to as a strawberry gallbladder

chordae tendineae—tendons within the heart that attach the tricuspid valve in the right ventricle and the mitral valve in the left ventricle to their respective papillary muscle

chorioangioma—a benign placental tumor

choriocarcinoma—the most malignant form of gestational trophoblastic disease with possible metastasis to the liver, lungs, and vagina

chorion frondosum—the part of the chorion, covered by chorionic villi, that is the fetal contribution of the placenta

chorionic cavity—the space between the chorionic sac and the amniotic sac that contains the secondary yolk sac; also referred to as the extraembryonic coelom

chorionic sac—the gestational sac; also see key term chorion

chorionic villi sampling—prenatal test used that obtains placental tissue for chromosomal analysis

chorionic villi—fingerlike projections of gestational tissue that attach to the decidualized endometrium and allow transfer of nutrients from the mother to the fetus

chorionicity—relates to the number of chorions and the type of placentation in a multiple gestation

chorion—the outer membrane of a gestation that surrounds the amnion and developing embryo

choroid plexus cysts—cysts located within the lateral ventricles of the brain, specifically in the choroid plexus

choroid plexus—specialized cells within the ventricular system responsible for cerebrospinal fluid production

chromaffin cells—the cells in the adrenal medulla that secrete epinephrine and norepinephrine

chromosomal abnormality—an error in either the number or structure of chromosomes

chromosomes—the cellular structures that contain genes

chronic cholecystitis—cholecystitis that results from the intermittent obstruction of the cystic duct by gallstones

chronic pancreatitis—the recurring destruction of the pancreatic tissue that results in atrophy, fibrosis with scarring, and the development of calcification within the gland

chronic pyelonephritis—chronic inflammation of the kidney or kidneys

chronic renal failure—the gradual decrease in renal function over time

chyme—partially digested food from the stomach

cilia—hairlike projections within the fallopian tube

cinnamon bun sign—a sonographic sign associated with the appearance of intussusception

circumvallate placenta—an abnormally shaped placenta caused by the membranes inserting inward from the edge of the placenta, producing a curled-up placental shape

cirrhosis—condition defined as hepatocyte death, fibrosis and necrosis of the liver, and the subsequent development of regenerating nodules

cisterna magna—the largest cistern in the skull; located in the posterior portion of the skull

cistern—a prominent space within the skull that contains cerebrospinal fluid; a cistern is created by the separation of the arachnoid membrane and pia mater

cleavage—the division of a cell

cleft lip—the abnormal division in the lip

cleft palate—the abnormal development of the soft and/or hard palate of the mouth where there is a division in the palate

climacteric—another name for menopause

clinical findings—the information gathered by obtaining a clinical history

clinical history—a patient's signs and symptoms, pertinent illnesses, past surgeries, laboratory findings, and the results of other diagnostic testing

clinodactyly—the bending of the fifth finger toward the fourth finger

clitoromegaly—enlargement of the clitoris

cloacal exstrophy—birth defect consisting of omphalocele, bladder exstrophy, imperforate anus, and spina bifida; also referred to as OEIS complex

cloaca—the embryonic structure that develops into the normal rectum and

urogenital sinus

Clomid or clomiphene citrate—fertility drug used to treat anovulation

closed spina bifida—see key term spina bifida occulta

cloverleaf skull—the abnormal shape of the cranium caused by premature fusion of the sutures in which there is frontal bossing and a cloverleaf shape to the skull

clubfoot—a malformation of the bones of the foot in which the foot is most often inverted and rotated medially, and the metatarsals lie in the same plane as the tibia and fibula

coagulopathies—disorders that result from the body's inability to coagulate or form blood clots also referred to as bleeding disorders

coarctation of the aorta—the narrowing of the aortic arch

coccygeus—pelvic muscle located posteriorly within the pelvis that helps support the sacrum

cold nodules—the hypofunctioning thyroid nodules seen on a nuclear medicine study that have malignant potential

colloid—the fluid produced by the thyroid that contains thyroid hormones

colpocephaly—the abnormal lateral ventricle shape in which there is a small frontal horn and enlarged occipital horn

columns of Bertin—an extension of the renal cortex located between the renal pyramids

comet tail artifact—a form of reverberation artifact in which there is a band of echoes that taper distal to a strong reflector

common iliac arteries—abdominal aortic bifurcation vessels

communicating hydrocephalus—the obstruction of cerebrospinal fluid from a source outside the ventricular system

compensatory hypertrophy—enlargement of an organ secondary to an increased workload; often seen when part of an organ has been destroyed or when there is absence or decreased function of paired organs

compression sonography—operator-applied transducer pressure on a structure during a sonographic examination

computed tomography—a diagnostic modality that utilizes ionizing radiation to produce images of the human body in cross-sectional and reconstructed 3D formats

conception—the combination of a female ovum with a male sperm to produce a zygote; also referred to as fertilization

congenital adrenal hyperplasia—a group of disorders in which there is a deficiency of cortisol production by the adrenal glands, although other hormones produced by the adrenal may be deficient as well

congenital cystic adenomatoid malformation—a mass consisting of abnormal bronchial and lung tissue that develops within the fetal chest

congenital hydronephrosis—the dilation of the renal collecting system at birth

congenital malformations—physical defects that are present in a person at birth; may also be referred to as congenital anomalies

conjoined twins—monoamniotic, monochorionic twins that are attached at the head, thorax, abdomen, or lower body

Conn syndrome—a syndrome caused by a functioning tumor within the adrenal cortex that produces excessive amounts of aldosterone

cordocentesis—prenatal test that obtains fetal blood for chromosomal analysis

cornua (uterus)—areas just inferior to the fundus of the uterus where the fallopian tubes are attached bilaterally

coronary heart disease—the buildup of plaque within the arteries that supply the myocardium of the heart

corpus (uterus)—the uterine body

corpus albicans—the remaining structure of the corpus luteum after its deterioration

corpus callosum—a thick band of white matter that provides communication between right and left halves of the brain

corpus cavernosa—paired erectile tissues of the penis

corpus luteum cyst—physiologic ovarian cyst that develops after ovulation has occurred

corpus luteum of pregnancy—the corpus luteum that is maintained during early pregnancy for the purpose of producing estrogen and primarily progesterone

corpus luteum—temporary endocrine gland that results from the rupture of the Graafian follicle after ovulation

corpus spongiosum—component of erectile tissue of the penis that contains the urethra

corrected-BPD—represents the biparietal diameter of a standard-shaped fetal head with the same cross-sectional area

cortical nephrocalcinosis—the accumulation of calcium within the cortex of the kidney

cortical thinning—the thinning of the (renal) cortex

corticomedullary differentiation—the ability to sonographically distinguish between the normal cortex and medullary portions of the kidney

cotyledons—groups or lobes of chorionic villi

Courvoisier gallbladder—the clinical detection of an enlarged, palpable gallbladder caused by a biliary obstruction in the area of the pancreatic head; typically caused by a pancreatic head mass

Cowper gland—see key term bulbourethral gland

craniopagus—twins joined at the cranium

craniosynostosis—the premature closure of the cranial sutures with subsequent fusion of the cranial bones

creatinine—a chemical waste molecule that is generated from muscle metabolism and excreted in the urine

cremaster muscle—the muscle that raises the testicle

Crohn disease—an autoimmune disease characterized by periods of inflammation of the gastrointestinal tract

crown rump length—the measurement of the embryo/fetus from the top of the head to the rump

crus of the diaphragm—a tendinous structure that extends from the diaphragm to the vertebral column; there are two crura (plural for crus), a right crus and a left crus

cryptorchidism—the condition of having an undescended testis or testicles

culling—the splenic process of removing irregular red blood cells from the bloodstream

cumulus oophorus—structure that contains the developing oocyte

Cushing disease—the presence of a brain tumor in the pituitary gland that increases the release of adrenocorticotropic hormone resulting in Cushing syndrome

Cushing syndrome—a syndrome that results from an anterior pituitary gland or adrenal tumor that causes overproduction of cortisol by the adrenal glands

cyclopia—fusion of the orbits

cystic adenomatoid malformation—a mass consisting of abnormal bronchial and lung tissue that develops within the fetal chest

cystic duct—the duct that connects the gallbladder to the common hepatic duct

cystic fibrosis—an inherited disorder in which mucus secreting organs such as the lungs, pancreas, and other digestive organs produce thick and sticky secretions instead of normal secretions

cystic hygroma—a mass, typically found in the neck region, that is the result of an abnormal accumulation of lymphatic fluid within the soft tissue

cystic teratoma—benign ovarian mass that is composed of the three germ cell layers; also referred to as a dermoid cyst

cystitis—inflammation of the urinary bladder

Dandy–Walker complex—a spectrum of posterior fossa abnormalities that involves the cystic dilatation of the cisterna magna and fourth ventricle

Dandy–Walker malformation—congenital brain malformation in which there is enlargement of the cisterna magna, agenesis of the cerebellar vermis, and dilation of the fourth ventricle

dangling choroid sign—a sonographic sign associated with ventriculomegaly when the choroid plexus is noted hanging freely within the dilated lateral ventricle

daughter cyst—a small cyst within a large cyst

decidua basalis—the endometrial tissue at the implantation site, and the maternal contribution of the placenta

decidual reaction—the physiologic effect on the endometrium in the presence of a pregnancy

delta sign—see key term lambda sign

dermoid cyst—another name for a cystic teratoma

dermoid mesh—mass of hair within a cystic teratoma

dermoid plug—part of a dermoid tumor that contains various tissues and may produce posterior shadowing during a sonographic examination

detrusor muscle—the muscle that controls the appropriate emptying of the urinary bladder

developmental dysplasia of the hip—a congenital anomaly in which the ball of the hip is prohibited from resting appropriately in the natural socket provided for it on the pelvis

dextroverted uterus—the long axis of the uterus deviating to the right of the midline

diamniotic—having two amniotic sacs

diaphragmatic hernia—the herniation of the abdominal contents into the chest cavity through a defect in the diaphragm

diaphragmatic slip—a pseudomass of the liver seen on sonography resulting from hypertrophied diaphragmatic muscle bundles

dichorionic diamniotic—having two placentas and two amniotic sacs

dichorionic—having two placentas

diethylstilbestrol (DES)—a drug administered to pregnant woman from the 1940s to the 1970s to treat threatened abortions and premature labor that has been linked with uterine malformation in the exposed fetus

diethylstilbestrol—a drug administered to pregnant women from the 1940s to the 1970s to treat threatened abortions and premature labor that has been linked with uterine malformation in the exposed fetus

DiGeorge syndrome—a genetic disorder characterized by an absent or hypoplastic thymus, which ultimately leads to impairment of the immune system and susceptibility to infection, as well as cognitive disorders, congenital heart defects, palate defects, and hormonal abnormalities

digital rectal examination—the medical procedure that requires the insertion of the finger into the rectum to palpate the prostate gland and lower gastrointestinal tract

dilatation—an enlargement or expansion of a structure

dilation and curettage—a procedure in which the cervix is dilated and the uterine cavity is scraped with a curette

dirty shadowing—shadowing seen posterior to gas or air

discordant fetal growth—asymmetric fetal weight between twins

discriminatory zone—the level of human chorionic gonadotropin beyond which an intrauterine pregnancy is consistently visible

diverticulitis—the inflammation of diverticuli within the digestive tract, most often in the sigmoid colon

diverticulosis—the development of small outpouchings termed diverticuli in the digestive tract, most often in the sigmoid colon

dizygotic—two ova are fertilized by two sperms

dolichocephaly—an elongated, narrow head shape; may also be referred to as scaphocephaly

double bubble sign—classic sonographic sign of duodenal atresia representing the stomach and proximal duodenum

double decidual sign—the normal sonographic appearance of the decidua capsularis and decidua parietalis, separated by the anechoic fluid-filled uterine cavity

double sac sign—see key term double decidual sign

double-duct sign—coexisting dilation of the common bile duct and pancreatic duct

double-layer thickness—measurement of the endometrium from basal layer to basal layer excluding both the adjacent hypoechoic myometrium and the intracavitary fluid (if present)

doughnut sign—a sonographic sign associated with pyloric stenosis in the short axis

Down syndrome—see key term trisomy 21

duct of Santorini—the accessory duct of the pancreas

duct of Wirsung—the main pancreatic duct

ductus (vas) deferens—the tube that connects the epididymis to the seminal vesicles

ductus arteriosus—a fetal shunt that connects the pulmonary artery to the aortic arch

ductus venosus—a fetal shunt that connects the umbilical vein to the inferior vena cava

duodenal atresia—congenital maldevelopment or absence of duodenum

duodenal bulb—the proximal portion of the duodenum closest to the stomach

duodenum—the first segment of the small intestine

dura mater—the dense, fibrous outer layer of the meninges

dwarfism—abnormal short stature

dyschezia—difficult or painful defecation

dysentery—infection of the bowel which leads to diarrhea that may contain mucus and/or blood

dysfunctional uterine bleeding—a change in menstrual bleeding patterns related to hormonal imbalances, resulting in endometrial changes and subsequent abnormal bleeding

dysmenorrhea—difficult or painful menstruation

dyspareunia—painful sexual intercourse

dysphagia—difficulty swallowing

dysplasia—denotes the abnormal development of a structure

dyspnea—difficulty breathing

dysuria—painful or difficult urination

Ebstein anomaly—the malformation or malpositioning of the tricuspid valve that causes multiple heart defects

ecchymosis—subcutaneous spot of bleeding

echinococcal cyst—see key term hydatid liver cyst

Echinococcus granulosus—a parasite responsible for the development of hydatid liver cysts

echotexture—the sonographic appearance of a structure

eclampsia—a sequela of preeclampsia in which uncontrollable maternal hypertension and proteinuria lead to maternal convulsions and possibly fetal and maternal death

ectoderm—the outer germ cell layer of the embryo that develops into the skin, hair, and nails, and other structures

ectopic cordis—a condition in which the heart is located either partially or completely outside the fetal chest

ectopic pregnancy—a pregnancy located outside the endometrial cavity of the uterus

edema—abnormal swelling of a structure as a result of a fluid collection

Edwards syndrome—see key term trisomy 18

elastography—a sonographic technique employed to evaluate a mass based on its stiffness, ultimately providing a prediction as to whether a mass is more likely malignant or benign

embolism—a blockage caused by an abnormal mass (embolus) within the bloodstream that hinders circulation downstream, leading to tissue damage

embryonic demise—the death of an embryo before 10 weeks' gestation

embryo—term given to the developing fetus before 10 weeks' gestation

emphysematous pyelonephritis—the formation of air within the kidney parenchyma secondary to bacterial infiltration

emphysematous—abnormal distention of an organ with air or gas

empyema—the presence or collection of pus

encephalocele—protrusion of the brain and meninges through a defect in the skull

endocardial cushion defect—see key term atrioventricular defect

endocrine glands—glands that release their hormones directly into the bloodstream

endoderm—the germ cell layer of the embryo that develops into the gastrointestinal and respiratory tracts

endometrial atrophy—the degeneration of the endometrium with advancing age; most often seen in postmenopausal women

endometrial carcinoma—cancer of the endometrium

endometrial cavity—area that lies between the two layers of the endometrium; may also be referred to as the uterine cavity

endometrial hyperplasia—an increase in the number of endometrial cells

endometrial polyps—small nodules of hyperplastic endometrial tissue

endometrioid tumor—a typically malignant ovarian tumor that is often associated with a history of endometrial cancer, endometriosis, and endometrial hyperplasia

endometrioma—benign, blood-containing tumor that forms from the implantation of ectopic endometrial tissue; tumor associated with endometriosis

endometriosis—functional ectopic endometrial tissue located outside the uterus

endometritis—inflammation of the endometrium

endometrium—the inner mucosal layer of the uterus

endoscopic retrograde cholangiopancreatography—endoscopic procedure that utilizes fluoroscopy to evaluate the biliary tree and pancreas

endoscopic-guided laser photocoagulation—a treatment that uses lasers to separate abnormal placental vascular connections between twins that are suffering from twin–twin transfusion syndrome

endoscopy—a means of looking inside of the human body using an endoscope

endovascular aortic stent graft repair—nonsurgical method for treating abdominal aortic aneurysms

end-stage renal disease—medical condition in which the kidneys fail to function adequately, thus requiring the use of dialysis

ependyma—the lining of the ventricles within the brain

epidermoid cyst—small benign mass within the testicle that contains keratin

epididymal cyst—a cyst located anywhere along the length of the epididymis

epididymis—a coiled structure that is attached to the testicle and the posterior scrotal wall that is responsible for storing sperm

epididymitis—inflammation of all or part of the epididymis

epididymo-orchitis—inflammation of the epididymis and testis

epignathus—an oral teratoma

Epstein–Barr infection—a herpesvirus that can lead to infectious mononucleosis

Epstein–Barr virus—the virus responsible for mononucleosis and other potential complications

erythroblastosis fetalis—condition in which there is an incompatibility between the fetal and maternal red blood cells

erythropoiesis—the process of making red blood cells

esophageal atresia—congenital absence of part of the esophagus

Essure device—a permanent form of birth control that uses small coils placed into the proximal isthmic segment of the fallopian tubes

estimated fetal weight—the fetal weight based on sonographic

measurements

estriol—an estrogenic hormone produced by the placenta

estrogen replacement therapy—hormone replacement therapy that involves the administration of synthetic estrogen

estrogen—the hormone released by the ovary that initiates the proliferation and thickening of the endometrium

ethmocephaly—a condition in which there is no nose and a proboscis separating two close-set orbits; associated with holoprosencephaly

eventration of the diaphragm—lack of muscle in the dome of the diaphragm

exencephaly—a form of acrania in which the entire cerebrum is located outside the skull

exophytic—growing outward

exsanguination—total blood loss; to bleed out

external iliac arteries—external branches of the common iliac arteries

external os—the inferior portion of the cervix that is in close contact with the vagina

extraembryonic coelom—see key term chorionic cavity

extramedullary hematopoiesis—the spleen's hematopoietic function which can return in cases of severe anemia

exudate ascites—a collection of abdominal fluid within the peritoneal cavity that may be associated with cancer

facies—the features or appearance of the face

false aneurysm—a contained rupture of a blood vessel that is most likely secondary to the disruption of one or more layers of that vessel's wall

false lumen—the residual channel of a vessel created by the accumulation of a clot within that vessel

false pelvis—superior portion of the pelvis

falx cerebri—a double fold of dura mater located within midline of the brain

fatty liver—a reversible disease characterized by deposits of fat within the hepatocytes; also referred to as hepatic steatosis

fecalith—a stone that consists of feces

femur length—a sonographic measurement of the femoral diaphysis that

provides an estimated gestational age

fetal goiter—diffuse enlargement of the fetal thyroid gland

fetal hydrops—an abnormal accumulation of fluid in at least two fetal body cavities

fetal karyotyping—an analysis of fetal chromosomes; reveals the morphology and number of chromosomes

fetus papyraceus—the death of one fetus in a twin pregnancy that is maintained throughout the pregnancy; actually means paperlike fetus

fibroid—see key term leiomyoma

fibroma—an ovarian sex cord-stromal tumor found in middle-aged women

fibromatosis colli—a rare, pediatric fibrous tumor located within the sternocleidomastoid muscle

fibrosis—the formation of excessive fibrous tissue; the development of scar tissue within an organ

fimbria—the fingerlike extension of the fallopian tube located on the infundibulum

Fitz-Hugh–Curtis syndrome—a perihepatic infection that results in liver capsule inflammation from pelvic infections such as gonorrhea and chlamydia

flank pain—pain in one side of the body between the upper abdomen and the back

fluid-fluid level—a distinctive line seen within a cyst representing the layering of two different fluid densities

focal fatty infiltration—manifestation of fatty liver disease in which fat deposits are localized

focal fatty sparing—manifestation of fatty liver disease in which an area of the liver is spared from fatty infiltration

focal myometrial contraction—localized, painless contractions of the myometrium in the gravid uterus that should resolve within 20 to 30 minutes

focal nodular hyperplasia—a benign liver mass composed of a combination of hepatocytes and fibrous tissue that typically contains a central scar

folate—a vitamin that has been shown to significantly reduce the likelihood of neural tube defects; also referred to as folic acid

Foley catheter—a catheter placed into the urinary bladder via the urethra

that is used to drain urine; it can also be clamped and used to temporarily distend the bladder for pelvic sonography

follicle-stimulating hormone—the hormone of the anterior pituitary gland that causes the development of multiple follicles on the ovaries

follicle—small, round groups of cells

follicular aspiration—technique used for in vitro fertilization in which follicles are drained for oocyte retrieval

follicular cyst—ovarian cyst that forms as a result of the failure of the Graafian follicle to ovulate

follicular phase—the first phase of the ovarian cycle

foramen magnum—the opening in the base of the skull through which the spinal cord exits

foramen of Bochdalek—an opening located in the left posterolateral portion of the diaphragm

foramen of Morgagni—an opening located right anteromedially within the diaphragm

foramen ovale—an opening within the fetal heart within the atrial septum that allows blood to flow from the right atrium to the left atrium

fraternal twins—twins that result from the fertilization of two separate ova and have dissimilar characteristics

frontal bossing—the angling of the frontal bones that produces an unusually prominent forehead

functional layer (endometrium)—the functional inner layer of the endometrium that is altered by the hormones of the menstrual cycle

fundus (uterus)—the most superior and widest portion of the uterus

funneling (cervical)—the result of the premature opening of the internal os and the subsequent bulging of the membranes into the dilated cervix

fusiform—shaped like a spindle; wider in the middle and tapering toward the ends

galactocele—a milk-filled breast cyst

gallbladder torsion—the twisting of the vascular supply to the gallbladder

gamete intrafallopian tube transfer—infertility treatment in which oocytes and sperm are placed in the fallopian tube by means of laparoscopy

ganglion cyst—a common cyst found adjacent to a joint or tendon; most often found along the dorsal aspect of the hand, wrist, ankle, or foot

Gartner duct cyst—a benign cyst located within the vagina

gastrin—hormone produced by the stomach lining that is used to regulate the release of digestive acid

gastrinoma—an islet cell tumor found within the pancreas

gastroesophageal junction—the junction between the stomach and the esophagus

gastroesophageal reflux—an abnormality in which fluid is allowed to reflux out of the stomach back into the esophagus

gastroschisis—herniation of abdominal contents through a right-sided, periumbilical abdominal wall defect

germ cell tumor—a type of neoplasm derived from germ cells of the gonads; may also be found outside the reproductive tract

germinal matrix—a group of thin-walled blood vessels and cells within the subependymal layer of the fetal brain responsible for brain cell migration during fetal development

Gerota fascia—the fibrous envelope of tissue that surrounds the kidney and adrenal gland

gestational age—the way in which a pregnancy can be dated based on the first day of the last menstrual cycle; also referred to as menstrual age

gestational diabetes—diabetes acquired as a result of pregnancy

gestational trophoblastic disease—a disease associated with an abnormal proliferation of the trophoblastic cells during pregnancy; may also be referred to as a molar pregnancy

gestational trophoblastic disease—a disease associated with an abnormal proliferation of the trophoblastic cells during pregnancy; may also be referred to as molar pregnancy

Glisson capsule—the thin fibrous casing of the liver

glomerulonephritis—an infection of the kidney glomeruli

glomus (of choroid plexus)—the largest part of the choroid plexus

goiter—an enlarged, hyperplastic thyroid gland

gonadotropin-releasing hormone—the hormone released by the hypothalamus that stimulates the pituitary gland to release the hormones that

regulate the female menstrual cycle

gonorrhea—sexually transmitted disease that leads to infection of the genitals

Graafian follicle—the name for the dominant follicle prior to ovulation

Graf technique—a technique used to measure the relationship of the femoral head and acetabulum by evaluating the alpha and beta angles created by the relationships of these structures

granulomas—small echogenic calcifications that result from inflammation of the tissue in that area

granulomatous disease—an inherited disease that disrupts the normal immune system and causes it to malfunction resulting in immunodeficiency; chronic inflammation can lead to the development of granulomas in several organs

Graves disease—the most common cause of hyperthyroidism that produces bulging eyes, heat intolerance, nervousness, weight loss, and hair loss

gravidity—the number of times that a woman has been pregnant

gravid—pregnant

gross hematuria—blood within the urine that is visible to the naked eye

gynecomastia—the benign enlargement of the male breast; typically located posterior to the areola

gyri—folds in the cerebral cortex

Hartmann pouch—an outpouching of the gallbladder neck

Hashimoto thyroiditis—the most common cause of hypothyroidism in the United States

hemangioma—a benign tumor composed of blood vessels

hematemesis—vomiting blood

hematocele—a collection of blood within the scrotum

hematocolpos—blood accumulation within the vagina

hematocrit—the laboratory value that indicates the amount of red blood cells in blood

hematoma—a localized collection of blood

hematometra—blood accumulation within the uterine cavity

hematometrocolpos—blood accumulation within the uterus and vagina

hematopoiesis—the development of blood cells

hematosalpinx—blood within the fallopian tube

hematospermia—the presence of blood within the semen

hematuria—blood within the urine; can be described as microscopic or gross

hemivertebra—the anomaly of the spine in which there is absence of all or part of a vertebral body and posterior element

hemochromatosis—an inherited disease characterized by disproportionate absorption of dietary iron

hemodialysis—form of dialysis that utilizes a machine that essentially acts as a kidney whereby it extracts the patient's blood, filters it, and returns the filtered blood to the patient

hemolytic anemia—a condition that results in the destruction of red blood cells

hemophiliac—an inherited bleeding disorder that inhibits the control of blood clotting

hemopoiesis—the formation and development of blood cells

hemorrhagic cyst—a cyst that contains blood

Henoch–Schonlein purpura—an autoimmune disorder and form of vasculitis associated with purple spots on the skin, gastrointestinal complications, joint pain, and possibly kidney failure; mostly occurs in childhood

hepatic candidiasis—a hepatic mass that results from the spread of fungus in the blood to the liver

hepatic encephalopathy—a condition in which a patient becomes confused or suffers from intermittent loss of consciousness secondary to the overexposure of the brain to toxic chemicals that the liver would normally remove from the body

hepatic steatosis—see fatty liver

hepatitis—inflammation of the liver

hepatization of the gallbladder—situation in which the gallbladder is completely filled with tumefactive studge, causing the gallbladder to appear isoechoic to the liver tissue

hepatocellular adenoma—a benign liver mass often associated with the use

of oral contraceptives

hepatocellular carcinoma—the primary form of liver cancer

hepatofugal—blood flow away from the liver

hepatoma—the malignant tumor associated with hepatocellular carcinoma

hepatomegaly—enlargement of the liver

hepatopancreatic ampulla—the level of the biliary tree where the common bile duct and the main pancreatic duct meet; may also be referred to as the ampulla of Vater

hepatopancreatic sphincter—the muscle that controls the emptying of bile and pancreatic juices into the duodenum; may also be referred to as the sphincter of Oddi

hepatopetal—blood flow toward the liver

hepatorenal space—peritoneal space located between the liver and right kidney; also referred to as Morison pouch

hepatosplenomegaly—enlargement of the spleen and liver

heterotaxia syndromes—a situation in which the organs of the chest and abdomen are abnormally arranged

heterotopic pregnancy—coexisting ectopic and intrauterine pregnancies

heterozygous achondroplasia—most common nonlethal skeletal dysplasia that is characterized by rhizomelia

high-resistance flow—the flow pattern that results from small arteries or arterioles that are contracted, which produces an increase in the resistance to blood flow to the structure that is being supplied

hip joint effusion—buildup of fluid within the hip secondary to inflammation

Hirschsprung disease—a disease that leads to a functional bowel obstruction because of the lack of nerve cells within the colon wall

hirsutism—excessive hair growth in women in areas where hair growth is normally negligible

histoplasmosis—a disease that results from the inhalation of an airborne fungus that can affect the lungs and may spread to other organs

Hodgkin lymphoma—carcinoma of the lymphocytes that has a relatively high recovery rate; cancer of the lymphatic system

holoprosencephaly—a group of brain abnormalities consisting of varying degrees of fusion of the lateral ventricles, absence of the midline structures, and associated facial anomalies

homeostasis—the body's ability or tendency to maintain internal equilibrium by adjusting its physiologic processes

homozygous achondroplasia—the fatal form of achondroplasia

hormone replacement therapy—the medical treatment used to accommodate the reduction of estrogen and progesterone that occurs during menopause

horseshoe kidneys—the attachment of the lower poles of the kidneys by a band of renal tissue that crosses the midline of the abdomen

hot nodules—the hyperfunctioning thyroid nodules seen on a nuclear medicine study that are almost always benign

human chorionic gonadotropin—the hormone produced by the trophoblastic cells of the early placenta; may also be used as a tumor marker in nongravid patients and males

hydatid cyst—a cyst that results from the parasitic infestation of an organ by a tapeworm

hydatid liver cyst—a liver cyst that develops from a tapeworm that lives in dog feces; also referred to as an echinococcal cyst because it originates from the parasite *Echinococcus granulosus*

hydatidiform mole—the most common form of gestational trophoblastic disease in which there is excessive growth of the placenta and high levels of human chorionic gonadotropin; typically benign

hydranencephaly—a fatal condition in which the entire cerebrum is replaced by a large sac containing cerebrospinal fluid

hydrocele—a fluid collection within the scrotum; most often found between the two layers of the tunica vaginalis

hydrocephalus—refers to the dilation of the ventricular system caused by an increased volume of cerebrospinal fluid, resulting in increased intraventricular pressure with possible enlargement of the head

hydrocolpos—fluid accumulation within the vagina

hydrometrocolpos—fluid accumulation within the uterus and vagina

hydronephrosis—the dilation of the renal collecting system resulting from the obstruction of the flow of urine from the kidney(s) to the bladder; also

referred to as pelvocaliectasis or pelvicaliectasis

hydropic gallbladder—an enlarged gallbladder; also referred to as mucocele of the gallbladder

hydrops (fetal)—an abnormal accumulation of fluid in at least two fetal body cavities

hydrosalpinx—the abnormal accumulation of fluid within the fallopian tube

hydroureter—distension of the ureter with fluid because of obstruction

hyperalimentation—the intravenous administration of nutrients and vitamins

hyperamylasemia—elevated amylase

hyperandrogenism—excessive serum androgen levels; produces male characteristics in females

hypercortisolism—high levels of cortisol in the blood

hyperemesis gravidarum—excessive vomiting during pregnancy

hyperemesis—excessive vomiting

hyperemic—an increase in blood flow

hyperkalemia—high levels of potassium in the blood

hyperlipidemia—abnormally high levels of fats within the blood (i.e., high cholesterol and high triglycerides)

hypernatremia—high levels of sodium in the blood

hypernephroma—carcinoma of the kidney; also referred to as renal cell carcinoma

hyperparathyroidism—the presence of elevated parathyroid hormone

hyperpigmentation—the darkening of the skin

hyperplasia—an increase in the number of cells of a tissue or an organ

hyperplastic cholecystosis—a group of proliferative and degenerative gallbladder disorders which includes both adenomyomatosis and cholesterolosis

hypertelorism—increased distance between the orbits; widely spaced orbits

hypertension—high blood pressure

hyperthyroidism—a condition that results from the overproduction of thyroid hormones

hypertrophic pyloric stenosis—a defect in the relaxation of the pyloric sphincter that leads to the enlargement of the pyloric muscles and closure of the pyloric sphincter

hypoalbuminemia—abnormal low level of albumin in the blood; albumin is a protein produced in the liver

hypokalemia—low levels of potassium in the blood

hypomenorrhea—decreased or scant menstrual flow

hyponatremia—low levels of sodium in the blood

hypoplasia—incomplete growth of a structure or an organ

hypoplastic left heart syndrome—incomplete development of the left ventricle, resulting in a small or absent left ventricle

hypoplastic left heart—incomplete development of the left ventricle resulting in a small or absent left ventricle

hypoplastic right heart syndrome—incomplete development of the right ventricle, resulting in a small or absent right ventricle

hypoplastic—incomplete or arrested development of a structure

hypospadias—abnormal ventral curvature of the penis as a result of a shortened urethra that exits on the ventral penile shaft

hypotelorism—reduced distance between the orbits

hypothalamic-pituitary-gonadal axis—the complex interactions that take place between the hypothalamus, pituitary gland, and ovaries as part of the female reproductive cycle

hypothalamus—the area within the brain that is located just beneath the thalamus and controls the release of hormones by the anterior pituitary gland

hypothyroidism—a condition that results from the underproduction of thyroid hormones

hypovolemia—decreased blood volume

hypoxia—a shortage of oxygen or decreased oxygen in the blood

hysterectomy—the surgical removal of the uterus

hysterosalpingography—a radiographic procedure that uses a dye instilled into the endometrial cavity and fallopian tubes to evaluate for internal abnormalities

hysteroscopic uterine septoplasty—the surgical repair of a uterine septum

in a septate uterus using a hysteroscopy

hysteroscopy—endoscopy of the uterine cavity

identical twins—twins that result from the split of a single zygote and share the same genetic structure

idiopathic—no recognizable cause; from an unknown origin

ileus—bowel obstruction caused by the lack of normal peristalsis

iliopsoas muscles—bilateral muscles located lateral to the uterus and anterior to iliac crest

ilium (pelvis)—the largest and most superiorly located pelvic bone

immune hydrops—fetal hydrops caused by Rh incompatibility

immunocompromised—the state of having an immune system that is impaired for some reason

imperforate hymen—a vaginal anomaly in which the hymen has no opening, resulting in an obstruction of the vagina

implantation bleeding—a bleed that occurs at the time in which the conceptus implants into the decidualized endometrium

in vitro fertilization—fertility treatment that requires that a mature ovum be extracted from the ovary, with fertilization taking place outside of the body

infantile polycystic kidney disease—an inherited renal disease that results in bilateral enlargement of the fetal kidneys and microscopic renal cysts; also referred to as autosomal recessive polycystic kidney disease

infertility—the inability to conceive a child after 1 year of unprotected intercourse

inflammatory bowel disease—chronic inflammation of all or parts of the bowel

infundibulum—the distal segment of the fallopian tube

inguinal canal—normal passageway in the lower anterior abdominal wall that allows for the passage of the spermatic cord into the scrotum

inguinal hernia—the protrusion of bowel or abdominal contents through the inguinal canal

inhibin A—a peptide hormone secreted by the placenta during pregnancy

insulinoma—an islet cell tumor found within the pancreas

interhemispheric fissure—groove within the midline of the brain that

divides the two cerebral hemispheres

intermenstrual bleeding—bleeding between periods

internal iliac arteries—internal branches of the common iliac arteries

internal os—the superior portion of the cervix closest to the isthmus

interocular diameter—the length between the orbits; measured from the medial margin of one orbit to the medial margin of the other orbit

interstitial—the segment of the fallopian tube that lies within the uterine horn (cornu)

interthalamic adhesion—the mass of tissue, located in the third ventricle within the midline of the brain, which connects the two lobes of the thalamus; also referred to as the massa intermedia

intimal flap—observation of the intimal layer of a vessel as a result of a dissection

intracavitary (fibroid)—a leiomyoma located within the uterine cavity

intracranial hemorrhage—general term used to denote a hemorrhage within the cranium

intradecidual sign—the appearance of a small gestational sac in the uterine cavity surrounded by the thickened, echogenic endometrium

intraluminal—something located within the lumen or opening of an organ or structure

intramural (fibroid)—location of leiomyoma within the myometrium of the uterus

intraperitoneal—located within the parietal peritoneum

intrauterine contraceptive device—a reversible form of contraception that is manually placed in the uterine cavity to prevent pregnancy; also referred to as an intrauterine device

intrauterine device—a common form of birth control in which a small device is placed within the endometrium to prevent pregnancy; also referred to as an intrauterine contraceptive device

intrauterine growth restriction—a fetus that is below the 10th percentile for gestational age (small for gestational age) and whose growth is impeded for some reason

intraventricular hemorrhage—hemorrhage located within the ventricles of the brain

intussusception—the telescoping of one segment of bowel into another; most often the proximal segment of the bowel inserts into the distal segment

intussusceptum—the proximal segment of the bowel with intussusception

intussuscipiens—the distal segment of the bowel with intussusception

invaginate—to insert

invasive mole—a type of gestational trophoblastic disease in which a molar pregnancy invades into the myometrium and may also invade through the uterine wall and into the peritoneum

islet cell tumors—tumor found within the islets of Langerhans of the pancreas

islets of Langerhans—small islands of tissue found within the pancreas that produce insulin and glucagon

isthmus—tube: the segment of the fallopian tube that is located between the interstitial and ampulla; uterus: area of the uterus between the corpus and the cervix

IVC filter—vascular filter placed in the inferior vena cava to prevent pulmonary emboli

jaundice—the yellowish discoloration of the skin, mucous membranes, and sclerae; found with liver disease and/or biliary obstruction

junctional fold—a fold in the neck of the gallbladder

Kaposi sarcoma—cancer that causes lesions to develop on the skin and other places; often associated with AIDS

Kawasaki disease—a condition associated with vasculitis and can affect the lymph node, skin, and mucous membranes; also referred to as mucocutaneous lymph node syndrome

kernicterus—brain damage from bilirubin exposure in a newborn with jaundice

"keyhole" sign—the sonographic appearance of a dilated fetal bladder and urethra in the presence of a bladder outlet obstruction

Klatskin tumor—a malignant biliary tumor located at the junction of the right and left hepatic ducts

Klinefelter syndrome—a condition in which a male has an extra X chromosome; characteristic features include small testicles, infertility, gynecomastia, long legs, and abnormally low intelligence

Krukenberg tumor—malignant ovarian tumor that metastasizes from most likely the gastrointestinal tract

Kupffer cells—specialized macrophages within the liver that engulf pathogens and damaged cells

kyphoscoliosis—the combination of both scoliosis and kyphosis in the fetus

kyphosis—an abnormal posterior curvature of the spine

lactate dehydrogenase—an enzyme found within the blood that may be used to monitor renal function; may also be used as a tumor marker for some ovarian tumors

lactiferous ducts—the ducts of the breast used to transport milk to the nipple

lactobezoar—a bezoar that consists of powdered milk

lambda sign—a triangular extension of the placenta at the base of the membrane is indicative of a dichorionic diamniotic pregnancy; also referred to as the delta sign or twin peak sign

lecithin to sphingomyelin ratio—a test of the amniotic fluid that predicts fetal lung maturity

leiomyoma (uterine)—a benign, smooth muscle tumor of the uterus; may also be referred to as a fibroid or uterine myoma

leiomyosarcoma—the malignant manifestation of a leiomyoma

lemon sign—the sonographic sign associated with a lemon-shaped cranium; most often found in the fetus with spina bifida

lesser sac—a peritoneal cavity located between the stomach and pancreas where fluid can accumulate

leukocytosis—an elevated white blood cell count

levator ani muscles—hammock-shaped pelvic muscle group located between the coccyx and pubis consisting of the iliococcygeus, pubococcygeus, and puborectalis

levoverted uterus—the long axis of the uterus deviating to the left of the midline

limb buds—early embryonic structures that will eventually give rise to the extremities

limb-body wall complex—a group of disorders with sonographic findings including a short or absent umbilical cord, ventral wall defects, limb defects, craniofacial defects, and scoliosis

linea terminalis—imaginary line that separates the true pelvis from the false pelvis

lipoma—a benign fatty tumor

lissencephaly—“smooth brain”; condition where there is little to no gyri or sulci within the cerebral cortex

liver hilum—the area of the liver where the common bile duct exits the liver and portal vein and hepatic artery enter the liver; also referred to as the porta hepatis

lobar holoprosencephaly—the least severe form of the holoprosencephaly

lower uterine segment—the term used for the isthmus of the uterus during pregnancy

low-resistance flow—the flow pattern characterized by persistent forward flow throughout the cardiac cycle

lung consolidation—the replacement of normal air-filled alveoli with fluid, inflammation, blood, or neoplastic cells

luteal phase deficiency—when the endometrium does not develop appropriately in the luteal phase of the endometrial cycle as a result of reduced progesterone production

luteal phase—the second phase of the ovarian cycle

luteinizing hormone—the hormone of the anterior pituitary gland that surges around day 14 of the menstrual cycle, resulting in ovulation

"lying down" adrenal sign—the sonographic appearance of the adrenal gland in a parallel position within the abdomen as a result of renal agenesis

lymphadenopathy—disease or enlargement of the lymph nodes

lymphedema—build-up of lymph that is most likely caused by the obstruction of lymph drainage

lymphocele—a collection of lymphatic fluid

lysis—destruction or breaking down (i.e., hemolysis, the breaking down of blood components)

macrocephaly—an enlarged head circumference

macroglossia—enlargement of the tongue

macroscopic—large enough to be discerned by the naked eye

macrosomia—an estimated fetal weight of greater than the 90th percentile

or the neonate that measures more than 4,500 g

magnetic resonance imaging—a diagnostic modality that utilizes electromagnetic radiation to produce images of the human body in cross-sectional and reconstructed 3D formats

magnetic resonance imaging-guided high-intensity focused ultrasound —a fibroid treatment that utilizes focused high-frequency, high-energy ultrasound guided by magnetic resonance imaging to heat and destroy fibroid tissue

malaise—feeling of uneasiness

malformation—a structural abnormality that results from an abnormal development

malignant degeneration—the deterioration of a benign mass into a malignancy

Marfan syndrome—a disorder of the connective tissue characterized by tall stature and aortic and mitral valve insufficiency

marginal cord insertion—abnormal cord insertion at the edge of the placenta

mass effect—the displacement or alteration of normal anatomy that is located adjacent to a tumor

massa intermedia—see key term interthalamic adhesion

mastitis—inflammation of the breast

maternal serum alpha-fetoprotein—a screening test that detects the amount of alpha-fetoprotein in the maternal blood stream

maternal serum screening—blood screening test that evaluates maternal levels of alpha-fetoprotein, estriol, and human chorionic gonadotropin (as well as other labs) during a pregnancy for neural tube defects and chromosomal abnormalities

McBurney point—a point halfway between the anterior superior iliac spine and the umbilicus; the area of pain and rebound tenderness in patients suffering from acute appendicitis

mean sac diameter—the measurement of the gestational sac to obtain a gestational age; achieved by adding the measurements of the length, width, and height of the gestational sac and dividing by 3

mechanical obstruction—a situation in which bowel is physically blocked by something

Meckel diverticulum—a common congenital outpouching of the wall of the small intestine

Meckel–Gruber syndrome—a fetal syndrome associated with microcephaly, occipital encephalocele, polydactyly, and polycystic kidneys

meconium—fetal stool that is composed of fetal skin, hair, amniotic fluid, and bile

median cleft lip—a subdivision within the middle of the lip

median raphe—the structure that separates the scrotum into two compartments externally

mediastinum testis—the structure that is formed by the tunica albuginea and contains the rete testis

mediastinum—the central portion of the chest cavity between the pleural sacs of the lungs that contains all of the chest organs but the lungs, including the heart, thymus gland, part of the trachea, esophagus, and many lymph nodes

medullary nephrocalcinosis—the accumulation of calcium within the medulla of the renal parenchyma

medullary sponge kidney—a congenital disorder characterized by the accumulation of calcium within abnormally dilated collecting ducts located within the medulla

mega cisterna magna—an enlargement of the cisterna magna as defined by a depth of more than 10 mm

megacystis—an abnormally enlarged urinary bladder

megaureter—an enlarged ureter; can be congenital or acquired

Meigs syndrome—ascites and pleural effusion in the presence of some benign ovarian tumors

melanoma—a malignant form of cancer found most often on the skin

menarche—the first menstrual cycle

meninges—the coverings of the brain and spinal cord

meningocele—the herniation of the cranial or spinal meninges caused by an open cranial or spinal defect

meningomyelocele—mass that results from open spina bifida that contains the spinal cord and the meninges; also referred to as a myelomeningocele

menometrorrhagia—excessive and prolonged menstrual bleeding at

irregular intervals

menopause—cessation of menstruation with advanced age

menorrhagia—abnormally heavy and prolonged menstruation

menses—menstrual bleeding

menstrual age—see key term gestational age

mermaid syndrome—see key term sirenomelia

mesencephalon—the primary brain vesicle also referred to as the midbrain; it eventually becomes the cerebral peduncles, quadrigeminal plate, and cerebral aqueduct

mesoblastic nephroma—the most common sold fetal renal mass

mesocephalic—normal head shape

mesoderm—the germ cell layer of the embryo that develops into the circulatory system, muscles, reproductive system, and other structures

metastasis—the spread of cancer from a distant site

methotrexate—a chemotherapy drug used to attack rapidly dividing cells like those seen in an early pregnancy; this drug is often used to manage ectopic pregnancies

metrorrhagia—irregular menstrual bleeding between periods; intermenstrual bleeding

microcephaly—small head

micrognathia—a small mandible and recessed chin

micropenis—an abnormally small penis

microphthalmia—a decrease in the size of the eye

microphthalmia—small eye or eyes

microscopic—too small to be seen by the naked eye and thus requiring the aid of a microscope

microtia—small ear(s)

midgut malrotation—abnormal rotation of the bowel that leads to a proximal small bowel obstruction

Mirena—a small plastic T-shaped intrauterine device

Mirizzi syndrome—a clinical condition when the patient presents with jaundice, pain, and fever secondary to a lodged stone in the cystic duct

causing compression of the common duct

mirror syndrome—a rare disorder in which the mother suffers from edema and fluid buildup similar to her hydropic fetus

miscarriage—the spontaneous end of a pregnancy before viability

missed abortion—fetal demise with a retained fetus

mittelschmerz—pelvic pain at the time of ovulation

moiety—(renal) refers to a separate collecting system in the upper pole or the lower pole of the kidney in a duplex collecting system

molar pregnancy—also referred to as gestational trophoblastic disease; is associated with an abnormal proliferation of the trophoblastic cells, enlargement of the placenta, and elevated levels of human chorionic gonadotropin

monoamniotic—having one amniotic sac

monochorionic diamniotic—having one placenta and two amniotic sacs

monochorionic monoamniotic—having one placenta and one amniotic sac

monochorionic—having one chorion

mononucleosis—an infectious disease caused by the Epstein–Barr virus

monophasic—vascular flow yielding a single phase

monosomy X—see key term Turner syndrome

monoventricle—one large ventricle within the brain associated with holoprosencephaly

monozygotic—coming from one fertilized ovum or zygote

morbidity—the relative frequency of occurrence of a disease

morphology—the form and structure of an organism

Morrison pouch—the space between the liver and the right kidney; also referred to as the posterior right subhepatic space

mortality—the rate of actual deaths

morula—the developmental stage of the conceptus following the zygote

mucoepidermoid carcinoma—the most common malignancy of the salivary glands; typically starts in the parotid gland

Müllerian ducts—paired embryonic ducts that develop into the female urogenital tract

multicystic dysplastic kidney disease—a renal disease thought to be caused by an early renal obstruction; leads to the development of multiple noncommunicating cyst of varying sizes in the renal fossa

multiloculated—having many cavities

multiparity—having had several pregnancies

multiparous—having birthed more than one child

mural nodules—small solid internal projections of tissue originating from the wall of cyst

Murphy sign—pain directly over the gallbladder with applied probe pressure

mycotic aneurysm—an aneurysm caused by infection

myelocele—mass that results from open spina bifida that contains spinal cord only

myelomeningocele—mass that results from spina bifida that contains the spinal cord and the meninges

myomectomy—the surgical removal of a myoma (fibroid) of the uterus

myometrium—the muscular layer of the uterus

nabothian cysts—benign cysts located within the cervix

natal cleft—area located between the groove of the buttocks

necrosis—death of tissue

neonatal period—the first 28 days of life

neonatal—the first 4 weeks (28 days) after birth

neoplasm—a mass of tissue that contains abnormal cells; also called a tumor

nephroblastoma—the most common solid malignant pediatric abdominal mass; may also be referred to as Wilms tumor

nephrocalcinosis—an accumulation of calcium within the renal parenchyma

nephrolithiasis—the urinary stones located within the kidney; kidney stones

nephron—the functional unit of the kidney

nephrotic syndrome—a kidney disorder caused by damage to the glomeruli that results in excess amounts of protein in the urine and the swelling of the ankles, face, and feet because of accumulation of excess water

neural plate—the early embryologic structure that develops into the central

nervous system

neural tube defects—a group of developmental abnormalities that involve the brain and spine

neural tube—embryologic formation that results from fusion of the two folded ends of the neural plate

neuroblastoma—malignant tumor that can occur within the adrenal gland and anywhere within the sympathetic nervous system

neurogenic bladder—a bladder that is poorly functioning secondary to any type of neurologic disorder

nocturia—frequent urination at night

nonbilious—not containing bile

noncommunicating hydrocephalus—the obstruction of cerebrospinal fluid from a source within of the ventricular system

nongravid—not pregnant

non-Hodgkin lymphoma—carcinoma of the lymphocytes; cancer of the lymphatic system

nonimmune hydrops—fetal hydrops caused by congenital fetal anomalies and infections

nonmechanical obstruction—a situation in which bowel is blocked because of the lack of normal peristalsis of a bowel segment or segments; also referred to as a paralytic ileus

nosocomial infections—hospital-acquired infections

nuchal cord—condition of having the umbilical cord wrapped completely around the fetal neck

nuchal cystic hygroma—a mass found in the neck that is the result of an abnormal accumulation of lymphatic fluid within the soft tissue

nuchal fold thickness—a measurement taken in the second trimester of the skin on the posterior aspect of the fetal neck

nuchal fold—a collection of solid tissue on the posterior aspect of the fetal neck

nuchal translucency—the anechoic space along the posterior aspect of the fetal neck

nuchal—the posterior part or nape of the neck

nuclear cystogram—a nuclear medicine examination of the urinary bladder and ureters

nuclear medicine—a diagnostic imaging modality that utilizes the administration of radionuclides into the human body for an analysis of the function of organs, or for the treatment of various abnormalities

nulliparity—having birthed no children

nutcracker syndrome—an anomaly where left renal vein entrapment occurs between the superior mesenteric artery and abdominal aorta

obesity—overweight to the point of causing significant health problems and increased mortality

obstructive cystic dysplasia—a fetal disorder caused by an early renal obstruction; leads to small and echogenic kidneys that have cysts located along their margins

obturator internus muscles—paired pelvic muscles located lateral to the ovaries

ocular diameter—the measurement from the lateral margin of the orbit to the medial margin of the same orbit

OEIS complex—acronym that stands for omphalocele, bladder exstrophy, imperforate anus, and spina bifida; also referred to as cloacal exstrophy

oligohydramnios—a lower-than-normal amount of amniotic fluid for the gestational age

oligomenorrhea—infrequent or light menstrual periods

oliguria—scant or decreased urine output

olive sign—when the pyloric sphincter muscle is enlarged and palpable on physical examination of the abdomen; often indicative of pyloric stenosis

omentum—a fold of peritoneum

omphalocele—an anterior abdominal wall defect where there is herniation of the fetal bowel and other abdominal organ into the base of the umbilical cord

omphalopagus—conjoined twins attached at the abdomen

oncocytes—large cells of glandular origin

oncocytoma—a benign renal tumor that is often found in men in their 60s

oocyte retrieval—the removal of oocytes from ovarian follicles by aspiration

oogenesis—the creation of an ovum

open spina bifida—see key term spina bifida aperta

orchiopexy—the surgery that moves an undescended testis into the scrotum

orchitis—inflammation of the testis or testicles

Ortolani test—clinical test for developmental hip dysplasia that is used to evaluate the hip for the reduction or relocation of a dislocated hip

osteogenesis imperfecta—a group of disorders that result in multiple fractures in utero; caused by decreased mineralization and poor ossification of the bones

osteopenia—a bone density that is lower than normal

osteoporosis—bone loss that predisposes the individual to fractures

ovarian cystectomy—the surgical removal of an ovarian cyst

ovarian dysgenesis—imperfect or abnormal development of the ovaries

ovarian hyperstimulation syndrome—a syndrome resulting from hyperstimulation of the ovaries by fertility drugs; results in the development of multiple, enlarged follicular ovarian cysts

ovarian ligaments—pelvic ligaments that provides support to the ovary extending from the ovary to the lateral surface of the uterus

ovarian torsion—an abnormality that results from the ovary twisting on its mesenteric connection, consequently cutting off the blood supply to the ovary

ovulation induction—the stimulation of the ovaries by hormonal therapy in order to treat infertility

ovulation—the release of the mature egg from the ovary

ovum—an unfertilized egg

pallor—extreme paleness of the skin

pampiniform plexus—the group of veins in the spermatic cord

pancreatic adenocarcinoma—the most common form of pancreatic malignancy, typically found within the head of the pancreas

pancreatic divisum—congenital anomaly of the pancreas that results in a shortened main pancreatic duct that only works to drain the pancreatic head and not the entire pancreas

pancreatic pseudocyst—a cyst surrounded by fibrous tissue that consists of

pancreatic enzymes that have leaked from the pancreas

pancreaticoduodenectomy—the surgical procedure in which the head of the pancreas, the gallbladder, some of the bile ducts, and the proximal duodenum are removed because of a malignant pancreatic neoplasm; also referred to as the Whipple procedure

pannus—a hanging flap of tissue

papillary carcinoma—the most common form of thyroid cancer

papillary muscle—paired muscles in both sides of heart that hold in place either the mitral or tricuspid valves

papillary projections—a small protrusion of tissue

paracentesis—a procedure that uses a needle to drain fluid from the abdominal cavity for diagnostic and/or therapeutic reasons

ParaGard—intrauterine contraceptive device that utilizes copper in its composition to inhibit sperm transport, or to prevent fertilization or transplantation

parallel tube sign—the enlargement of the common duct to the size of the adjacent portal vein within the porta hepatis

paralytic ileus—see key term nonmechanical obstruction

parasitic twin—see key term acardiac twin

parenchyma—the functional part of an organ

parietal peritoneum—the portion of the peritoneum that lines the abdominal and pelvic cavities

parity—the number of pregnancies in which the patient has given birth to a fetus at or beyond 20 weeks gestational age or an infant weighing more than 500 g

Patau syndrome—a chromosomal aberration in which there is a third chromosome 13; also referred to as trisomy 13

pedunculated uterine leiomyoma—leiomyoma (fibroid) that extends from the uterus on a stalk

pedunculated—something that grows off of a stalk

pelvic diaphragm—group of pelvic muscles consisting of the levator ani and coccygeous muscles that provide support to the pelvic organs

pelvic inflammatory disease—an infection of the female genital tract that may involve the ovaries, uterus, and/or the fallopian tubes

pelvic kidney—a kidney located within the pelvis

pelviectasis—dilation of the renal pelvis; may also be referred to as pyelectasis

pelviureteral junction—see key term ureteropelvic junction

pelvocaliectasis—see key term hydronephrosis

pentalogy of Cantrell—a group of anomalies that includes an omphalocele, along with ectopic cordis, cleft sternum, anterior diaphragmatic defect, and pericardial defects

percutaneous umbilical cord sampling—see key term cordocentesis

Pergonal—infertility medicine used to stimulate the follicular development of the ovaries

pericardial effusion—the accumulation of fluid around the heart in the pericardial cavity

pericholecystic fluid—fluid around the gallbladder

perienteric fat—fat around the intestines

perimenopausal—the time prior to menopause

perimetrium—the outer layer of the uterus; may also be referred to as the serosal layer

perinephric abscess—an abscess that surrounds the kidney

perineum—the region between the external genitalia and the anus

periovulatory phase—another name for the late proliferative phase of the endometrial cycle, which occurs around the time of ovulation

peripheral zone—the largest zone of the prostate and most common location for prostatic cancer

periportal cuffing—an increase in the echogenicity of the portal triads as seen in hepatitis and other conditions

peristalsis—contractions that move in a wavelike pattern to propel a substance

peritoneal dialysis—a form of dialysis that uses a solution that is instilled into the abdomen; uses diffusion and osmosis to filter waste products from the blood

peritonitis—inflammation of the peritoneal lining

Peyronie disease—the buildup of fibrous plaque (scar tissue) and

calcifications within the penis that results in a painful curvature

pheochromocytoma—a hyperfunctioning, benign adrenal mass that causes the adrenal gland to release excessive amounts of epinephrine and norepinephrine into the blood stream leading to uncontrollable hypertension

philtrum—the vertical groove seen between the upper lip and the nasal septum

phlegmon—the peripancreatic fluid collection that results from the inflammation of the pancreas

Phrygian cap—gallbladder variant when the gallbladder fundus is folded onto itself

physiologic bowel herniation—the normal developmental stage when the midgut migrates into the base of the umbilical cord

phytobezoars—a bezoar that consists of vegetable matter

pia mater—the innermost layer of the meninges

pilonidal cyst—cyst located along the natal cleft that is comprised of loose hairs and skin debris

pineal gland—endocrine gland located in the brain that secretes melatonin

piriformis muscles—paired pelvic muscles located posteriorly that extends from the sacrum to the femoral greater trochanter

pitting—the splenic process of cleaning red blood cells of unwanted material

placenta accreta—the abnormal adherence of the placenta to the myometrium in an area where the decidua is either absent or minimal

placenta increta—invasion of the placenta within the myometrium

placenta percreta—penetration of the placenta through the uterine serosa and possibly into adjacent pelvic organs

placenta previa—when the placenta covers or nearly covers the internal os of the cervix

placental abruption—the premature separation of the placenta from the uterine wall before the birth of the fetus

placentation—formation or structure of a placenta, structural organization, and mode of attachment of fetal to maternal tissues during placental formation

placentomegaly—enlargement of the placenta

pleomorphic adenoma—benign and most frequent tumor of the salivary glands; most commonly seen in the parotid gland

pleural effusion—the abnormal accumulation of fluid in the pleural space

pneumobilia—air within the biliary tree

pneumothorax—free air within the chest outside of the lungs that can lead to lung collapse

polycystic ovary syndrome—a syndrome characterized by anovulatory cycles, infertility, hirsutism, amenorrhea, and obesity; may also be referred to as Stein–Leventhal syndrome

polydactyly—having more than the normal number of fingers or toes

polyhydramnios—an excessive amount of amniotic fluid for the gestational age

polypectomy—the surgical removal of a polyp

polypoid—shaped like a polyp

polysplenia—having many small islands of splenic tissue

porcelain gallbladder—the calcification of all or part of the gallbladder wall

porencephaly—the development of a cystic cavity within the cerebrum; may be the result of an intraparenchymal hemorrhage

porta hepatis—the area of the liver where the portal vein and hepatic artery enter and the hepatic duct exit; also referred to as the liver hilum

portal hypertension—the elevation of blood pressure within the portal venous system

portal triads—an assembly of a small branch of the portal vein, bile duct, and hepatic artery that surround each liver lobule

portal vein thrombosis—the development of clot within the portal vein

posterior cul-de-sac—see key term rectouterine pouch

posterior fossa—posterior portion of the cranium located near the cerebellum and containing the cisterna magna

posterior urethral valves—irregular thin membranes of tissue located within the male posterior urethra that do not allow urine to exit the urethra

postmenopausal vaginal bleeding—vaginal bleeding after the onset of menopause

postmenopause—the time after menopause

postpartum—the time directly after giving birth and extending to about 6 weeks

postprandial—after a meal

Potter facies—facial features seen with severe oligohydramnios, including low set ears, flattened nose, wrinkled skin, and micrognathia

Potter syndrome—physical features of a fetus as a result of oligohydramnios; characterized by bilateral renal agenesis, abnormal facies, pulmonary hypoplasia, and limb abnormalities; also referred to as Potter sequence

pouch of Douglas—see key term rectouterine pouch

precocious puberty—pubertal development before the age of 8; the early development of pubic hair, breast, or genitals

preeclampsia—pregnancy-induced maternal high blood pressure and excess protein in the urine after 20 weeks' gestation

pregestational diabetes—maternal diabetes that existed before pregnancy; includes both type 1 and 2 diabetes mellitus

pregnancy-associated plasma protein A—a protein that is produced by the placenta and that can be monitored during pregnancy

premature rupture of membranes—the rupture of the amniotic sac prior to the onset of labor

primary amenorrhea—failure to experiencing menarche before age 16

proboscis—fleshy, tongue-like appendage that is typically located within the midline above the orbits in association with cyclopia and holoprosencephaly

progesterone—a hormone that prepares the uterus for pregnancy, maintains pregnancy, and promotes development of the mammary glands; primarily produced by the ovary and placenta

progestin—synthetic progesterone secreted by some intrauterine devices to regulate menstrual flow

progestogen therapy—a hormone replacement therapy that involves administering synthetic progesterone

prolapse—(uterine prolapse) a condition that results from the weakening of the pelvic diaphragm muscles and allows for the displacement of the uterus, often through the vagina

proliferation—the multiplication of similar forms

proliferative phase—the first phase of the endometrial cycle

prosencephalon—the primary brain vesicle also referred to as the forebrain; it eventually becomes the lateral ventricles, cerebral hemispheres, third ventricle, thalamus, hypothalamus, pineal gland, and pituitary gland

prostate-specific antigen—a protein produced by the prostate gland

prostatitis—inflammation of the prostate gland

proteinuria—protein in the urine

prune belly syndrome—syndrome that is a consequence of the abdominal wall musculature being stretched by the extremely enlarged urinary bladder

pruritus—sever itchiness of the skin

psammoma bodies—round, punctate calcific deposits

pseudoaneurysm—see key term false aneurysm

pseudocirrhosis—nodular appearance of the liver caused by multiple metastatic tumors

pseudogestational sac—the appearance of an abnormally shaped false gestational sac within the uterine cavity as a result of an ectopic pregnancy; this often corresponds with the accumulation of blood and secretions within the uterine cavity

pseudomass—false mass

pseudomyxoma peritonei—an intraperitoneal extension of mucin-secreting cells that result from the rupture of a malignant mucinous ovarian tumor or possibly a malignant tumor of the appendix

pseudoprecocious puberty—secondary sexual development induced by sex steroids or from other sources such as ovarian tumors, adrenal tumors, or steroid use

puerperal mastitis—inflammation of the breast that is related to pregnancy

pulmonary atresia—the absence of the pulmonary valve, which in turn prohibits blood flow from the right ventricle into the pulmonary artery and essentially to the lungs

pulmonary embolus—blood clot that has traveled to the lungs and is obstructing the pulmonary arterial circulation; most often the result of a deep venous thrombosis

pulmonary hypoplasia—underdevelopment of the lungs

pulmonary sequestration—a separate mass of nonfunctioning lung tissue

with its own blood supply

pulmonary stenosis—the narrowing of the pulmonary valve

punctate—marked with dots

purulent—an inflammatory reaction that leads to the formation of pus

pyelectasis—enlargement of the renal pelvis; also referred to as pelviectasis

pylorospasm—a temporary spasm and thickening of the pyloric sphincter that can replicate the sonographic appearance of pyloric stenosis

pyocele—a pus collection within the scrotum

pyogenic liver abscess—a liver abscess that can result from the spread of infection from inflammatory conditions such as appendicitis, diverticulitis, cholecystitis, cholangitis, and endocarditis

pyometra—the presence of pus within the uterus

pyonephrosis—the condition of having pus within the collecting system of the kidney

pyopagus—conjoined twins joined back-to-back in the sacral region

pyosalpinx—the presence of pus within the fallopian tube

pyramidal lobe—a normal variant of the thyroid gland in which there is a superior extension of the isthmus

pyuria—pus within the urine

quadrate lobe—the medial segment of the left lobe

quadruple screen—a maternal blood test that includes an analysis of human chorionic gonadotropin, alpha-fetoprotein, estriol, and inhibin A

radial arteries—arteries that supply blood to the deeper layers of the myometrium

radial ray defect—absence or underdevelopment of the radius

radiography—a diagnostic imaging modality that uses ionizing radiation for imaging bones, joints, organs, and some other soft tissue structures

rebound tenderness—pain encountered after the removal of pressure; a common clinical finding in patients suffering from acute appendicitis

recanalization—the reopening of canals or pathways

rectouterine pouch—peritoneal outpouching located between the uterus and rectum; also referred to as the posterior cul-de-sac and pouch of Douglas

rectus abdominis muscles—paired anterior abdominal muscles that extend from the xiphoid process of the sternum to the pubic bone

red currant jelly stool—feces that contains a mixture of mucus and blood; a common clinical finding in patients suffering from intussusception

red pulp—specialized tissue within the spleen that performs its phagocytic function

Reed–Sternberg cells—the cells that indicate the presence of Hodgkin lymphoma

refractive shadowing—acoustic shadowing caused by bending of a sound beam at the edge of a curved reflector; may be referred to as edge artifact or edge shadowing

renal adenoma—a benign renal mass

renal agenesis—failure of the kidney to develop; may be unilateral or bilateral

renal agenesis—failure of the kidney to develop; may be unilateral or bilateral

renal artery stenosis—the narrowing of the renal artery

renal calices—the part of the collecting system that encompasses the apex of the renal pyramids

renal cell carcinoma—the carcinoma of the kidney; also referred to as hypernephroma

renal colic—a sharp pain in the lower back that radiates into the groin and is typically associated with the passage of a urinary stone through the ureter

renal cortex—the outer part of the renal parenchyma that is responsible for filtration

renal ectopia—refers to an abnormal location of the kidney or kidneys

renal fossa—the region where the kidney is located in the abdomen

renal hamartoma—see angiomyolipoma

renal hemangioma—a benign renal mass that consists of blood vessels

renal hematoma—a collection of blood on or around the kidney that is typically associated with some form of trauma or perhaps an invasive kidney procedure

renal infarction—an area in the kidney that becomes necrotic because of a lack of oxygen

renal lipoma—a fatty tumor on the kidney

renal medulla—the inner part of the renal parenchyma that is responsible for absorption

renal pelvic diameter—measurement of the fetal renal pelvis; this dimension is obtained from the transverse kidney plane

renal pelvis—the funnel-shaped collecting system in the central portion of the kidney that allows urine to flow from the kidney to the ureter

renal pyramids—cone-shaped structures located within the renal medulla that contains part of the nephron

renal sinus—the portion of the kidney containing the minor calices, major calices, renal pelvis, and infundibula

renal vein thrombosis—a blood clot located within the renal vein

renal:aorta ratio—a ratio calculated by dividing the highest renal artery velocity by the highest aortic velocity obtained at the level of the renal arteries

renin—enzyme produced by the kidneys that helps regulate blood pressure

renunculi—the two embryonic parenchymal tissue masses that combine to create the kidney; singular form is renunculus

retained products of conception—when additional placental tissue remains within the uterus after the bulk of the placenta has been delivered

rete testis—a network of tubules that carry sperm from the seminiferous tubules to the epididymis

retroflexion—the uterine body tilts backward and comes in contact with the cervix, forming an acute angle between the body and the cervix

retroperitoneal fibrosis—a disease characterized by the buildup of fibrous tissue within the retroperitoneum; this mass may involve the abdominal aorta, inferior vena cava, ureters, and sacrum

retroperitoneal hematoma—a bloody tumor located within the retroperitoneum

retroperitoneal lymphadenopathy—the enlargement of the abdominal lymph nodes located within the abdomen

retroperitoneal—posterior to the peritoneum

retroversion—the uterine body tilts backward, without a bend where the cervix and body meet

reverberation artifact—an artifact that results from a sound wave interacting with a large acoustic interface that repeatedly bounces back and forth from the interface to the transducer

rhabdomyoma—a fetal heart tumor found within the myocardium

rhizomelia—shortening of the proximal segment of a limb

rhombencephalon—the primary brain vesicle also referred to as the hindbrain; it eventually becomes the cerebellum, pons, medulla oblongata, and fourth ventricle

Riedel lobe—a tonguelike extension of the right hepatic lobe

ring-down artifact—artifact seen posterior to air or gas bubbles

rockerbottom feet—abnormal curved shape of the sole of the feet

Rokitansky–Aschoff sinuses—tiny pockets within the gallbladder wall

saccular aneurysm—a saclike dilation of a blood vessel

sacral agenesis—the nondevelopment of the sacrum; see key term caudal regression syndrome

sacral dimple—an opening in the skin over the distal spine

saline infusion sonography—see key term saline infusion sonohysterography

saline infusion sonohysterography—a sonographic procedure that uses saline instillation into the endometrial cavity and possibly the fallopian tubes to evaluate for internal abnormalities; also referred to as sonohysterography

saliva—fluid produced by the salivary glands which aids in digestion

salpingitis—inflammation of the fallopian tube

sandal gap—a large space between the first and second toes

sandwich sign—the sign associated with abnormal abdominal lymph node enlargement that leads to the compression of the aorta and inferior vena cava

sarcoidosis—a systemic disease that result in the development of granulomas throughout the body

scaphocephaly—see key term dolichocephaly

schizencephaly—a cerebral malformation associated with the development of fluid-filled clefts

scintigraphy (thyroid)—nuclear medicine study in which a radiopharmaceutic is used to examine the thyroid gland

scoliosis—an abnormal lateral curvature of the spine

scrotal pearl—an extratesticular calculus

scrotum—sac of cutaneous tissue that holds the testicles

sebum—an oily substance secreted by the sebaceous glands

secondary amenorrhea— the cessation of menstruation characteristically diagnosed in the postmenarchal woman who has had at least 12 months without a menstrual cycle

secondary yolk sac—the structure responsible for early nutrient transfer to the embryo; the yolk sac seen during a sonographic examination of the early gestation

secretory phase—the second phase of the endometrial cycle

selective reduction—a method of reducing the number of pregnancies in a multiple gestation, whereby certain embryos/fetuses are terminated

semen—a fluid that contains secretions from the testicles, seminal vesicles, and prostate gland

seminal vesicles—small glands located superior to the prostate gland and posterior to the base of the bladder, which secrete an alkaline-based fluid

seminiferous tubules—the location of spermatogenesis within the testicles

seminoma—the most common malignant neoplasm of the testicles

sepsis—a life-threatening condition caused by the body's response to a systemic infection

septate uterus—common congenital malformation of the uterus that results in a single septum that separates two endometrial cavities

septate uterus—congenital malformation of the uterus that results in a single septum that separates two endometrial cavities

septation—a partition separating two or more cavities

septations—separations; structures that divide something into separate sections

sequela—an illness resulting from another disease, trauma, or injury

sequela—an illness resulting from another disease, trauma, or injury

serosal fluid—fluid that is secreted by the serous membranes to reduce friction in the peritoneal and other cavities of the body

serosal layer (uterus)—the outermost layer of the uterus; may also be

referred to as the perimetrium

serpiginous—twisted or snakelike pattern

Sertoli–Leydig cell tumor—malignant sex cord-stromal ovarian neoplasm that is associated with virilization

serum lactate dehydrogenase—tumor marker that is elevated in the presence of an ovarian dysgerminoma and other abdominal abnormalities

sex cord-stromal tumors—ovarian tumors that arise from the gonadal ridges

shotgun sign—the enlargement of the common duct to the size of the adjacent portal vein within the porta hepatis; also referred to as the parallel tube sign

shoulder dystocia—when the shoulder of the fetus cannot pass through the birth canal during pregnancy

sialadenitis—inflammation of the salivary gland or glands

sialadenosis—benign, painless enlargement of a salivary gland or glands

sialolithiasis—salivary duct stones

sickle cell anemia—an inherited disease in which the body produces abnormally shaped red blood cells

sickle cell disease—form of hemolytic anemia typically found in Africans or people of African descent; characterized by dysfunctional sickle-shaped red blood cells

signs—an objective evidence of a disease such as abnormal laboratory findings and fever

simple cyst—an anechoic, round mass that has smooth walls and demonstrates through transmission

singleton pregnancy—a single developing fetus

sirenomelia—a fetal abnormality characterized by fusion of the lower extremities, renal agenesis, and oligohydramnios; may also be referred to as mermaid syndrome

sirenomelia—a fetal abnormality characterized by fusion of the lower extremities, renal agenesis, and oligohydramnios; may also be referred to as mermaid syndrome

situs inversus—condition in which the organs of the abdomen and chest are on the opposite sides of the body (e.g., the liver is within the left upper

quadrant instead of the right upper quadrant)

Sjögren syndrome—an autoimmune disease that affects all glands that produce moisture, leading to dysfunction of the salivary glands and severe dryness of the eyes, nose, skin, and mouth

small bowel ischemia—a condition resulting in interruption or reduction of the blood supply to the small intestines

sonographic findings—information gathered by performing a sonographic examination

sonohysterogram—a sonographic procedure that uses saline instillation into the endometrial cavity and fallopian tubes to evaluate for internal abnormalities

sonohysterography—a sonographic procedure that uses saline instillation into the endometrial cavity and fallopian tubes to evaluate for internal abnormalities

space of Retzius—the space between the urinary bladder and the pubic bone; also referred to as the retropubic space

spermatic cord—the structure that travels through the inguinal canal and contains blood vessels, nerves, lymph nodes, and the cremaster muscle

spermatocele—a common cyst found most often in the head of the epididymis that is composed of nonviable sperm, fat, cellular debris, and lymphocytes

spermatogenesis—the production of sperm

sphincter of Oddi—the muscle that controls the emptying of bile and pancreatic juices into the duodenum; also referred to as the hepatopancreatic sphincter

spina bifida aperta—most common form of spina bifida; results in open lesions that are typically not covered by skin and a mass that protrudes from the spine; also referred to as open spina bifida

spina bifida occulta—closed spinal lesions are completely covered by skin and can be difficult to identify sonographically; also referred to as closed spina bifida

spina bifida—a birth defect in which there is incomplete closure of the spine

spinal dysraphism—a group of neural tube defects that describe some manifestation of incomplete closure of the spine

spiral arteries—tiny, coiled arteries that supply blood to the functional layer

of the endometrium

spiral valves of Heister—folds located within the cystic duct that prevent it from collapsing and distending

splay—turned outward

splenic cleft—a congenital anomaly in which the spleen is divided into two portions by a band of tissue

splenic hamartoma—benign splenic mass that has been associated with Beckwith–Weidemann syndrome and tuberous sclerosis

splenic infarct—an area within the spleen that has become necrotic because of a lack of oxygen

splenic lymphangioma—benign tumor composed of lymph spaces

splenic torsion—the twisting of the splenic vasculature causing a disruption in the blood supply to the spleen and subsequent ischemia

splenomegaly—enlargement of the spleen

splenosis—the implantation of ectopic splenic tissue possibly secondary to splenic rupture

splenule—an accessory spleen

spontaneous abortion—the loss of a pregnancy before 20 gestational weeks

staghorn calculus—a large urinary stone that completely fills and takes the shape of the renal pelvis

standoff pad—a gel pad that is used to provide some distance between the transducer face and the skin surface, allowing superficial structures to be imaged more clearly

starry sky sign—the sonographic sign associated with the appearance of periportal cuffing in which there is an increased echogenicity of the walls of the portal triads

steatohepatitis—a type of fatty liver disease that causes inflammation of the liver

Stein–Leventhal syndrome—see key term polycystic ovary syndrome

Stensen duct—the main duct of the parotid gland

stillborn—dead at birth

straight arteries—uterine radial artery branch that supplies blood to the basal layer of the endometrium

striae—stretch marks

"string of pearls" sign—sonographic finding that is described as the presence of 10 or more small cysts measuring 2 to 18 mm along the periphery of the ovary

stuck twin—when a twin fetus, suffering from twin–twin transfusion syndrome, experiences severe oligohydramnios and is closely adhered to the uterine wall

subarachnoid space—an area located between the arachnoid membrane and the pia mater

subchorionic hemorrhage—a bleed between the endometrium and the gestational sac at the edge of the placenta

subcutaneous edema—a buildup of fluid under the skin

subependymal (layer)—the area just beneath the ependymal lining the lateral ventricles

subluxation—partial dislocation of the hip

submucosal (fibroid)—a leiomyoma that distorts the shape of the endometrium

subseptate uterus—congenital malformation of the uterus that results in a normal uterine contour with an endometrium that branches into two horns

subserosal (fibroid)—location of a leiomyoma in which the tumor grows outward and distorts the contour of the uterus

subureteral Teflon injection—a treatment method for vesicoureteral reflux disease that uses a bulking agent to elevate the ureteral orifice and distal ureter, allowing for the normal flow of urine from the ureter into the bladder

succenturiate lobe—an accessory lobe of the placenta

sulci—grooves within the brain

superficial epidermal cyst—cysts commonly found in the scalp, face, neck, trunk, or back; they can be congenital, the result of trauma, or the result of an obstructed hair follicle

supine hypotensive syndrome—a reduction in blood return to the maternal heart caused by the gravid uterus compressing the maternal inferior vena cava

suppurative cholecystitis—complication of acute cholecystitis characterized by pus accumulation within the gallbladder

suprarenal glands—another name for the adrenal glands

suspensory ligament of the ovary—pelvic ligament that provides support to the ovary and extends from the ovaries to the pelvic side walls

suture (skull)—a flexible, connective tissue that lies between the cranial bones

symptoms—any subjective evidence of a disease such as nausea, weakness, or numbness

syncytiotrophoblastic cells—the trophoblastic cells surrounding the blastocyst that are responsible for producing human chorionic gonadotropin

syndactyly—webbed fingers or toes

syndrome—a group of clinically observable findings that exist together and allow for classification

synechiae—adhesion

tachycardia—abnormally rapid heart rate

talipes equinovarus—see key term clubfoot

tamoxifen—a breast cancer drug that inhibits the effects of estrogen in the breast

tardus–parvus—the combination of a slow systolic upstroke and a decreased systolic velocity

tendosynovitis—inflammation of the tendon and synovial tendon sheath

teratoma—a tumor that typically consists of several germ cell layers

testicular torsion—a condition that results from the arterial blood supply to the testicle being cut off secondary to the twisting of the testicular axis

tetralogy of Fallot—a group of abnormalities consisting of an overriding aortic root, ventricular septal defect, pulmonary stenosis, and right ventricular hypertrophy

thalamus—a brain structure that allows communication between the senses; also performing many other functions

thanatophoric dysplasia—the most common lethal skeletal dysplasia characterized by a cloverleaf skull with frontal bossing and hydrocephalus

theca internal cells—cells of the follicle that produce estrogen

theca lutein cysts—functional ovarian cysts that are found in the presence of elevated levels of human chorionic gonadotropin; also referred to as a theca

luteal cysts

thecoma—benign ovarian sex cord-stromal tumor that produces estrogen in older women

therapeutic amniocentesis—type of amniocentesis used to remove a large amount of amniotic fluid around a fetus suffering from polyhydramnios

Thompson test—clinical test used to evaluate for a complete tear of the Achilles tendon

thoracentesis—a procedure that uses a needle to drain fluid from the pleural cavity for either diagnostic or therapeutic reasons

thoracopagus—conjoined twins attached at the chest

three-line sign—the periovulatory endometrial sonographic appearance in which the outer echogenic basal layer surrounds the more hypoechoic functional layer, with the functional layer is separated by the echogenic endometrial stripe

thromboembolism—the formation of clot within a blood vessel with the potential to travel to a distant site and cause an occlusion

thrombus—blood clot

thymus gland—gland of the immune and lymphatic system located in the chest

thyroglossal duct cyst—benign congenital cysts located within the midline of the neck superior to the thyroid gland and near the hyoid bone

thyroglossal duct—the embryonic duct that is located from the base of the tongue to the midportion of the anterior neck

thyroid in the belly sign—the sonographic appearance of the hyperechoic edematous connective tissue that surrounds the inflamed appendix

thyroid inferno—the sonographic appearance of hypervascularity demonstrated with color Doppler imaging of the thyroid gland

thyroidectomy—the surgical removal of the thyroid or part of the thyroid

"tip of the iceberg" sign—denotes the sonographic appearance of a cystic teratoma (dermoid) when only the anterior element of the mass is seen, while the greater part of the mass is obscured by shadowing

TORCH infections—an acronym that stands for toxoplasmosis, other infections, rubella, cytomegalovirus, and herpes simplex virus; this group of infections may be acquired by a woman during pregnancy

torsion—twisting

torticollis—twisted neck

total abdominal hysterectomy—the removal of the uterus and cervix

total parental hyperalimentation—procedure in which an individual receives vitamin and nutrients through a vein, often the subclavian vein

total parenteral nutrition—the feeding of a person intravenously

trabeculae—muscular bundles

tracheoesophageal fistula—an abnormal connection between the esophagus and the trachea

transitional cell carcinoma—a malignant tumor of the urinary tract that is often found within the urinary bladder or within the renal pelvis

transitional zone—the prostatic zone that is the most common site for benign prostatic hypertrophy

transjugular intrahepatic portosystemic shunt (TIPS)—the therapy for portal hypertension that involves the placement of a stent between the portal veins and hepatic veins to reduce portal systemic pressure

translabial sonogram—sonogram that requires the transducer be placed against the labia; often used for imaging of the cervix

transposition of the great vessels—abnormality in which the pulmonary artery arises from the left ventricle and the aorta arises from the right ventricle

transudate ascites—a collection of abdominal fluid within the peritoneal cavity often associated with cirrhosis

transurethral resection of the prostate—surgical procedure performed to treat benign prostatic hypertrophy in which prostatic tissue is removed to relieve urinary complications

trichobezoars—a bezoar that consists of matted hair

tricuspid regurgitation—the leakage of blood back through the tricuspid valve

trident hand—a wide separation between the middle and ring finger

trigone of the urinary bladder—the area within the urinary bladder where the two ureteral orifices and urethral orifice are located

triphasic—vascular flow yielding three phases

triple screen—a maternal blood test that typically includes an analysis of human chorionic gonadotropin, alpha- fetoprotein, and estriol

triploid—having three sets of each chromosome or 69 total

triploidy—a fetus that has three of every chromosome

trisomy—a cell having three copies of an individual chromosome

trisomy 8—chromosomal aberration in which there is a third chromosome 8; also referred to as Warkany syndrome 2

trisomy 13—chromosomal aberration in which there is a third chromosome 13; also referred to as Patau syndrome; often associated with holoprosencephaly

trisomy 18—chromosomal aberration in which there is a third chromosome 18; also referred to as Edwards syndrome

trisomy 21—chromosomal aberration in which there is a third chromosome 21; also referred to as Down syndrome

trophoblastic cells—the cells that surround the gestation that produce human chorionic gonadotropin

true aneurysm—the enlargement of a vessel that involves all three layers of the wall

true lumen—the true or original channel within a vessel

true pelvis—inferior portion of the pelvis that contains the uterus, ovaries, fallopian tubes, urinary bladder, small bowel, sigmoid colon, and rectum

tubal ligation—a permanent form of female sterilization in which the fallopian tubes are severed

tubal sterilization—see key term tubal ligation

tuberous sclerosis—a systemic disorder that leads to the development of tumors within various organs

tubo-ovarian abscess—a pelvic abscess involving the fallopian tubes and ovaries that is often caused by pelvic inflammatory disease

tubo-ovarian complex—when adhesions develop within the pelvis that leads to the fusion of the ovaries and the dilated tubes as a result of pelvic inflammatory disease

tubular ectasia of the rete testis—the cystic dilation and formation of cysts within the rete testis

tumefactive sludge—thick sludge

tumor markers—substances produced by cancer cells or organs in response to cancer

tunica adventitia—the outer wall layer of a vessel

tunica albuginea cysts—cysts located within the tunica albuginea surrounding the testis

tunica albuginea—the dense connective tissue that is closely applied to each testicle; it is also located within the penis

tunica dartos—the structure that separates the scrotum into two separate compartments internally

tunica intima—the inner wall layer of a vessel

tunica media—the middle, muscular layer of a vessel

tunica vaginalis—the paired serous coatings of the testis; hydroceles are most often found between the two layers of the tunica vaginalis

Turner syndrome—a chromosomal aberration where one sex chromosome is absent; may also be referred to as monosomy X

twin embolization syndrome—when vascular products travel from a demised twin to the surviving twin by means of the common vascular channels within the shared placenta

twin peak sign—see key term lambda sign

twinkle sign—an artifact noted as an increased color Doppler signal posterior to a kidney stone or biliary stone

twin-reversed arterial perfusion sequence—another name for acardiac twinning

twin–twin transfusion syndrome—shunting of venous or arterial blood from one twin to another through placental circulation

two-vessel cord—an umbilical cord with one artery and one vein; could possibly be associated with other fetal abnormalities and intrauterine growth restriction

ulcerative colitis—an inflammatory bowel disease that leads to the development of ulcers within the bowel

umbilical arteries—two vessels of the umbilical cord that carry deoxygenated blood from the fetus to the placenta

umbilical vein varix—focal dilatation of the intra-abdominal portion of the umbilical vein

umbilical vein—the vessel of the umbilical cord that carries oxygenated blood from the placenta to the fetus

uncinate process—a posteromedial extension of the pancreatic head

undescended testis—testicles that do not descend into the scrotum; also referred to as cryptorchidism

unicornuate uterus—congenital malformation of the uterus that results in a uterus with one horn

unilocular—having a single cavity

upper genital tract—the uterus, ovaries, and fallopian tubes

urachus—canal connecting the fetal bladder with the allantois; normally closes during fetal development and becomes a fibrous cord

ureteral jets—jets of urine that are the result of urine being forced into the urinary bladder from the ureters; can be demonstrated with color Doppler imaging

ureterocele—an abnormality in which the distal ureter projects into the urinary bladder

ureteropelvic junction obstruction—an obstruction located in the region where the ureter meets the renal pelvis

ureteropelvic junction—the junction of the ureter and the renal pelvis

ureterovesicular junction obstruction—an obstruction located in the region where the ureter meets the bladder

ureterovesicular junction—the junction of the ureter and urinary bladder

urethral atresia—the congenital absence of the urethra

urethritis—inflammation of the urethra

urinoma—a localized collection of urine

urolithiasis—a urinary stone

uterine arteries—branches of the internal iliac artery that supplies blood to the uterus, ovaries, and fallopian tubes

uterine artery embolization—procedure used to block the blood supply to a leiomyoma (fibroid)

uterine leiomyoma—a benign, smooth muscle tumor of the uterus; may also be referred to as a fibroid or uterine myoma

uterine myoma—see key term leiomyoma

uterus didelphys—congenital malformation of the uterus that results in the complete duplication of the uterus, cervix, and vagina

VACTERL association—an acronym for a combination of abnormalities that represent vertebral anomalies, anorectal atresia, cardiac anomalies, tracheoesophageal fistula, renal anomalies, and limb anomalies; may also be referred to as VATER association

vaginal atresia—occlusion or imperforation of the vagina; can be congenital or acquired

vaginal cuff—the portion of the vagina remaining after a hysterectomy

vaginal fornices—recesses of the vagina

vaginitis—inflammation of the vagina

Valsalva maneuver—performed by attempting to forcibly exhale while keeping the mouth and nose closed

Valsalva technique—performed by attempting to forcibly exhale while keeping the mouth and nose closed

vanishing twin—the death and reabsorption of a twin

varicocele—a dilated group of veins found within the scrotum

vasa previa—fetal vessels resting over the internal os of the cervix

vasectomy—a form of male contraception in which the vas deferens is surgically interrupted to prohibit the flow of sperm from the testicles

vein of Galen aneurysm—an arteriovenous malformation that occurs within the fetal brain and is associated with congestive heart failure

velamentous cord insertion—the abnormal insertion of the umbilical cord into the membranes beyond the placental edge

venous lakes—pools of maternal blood within the placental substance

ventricular septal defect—an opening within the septum that separates the right and the left ventricles

ventriculomegaly—buildup of cerebrospinal fluid that results in an enlargement of one or more of the ventricles within the brain

vermiform appendix—a blind-ended tube that is connected to the cecum of the colon

vernix—protective fetal skin covering

verumontanum—an elevated area within the prostatic urethra at which the

ejaculatory ducts meet the urethra

vesicoureteral junction—see key term ureteropelvic junction

vesicoureteral reflux—the abnormal retrograde flow of urine from the urinary bladder into the ureter and possibly into the kidney(s)

vesicouterine pouch—peritoneal outpouching located between the bladder and the uterus; also referred to as the anterior cul-de-sac

virilization—changes within the female that are caused by increased androgens; may lead to deepening of the voice and hirsutism

visceral peritoneum—the portion of the peritoneum that is closely applied to each organ

vitelline duct—the structure that connects the developing embryo to the secondary yolk sac

voiding cystourethrogram—a radiographic examination that involves the assessment of the urinary bladder and distal ureter for urinary reflux and other abnormalities

volvulus—a situation in which a loop of bowel twists upon itself

von Gierke disease—condition in which the body does not have the ability to break down glycogen; also referred to as glycogen storage disease type 1

von Hippel–Lindau disease—a inherited disease that includes the development of cysts within the liver, pancreas, and other organs

von Hippel–Lindau syndrome—an inherited disorder characterized by tumors of the central nervous system and the development of cysts within the kidneys, renal cell carcinoma, and pheochromocytomas

wall-echo-shadow sign—shadowing from the gallbladder fossa produced by a gallbladder that is completely filled with gallstones

wandering spleen—a highly mobile spleen

Wharton duct—the duct that drains the submandibular gland

Wharton jelly—gelatinous material that is located within the umbilical cord around the umbilical vessels

Whipple procedure—see pancreaticoduodenectomy

"whirlpool" sign—an indicator of the torsed ovarian pedicle adjacent to the ovary, appearing as a round mass with concentric hypoechoic and hyperechoic rings that demonstrates a swirling color Doppler signature

white pulp—specialized lymphatic tissue within the spleen

Wilms tumor—the most common solid malignant pediatric abdominal mass; a malignant renal mass that may also be referred to as nephroblastoma

Wilson disease—a congenital disorder that causes the body to accumulate excess copper

xanthogranulomatous pyelonephritis—a rare chronic form of pyelonephritis that is typically the result of a chronic obstructive process

yolk sac tumor—(ovary) malignant germ cell tumor of the ovary

Zinner syndrome—syndrome that consists of unilateral renal agenesis, ipsilateral seminal vesicle cyst, and ejaculatory duct obstruction

Zollinger–Ellison syndrome—the syndrome that includes an excessive secretion of acid by the stomach caused by the presence of a functional gastrinoma within the pancreas

zygosity—relates to the number of zygotes (fertilized ova)

zygote intrafallopian transfer—infertility treatment where the zygote is placed into the fallopian tube

zygote—the cell formed by the union of two gametes; the first stage of a fertilized ovum

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Chapter 32

Figure 32-1. From Doubilet PM, Benson CB. Atlas of Ultrasound in Obstetrics and Gynecology. 2nd Ed. Philadelphia, PA: Wolters Kluwer, 2011. Figure 3-3.1.

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