ESSENTIALS OF RADIOLOGY

Third Edition

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Radiology receives little attention in most medical school curricula except perhaps as an elective. The classic gross anatomy laboratory is dead, and most health care providers encounter human internal anatomy and function through radiology. This text is not meant to make you into a radiologist or to be just a text for a radiology medical student elective. It is intended to be a text that will provide a basis for radiologic anatomy, imaging fundamentals, and common clinical problems and to be a book that you will keep and use in your future practice. Since the first edition, this text has been widely used by medical students, nurse practitioners, physician assistants, primary care physicians, and first-year radiology residents.

With a basic text containing fundamentals, one may wonder why a third edition is needed. Even though many aspects of radiology have remained unchanged over the past decade, rapid and significant changes have occurred in both technology and applications.

With digital imaging systems and rapid dictation with voice recognition technology, there is much less reason for a physician to visit the radiology department. In-person consultations with radiologists have become rare. Greater expertise in radiology will be required because medical students, residents, and others will be examining digital images at sites remote from the radiology department.

Uses of computed tomography (CT) scanning have significantly expanded. CT scanners are now capable of imaging large portions of the body in a few seconds. Applications that previously could not be performed, because of patient or organ motion, now are no problem. CT scans are rapidly replacing most plain films of the abdomen and have completely replaced intravenous pyelograms and a number of nuclear medicine procedures. All of this has added significant radiation dose to the U.S. population, and unnecessary radiation dose has become a matter of concern.

With the coming changes to our health care system, it will be even more important to order and use imaging studies wisely, efficiently, and appropriately. Information has been added on the appropriate workup of common clinical problems such as headache, hypertension, and low back pain. Information is also included on current screening guidelines. I have endeavored to include this information without expanding the total volume of the text and yet retaining the essentials. Because readers often have questions about the cost and radiation dose associated with common examinations, this information has been retained in the appendix.

Fred A. Mettler, Jr.
I thank my colleagues, especially Charles Hickam, MD; Blaine Hart, MD; and Josh Robertson, MD, for helpful comments and for providing a number of the images. I would also like to thank RuthAnne Bump for advice with images.
Introduction

AN APPROACH TO IMAGE INTERPRETATION

The first step in medical imaging is to examine the patient and determine the possible cause of his or her problem. Only after this is done can you decide which imaging study is the most appropriate. A vast number of algorithms or guidelines have been developed, but no definite consensus exists on the “right” one for a given symptom or disease because a number of imaging modalities have similar sensitivities and specificities. In this text I provide tables of appropriate initial imaging studies for various clinical situations. When possible, these tables are based on the published literature and recommendations of professional societies. When this is not possible, I give you my opinion based on 40 years of clinical practice.

What should you expect from an imaging examination? Typically one expects to find the exact location of a problem and hopes to make the diagnosis. Although some diseases present a characteristic picture, most can appear in a variety of forms depending on the stage. As a result, image interpretation will yield a differential diagnosis that must be placed in the context of the clinical findings.

Examination of images requires a logical approach. First you must understand the type of image, the orientation, and the limitations of the technique used. For example, I begin by mentally stating, “I am looking at a coronal computed tomography (CT) scan of the head done with intravenous contrast.” This is important, because intravenous contrast can be confused with fresh blood in the brain.

Next I look at the name and age on the image label to avoid mixing up patients, and it allows making a differential diagnosis that applies to a patient of that age and sex. You would not believe the number of times that this seemingly minor step will keep you from making dumb mistakes.

The next step is to determine the abnormal findings on the image. This means that you need to know the normal anatomy and variants of that particular part of the body as well as their appearance on the imaging technique used. After this, you should describe the abnormal areas, because a number of imaging modalities have similar sensitivities and specificities. In this text I provide tables of appropriate initial imaging studies for various clinical situations. When possible, these tables are based on the published literature and recommendations of professional societies. When this is not possible, I give you my opinion based on 40 years of clinical practice.

After reviewing the common causes of the imaging findings that you have observed, you should reorder the causes in light of the clinical findings. At this point, you probably think that you are finished. Not so. Often a plethora of information is contained in the patient’s image files or in the hospital computer information system. This comes in the form of previous findings and histories supplied for the patient’s other imaging examinations. Reviewing the old reports has directed me to areas of pathology on the current image that I would have missed if I had not looked into the medical information system. A simple example is a pneumonia that has almost but not completely resolved or a pulmonary nodule that, because of inspiratory difference, is hiding behind a rib on the current examination.

You probably think that you are finished now. Wrong again. A certain number of entities could cause the findings on the image, but you just have not thought of them all. After I have finished looking at a case, I try to go through a set sequence of categories in search of other differential possibilities. The categories I use are congenital, physical/chemical, infectious, neoplastic, metabolic, circulatory, and miscellaneous.

X-RAY

Regular x-rays (plain x-rays, also sometimes called radiographs) account for about 75% of imaging examinations. X-ray examinations, or plain x-rays, are made by an x-ray beam passing through the patient. The x-rays are absorbed in different amounts by the various tissues or materials in the body. Most of the beam is absorbed or scattered. This represents deposition of energy in the tissue but does not cause the patient to become radioactive or to emit radiation. A small percentage of the incident radiation beam exits the patient and strikes a detector.

The historical imaging receptor was a film/screen combination. The x-ray beam would strike a fluorescent screen, which produced light that exposed the film, and then the

“viral cardiomyopathy” in a patient who really has a malignant pericardial effusion.

After practicing for 20 years or so, a radiologist knows the spots where pathology most commonly is visualized. Throughout this text, I point out the high-yield areas for the different examinations. Although no absolute rules exist, knowing the pathology and natural history of different diseases will help you. For example, colon cancer typically metastasizes first to the liver rather than the lungs, whereas sarcomas preferentially metastasize to the lungs rather than the liver.

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Without these, mistakes can easily be made. You must remember that an object visualized on a specific view is somewhere in the path of the x-ray beam (not necessarily in the patient). If an object projects outside the patient on any view, it is outside the patient. However, even if an object projects within the patient on two orthogonal views, it can still be located outside the patient (Figs. 1-2 and 1-3). Each additional view needed to make a diagnosis requires an additional x-ray exposure and therefore adds to the patient’s radiation dose. Radiation doses from various examinations are given in the Appendix.

The terminology used to describe images is usually quite straightforward. Chest and abdominal radiographs are referred to as upright or supine, depending on the position of the patient. In addition, chest x-rays are usually described as posteroanterior (PA) or anteroposterior (AP) (Fig. 1-4). These terms indicate the direction in which the x-ray beam traversed the patient on its way to the detector. PA means that the beam direction through the patient was anterior to posterior. A left lateral decubitus view is one taken with the patient’s left side down.

**FIGURE 1-1** The four basic densities on an x-ray. A lateral view of the forearm shows that the bones are the densest, or white; soft tissue is gray; fat is somewhat dark; and air is very dark. The abnormality in this case is the fat in the soft tissue of the forearm, which is due to a lipoma.

**FIGURE 1-2** Spatial localization on an x-ray. On both antero-posterior (AP) and lateral projections, the square and round objects will be seen projecting within the view of the chest, even though the square object is located outside the chest wall. If you can see an object projecting outside the chest wall on at least one view (the triangle), it is outside the chest. If, however, an object looks as though it is inside the chest on both views, it may be either inside or outside.
Use of contrast agents permits visualization of anatomic structures that are not normally seen. For example, intravenous or intra-arterially injected agents allow visualization of blood vessels (Fig. 1-5). If imaging is done with standard format, the blood vessels appear white. Digital imaging allows subtraction or removal of unwanted structures, such as the bones, from an image (see Fig. 1-5, B). Often the computer manipulation is done in such a way that the arteries may appear black instead of white, although this usually does not present a problem in interpretation.

Contrast agents are used to fill either a hollow viscus (such as the stomach) or anatomic tubular structures that can be accessed in some way (such as blood vessels, ureter, and common bile duct). When you see an abnormality on one of these studies, you must determine whether the location is intraluminal, mural, or extrinsic. This usually requires seeing the abnormality in perpendicular views (Fig. 1-6). Unless you are careful about this determination, you will make errors in diagnosis.

Contrast agents instilled orally, rectally, or retrograde into the ureter or bladder incur little or no risk unless aspiration or perforation occurs. With the intravenously or intra-arterially administered agents, a small but real risk for contrast reaction exists. This is something that you should consider before ordering a contrast-enhanced CT scan. About 5% of patients will experience an immediate mild reaction, such as a metallic taste or a feeling of warmth; some experience nausea and vomiting, wheeze, or get hives as a result of these contrast agents. Some of these mild reactions can be treated with 50 mg of intramuscular diphenhydramine (Benadryl). Because contrast agents also can reduce renal function, they should not generally be used in patients with compromised renal function (estimated glomerular filtration rate [eGFR] <50 to 60 mL/min).

Position is important to note, because it can affect magnification, organ position, and blood flow and therefore significantly affect image interpretation. For example, the heart appears larger on AP than on PA images because on an AP projection the heart is farther from the detector and is magnified more by the diverging x-ray beam. It also appears larger on supine than on upright images because the hemidiaphragms are pushed up, making the heart appear wider. Portable chest images are taken not only in the AP projection but also with the tube closer to the patient than on standard upright images. This magnifies the heart even more.

**FIGURE 1-3** What is the location of the keys? On both the posteroanterior (PA) view of the chest (A) and the lateral view (B), the keys seem to be within the center of the chest. Actually if you look carefully, you will notice that the keys do not change position at all, even though the patient has rotated 90 degrees. The keys are located on the receptor cassette and are not in the patient.

**FIGURE 1-4** Typical x-ray projections. X-ray projections are typically listed as anteroposterior (AP) or posteroanterior (PA). This depends on whether the x-ray beam passed to the patient from anterior to posterior (AP) or the reverse. Lateral (LAT) and oblique (OBL) views also are commonly obtained.
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COMPUTED TOMOGRAPHY

CT is accomplished by passing a rotating fan beam of x-rays through the patient and measuring the transmission at thousands of points. The data are handled by a computer that calculates exactly what the x-ray absorption was at any given spot in the patient. The data can be manipulated in a number of ways, displayed on a screen, or photographed. Because the data points are in the computer memory, it is possible to “window” the data and obtain a number of images without additional radiation exposure (Fig. 1-7).

About 1 in 1000 patients have a severe reaction to intravascular contrast. This may be a vasovagal reaction, laryngeal edema, severe hypotension, an anaphylactic-type reaction, or cardiac arrest. A vasovagal reaction can be treated with 0.5 to 1.0 mg of intravenous atropine. The most important initial therapeutic measures in these severe reactions are to establish an airway, ensure breathing and circulation, and give intravenous fluids. Other drugs obviously also may be necessary. The risk for death from a study using intravenously administered contrast agents is between 1 in 40,000 and 1 in 100,000.

FIGURE 1-5 Pulmonary angiogram. A conventional view of blood vessels can be obtained by injecting iodinated contrast material into the vessels (A). On these images the vessels will appear white, and the bones will be seen as you would normally expect (white). A digital subtraction technique with computers may show the vessels either as black (B) or as white, but the bones will have been subtracted from the image.

FIGURE 1-6 Appearances of different lesions depending on their location when using contrast. Contrast medium is used to visualize tubular structures, including the spinal canal, blood vessels, gastrointestinal tract, ureters, and bladder. Intraluminal lesions (A), such as stones or blood clots within the lumen of the given structure, produce a central defect on both anteroposterior (AP) and lateral projections. On the AP and lateral views the contrast will show acute angles on both sides and in both projections. Intramural lesions (B) will produce a defect that indents the column of contrast. When seen tangentially, an acute angle will appear between the normal wall and the beginning of the indentation. Extramural lesions (C) also can indent the wall, but at the point of indentation, the angle will be somewhat blunted as compared with the intramural lesion.
The computers can even display the data as a three-dimensional rotating image, although this is rarely necessary for diagnosis. Compared with plain x-rays, CT uses about 10 to 100 times more radiation.

On early CT scanners the x-ray tube rotated around the patient to obtain a single “slice,” and then the table was moved incrementally before another slice was obtained. Newer scanners allow the x-ray tube to stay on and rotate at the same time that the table is moving. This is called a **spiral scanner** or **helical scanner**. The most modern scanners not only have the helical motion but also have multiple rows of detectors and can obtain more than 100 image data slices at once.

The appearance of tissues on CT scan depends to some extent on the computer manipulation, but in general the basic four densities on CT images are the same as those in plain x-rays: air is black, fat is dark gray, soft tissue is light gray, and bone or calcium and contrast agents are white. One advantage of CT is that actual x-ray absorption of a specific tissue can be displayed. The units used are Hounsfield units. The Hounsfield density of water is zero. The greater sensitivity of CT compared with plain x-rays allows areas of tiny punctate calcification to be seen.

CT scans are presented as a series of slices of tissue. The method is similar in principle to slicing a loaf of bread and pulling up one slice at a time to examine it. Thus CT is a two-dimensional display of two-dimensional information, and objects appear where they really are in space. The scans or slices are shown as if you are viewing the patient from the foot of the patient’s bed. Thus the individual’s right side is on your left (Fig. 1-8). This also is the convention used for the transverse images of ultrasound and magnetic resonance imaging (MRI).

Contrast agents, frequently used in CT scans, are usually the same water-soluble oral, rectal, or intravenous iodinated agents used in other imaging studies. Intravenous contrast agents are common, being used in probably 75% of all CT studies, and obviously carry the risk for contrast reactions discussed previously. Rapid acquisition of images allows the intravenously administered contrast to be displayed and images acquired in arterial, venous, or delayed phases with only a single injection.

The appeal of CT is that a large number of structures are visualized simultaneously. In a patient with abdominal pain, one CT examination shows the liver, adrenal glands, kidneys, spleen, aorta, pancreas, and other structures. This allows the clinician to identify macroscopic pathology quickly.

**ULTRASOUND**

Ultrasound examination uses high-frequency sound waves to make images. The technology is that of sonar or a glorified fish finder used by fishermen. The image is made by sending high-frequency sound into the patient and assessing the magnitude and time of returning echoes. Echoes are the result of interfaces or changes in density. Typically a cyst has few if any echoes, because it is mostly water. Tissues such as liver and spleen give a picture with rather homogeneous small echoes caused by the fibrous interstitial tissue (Fig. 1-9). High-intensity echoes are caused by calcification, fat, and air.
The technology of ultrasound is attractive because it does not use ionizing radiation, and the machines are relatively inexpensive. For these reasons, ultrasound has found widespread use in obstetrics. The use of so-called real-time ultrasound allows the images to be seen in sequential frames just as in a movie. This capability has proved popular for imaging rapidly moving structures, such as the heart. Ultrasound images can be quite dependent on operator-set parameters, and the field of view within the patient is limited. Thus unless clear labels are placed relative to orientation, the images can be difficult or impossible for the novice to interpret. Ultrasound images are usually presented as white echoes on a black background. In addition to using echoes to generate images, the ultrasound equipment can analyze the returning echo frequencies. This Doppler analysis allows identification of moving blood as well as its direction and velocity. Examples of its use are to identify and quantitate stenoses of the carotid arteries or the direction of blood flow in the portal vein (Fig. 1-10).

**NUCLEAR MEDICINE**

Nuclear medicine images are made by giving the patient a short-lived radioactive material. The most commonly used radionuclides decay rapidly and have half-lives of only minutes or hours. Most materials administered are not detectable within a day or so after administration. With the attachment of a radionuclide (such as technetium 99m) to specific carrier compounds, concentration of the radioactivity can be imaged and measured in a chosen organ or tissue, such as the thyroid, bone, lung, heart, abscess, or tumor. Few, if any, significant patient reactions are found to radiopharmaceuticals used for diagnosis.

Nuclear medicine images are made by a gamma camera or positron emission scanner that records radiation emanating from the patient and makes an image of the distribution of the radioactive material (Fig. 1-11). The radiation dose to the patient is determined by the amount of radioactive material initially injected into the body. Therefore once the radiopharmaceutical has been given, additional images can be obtained without increasing the radiation dose. Images are usually obtained as planar images that, like plain x-rays, display three-dimensional data in two dimensions. These images are labeled as anterior, lateral,
The primary advantages of MRI are that it obtains exquisite images of the central nervous system and stationary soft tissues (such as the knee joint). It also does not use ionizing radiation. Recent developments and shorter imaging times have allowed images of the heart and blood vessels to be generated without the need to inject anything into the patient (Fig. 1-13).

Disadvantages of MRI have been artifacts caused by patient motion, the inability to bring ferrous objects near the magnet, and cost. The major safety problem with these magnets is that they are so strong that if you bring a ferromagnetic object (such as a wrench) into the room, it can accelerate to 150 miles per hour as it is ripped out of your hand and flies into the bore of the magnet. Large floor polishers have been sucked into magnets (Fig. 1-14). If a patient is in the machine at the time, lethal consequences will result. Be aware that some “sandbags” used for neck stabilization actually contain small BBs and can destroy magnets.

HYBRID IMAGING

Increases in computer power and advances in equipment manufacturing have allowed data imaging sets from various modalities to be combined and the images coregistered. The most popular use of this has been integration of positron emission tomography (PET) functional nuclear medicine data with CT anatomic data (PET/CT) (Fig. 1-15). This currently has wide use in the imaging of cancer. Other forms of hybrid imaging exist, including PET combined with MRI.

FIGURE 1-12 Magnetic resonance (MR) imaging of the brain. A wide variety of imaging parameters can make tissues appear vastly different. The two most common presentations are T1 images (A), in which fat appears white, water or cerebrospinal fluid (CSF) appears black, and brain and muscle appear gray. In almost all MR images, bone gives off no signal and will appear black. With T2 imaging (B), fat is dark, and water and CSF have a high signal and will appear bright or white. The brain and soft tissues still appear gray.
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**FIGURE 1-13** Magnetic resonance angiogram. An anterior view of the head showing intracerebral vessels, including the anterior cerebral artery (ACA) and the middle cerebral artery (MCA). These images were obtained without injection of any contrast agent.

**FIGURE 1-14** Floor polisher in a magnet. The high magnetic field strength of a magnetic resonance machine is shown by a heavy floor polisher sucked into the scanner. The polisher was inadvertently brought into the room by cleaning personnel. (Courtesy T. Haygood, MD.)

**FIGURE 1-15** PET/CT hybrid imaging. Positron emission tomography (PET) nuclear medicine data (A) and computed tomography (CT) data (B) can be coregistered to provide a single image combining both functional and anatomic information (C). In this case the patient has colon cancer with hepatic metastases, which were not easily seen on the CT scan alone.
**Suggested Textbooks and Website**

**General Radiology**

**Nuclear Medicine**

**Ultrasound**

**Computed Tomography and Magnetic Resonance**

**Appropriateness Criteria for Ordering Studies**
SKULL AND BRAIN

The appropriate initial imaging studies for various clinical problems are shown in Table 2-1.

The Normal Skull and Variants

Normal anatomy of the skull is shown in Figure 2-1. The most common differential problem on plain skull x-rays is distinguishing cranial sutures from vascular grooves and fractures. The main sutures are coronal, sagittal, and lambdoid. A suture also runs in a rainbow shape over the ear. In the adult, sutures are symmetric and very wiggly and have sclerotic (very white) edges. Vascular grooves are usually seen on the lateral view and extend posteriorly and superiorly from just in front of the ear. They do not have sclerotic edges and are not perfectly straight.

A few common variants are seen on skull x-rays. Hyperostosis frontalis interna is a benign condition of females in which sclerosis, or increased density, is seen in the frontal region and spares the midline (Fig. 2-2). Large, asymmetric, or amorphous focal intracranial calcifications should always raise the suspicion of a benign or malignant neoplasm. Occasionally areas of lucency (dark areas) are found where the bone is thinned. The most common normal variants that cause this are vascular lakes or biparietal foramen. Asymmetrically round or ill-defined “holes” should raise the suspicion of metastatic disease (Fig. 2-3).

Paget’s disease can affect the bone of the skull. In the early stages, very large lytic, or destroyed, areas may be seen. In later stages, increased density (sclerosis) and marked overgrowth of the bone, causing a “cotton-wool” appearance of the skull, may be seen (Fig. 2-4). Always be aware that both prostate and breast cancer can cause multiple dense metastases in the skull and that both diseases are more common than Paget’s disease.

BRAIN

Normal Anatomy

Table 2-2 gives a methodology to follow or checklist of items for use when examining a computed tomography (CT) scan. Both CT and magnetic resonance imaging (MRI) are capable of displaying anatomic “slices” in a number of different planes. The identical anatomy of the brain can appear quite differently on CT and MR images (Fig. 2-5). The normal anatomy of the brain on CT and MR images is shown in Figures 2-6 and 2-7. You should be able to identify some anatomy on these images. There are many very complex imaging sequences used during MRI depending upon the clinical question or suspected pathology. You are not expected to be familiar with all of these, but you should realize that success in making a diagnosis depends upon your indicating the clinical problem accurately so the radiologist can prescribe the correct imaging sequences.

Intracranial Calcifications

Intracranial calcifications can be seen occasionally on a skull x-ray, but they are seen much more often on CT. Intracranial calcifications may be due to many causes. Normal pineal as well as ependymal calcifications may occur. Scattered calcifications can occur from toxoplasmosis, cystercerosis, tuberous sclerosis (Fig. 2-8), and granulomatous disease. Unilateral calcifications are very worrisome, because they can occur in arteriovenous malformations, gliomas, and meningiomas.

Headache

Headaches are among the most common of human ailments. They can be due to a myriad of causes and should be characterized by location, duration, type of pain, provoking factors, and age and sex of the patient. In the primary care population, only fewer than 0.5% of acute headaches are the result of serious intracranial pathology. Simple headaches, tension headaches, migraine headaches, and cluster headaches do not warrant imaging studies. A good physical examination is essential, including evaluation of blood pressure, urine, eyes (for papilledema), temporal arteries, sinuses, ears, neurologic system, and neck. In a patient with a febrile illness, headache, and stiff neck, a lumbar puncture should be performed. In only a few circumstances is imaging indicated (Table 2-3).

In general, imaging is indicated when a headache is accompanied by neurologic findings, syncope, confusion, seizure, and mental status changes, or after major trauma. Sudden onset of the “worst headache of one’s life” (thunderclap headache) should raise the question of subarachnoid hemorrhage. Sudden onset of a unilateral headache with a suspected carotid or vertebral dissection or ipsilateral Horner’s syndrome should prompt a CT or MR angiogram.
<table>
<thead>
<tr>
<th>SUSPECTED CRANIAL PROBLEM</th>
<th>INITIAL IMAGING STUDY</th>
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</thead>
<tbody>
<tr>
<td>Skull fracture</td>
<td>CT scan including bone windows</td>
</tr>
<tr>
<td>Major head trauma</td>
<td>CT (neurologically unstable); MRI (neurologically stable)</td>
</tr>
<tr>
<td>Mild head trauma</td>
<td>Observe; CT (if persistent headache)</td>
</tr>
<tr>
<td>Acute hemorrhage</td>
<td>Noncontrasted CT</td>
</tr>
<tr>
<td>Intracerebral aneurysm or arteriovenous malformations</td>
<td>MRI</td>
</tr>
<tr>
<td>Aneurysm (chronic history)</td>
<td>MR angiogram or CT angiogram</td>
</tr>
<tr>
<td>Hydrocephalus</td>
<td>Noncontrasted CT</td>
</tr>
<tr>
<td>Transient ischemic attack</td>
<td>Noncontrasted CT, MRI if vertebrobasilar findings; consider carotid ultrasonography if bruit present</td>
</tr>
<tr>
<td>Acute transient or persistent CNS symptoms or findings</td>
<td>See Table 2-3</td>
</tr>
<tr>
<td>Acute stroke</td>
<td></td>
</tr>
<tr>
<td>Suspected hemorrhagic</td>
<td>Noncontrasted CT</td>
</tr>
<tr>
<td>Suspected nonhemorrhagic</td>
<td>MRI</td>
</tr>
<tr>
<td>Ataxia (acute or chronic unexplained)</td>
<td>MRI with and without contrast</td>
</tr>
<tr>
<td>Cranial neuropathy</td>
<td>MRI with and without contrast</td>
</tr>
<tr>
<td>Multiple sclerosis</td>
<td>MRI of the brain</td>
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<tr>
<td>Tumor or metastases</td>
<td>MRI</td>
</tr>
<tr>
<td>Carotid/vertebral dissection (ipsilateral Horner’s syndrome or unilateral headache)</td>
<td>CT angiogram of head and neck</td>
</tr>
<tr>
<td>Abscess</td>
<td>Contrasted CT or MRI</td>
</tr>
<tr>
<td>Preoperative for cranial surgery</td>
<td>Contrast angiography</td>
</tr>
<tr>
<td>Meningitis</td>
<td>Lumbar tap; CT only to exclude complications</td>
</tr>
<tr>
<td>Seizure</td>
<td></td>
</tr>
<tr>
<td>New onset or poor therapeutic response</td>
<td>MRI</td>
</tr>
<tr>
<td>New onset posttraumatic</td>
<td>CT or MRI</td>
</tr>
<tr>
<td>Febrile or alcohol withdrawal without neurologic deficit</td>
<td>Imaging not indicated</td>
</tr>
<tr>
<td>Focal neurologic deficit</td>
<td>MRI or CT without contrast</td>
</tr>
<tr>
<td>Vertigo</td>
<td></td>
</tr>
<tr>
<td>If suspect acoustic neuroma or posterior fossa tumor</td>
<td>MRI of internal auditory canal with and without contrast</td>
</tr>
<tr>
<td>Episodic or with hearing loss</td>
<td>MRI with and without contrast</td>
</tr>
<tr>
<td>Hearing loss</td>
<td></td>
</tr>
<tr>
<td>Sensorineural</td>
<td>MRI head and internal auditory canals</td>
</tr>
<tr>
<td>Conductive</td>
<td>CT petrous ridges</td>
</tr>
<tr>
<td>Vision loss</td>
<td></td>
</tr>
<tr>
<td>Adult sudden or proptosis</td>
<td>MRI with and without contrast</td>
</tr>
<tr>
<td>Head injury</td>
<td>CT</td>
</tr>
<tr>
<td>Child acute or progressive or proptosis</td>
<td>MRI</td>
</tr>
<tr>
<td>Ophthalmoplegia</td>
<td>MRI with and without contrast</td>
</tr>
<tr>
<td>Headache</td>
<td>See Table 2-3</td>
</tr>
<tr>
<td>Dementia</td>
<td>Nothing or MRI (see text)</td>
</tr>
<tr>
<td>Alzheimer’s disease</td>
<td>MRI or nuclear medicine FDG PET/CT scan</td>
</tr>
<tr>
<td>Unexplained confusion or altered level of consciousness</td>
<td>MRI or CT without contrast</td>
</tr>
<tr>
<td>Neuroendocrine (e.g., hyperthyroidism [high TSH], Cushing’s [high ACTH], hyperprolactinemia, acromegaly, precocious puberty, etc.)</td>
<td>MRI with and without contrast</td>
</tr>
<tr>
<td>Sinusitis</td>
<td>See Table 2-6</td>
</tr>
</tbody>
</table>

ACTH, Adrenocorticotropic hormone; CNS, central nervous system; CT, computed tomography; FDG, fluorodeoxyglucose; MRI, magnetic resonance imaging; PET, positron emission tomography; TSH, thyroid-stimulating hormone.
FIGURE 2-1 Normal skull. Lateral (A), anteroposterior (AP) (B),
FIGURE 2-1, cont'd AP Towne projection (C), and AP Waters view (D).
Chapter 2 | Head and Soft Tissues of Face and Neck

**FIGURE 2-2 Hyperostosis frontalis interna.** A normal variant, most common in female patients, in which increased density of the skull occurs in the frontal regions. Notice that sparing of the midline is present.

**FIGURE 2-3 Multiple myeloma.** Multiple asymmetric holes in the skull are seen only with metastatic disease. Metastatic lung or breast carcinoma can look exactly the same as this case of multiple myeloma.

**FIGURE 2-4 Paget's disease.** The fluffy cotton-wool densities overlying the skull are caused by bone expansion. Note also that the calvaria is very thick (arrow). The base of the skull has become softened; the cervical spine and foramen magnum look as though they are pushed up, but in reality the skull is sagging around them.

**FIGURE 2-5 Axial images of the brain on computed tomography (CT) and magnetic resonance imaging (MRI).** A, On a noncontrast CT scan the skull is easily seen, the brain is varying shades of gray, and cerebrospinal fluid (CSF) is dark. B, On a T1 MRI scan the skull is difficult to see, the brain is gray, and the CSF is dark. C, On a T2 image CSF is white.

**TABLE 2-2 Items to Look for on a Computed Tomography Brain Scan**

<table>
<thead>
<tr>
<th>Look for</th>
</tr>
</thead>
<tbody>
<tr>
<td>focally decreased density (darker than normal) due to stroke, edema, tumor, surgery, or radiation</td>
</tr>
<tr>
<td>increased focal density (whiter than normal) on a noncontrast scan in ventricles (hemorrhage)</td>
</tr>
<tr>
<td>increased focal density (whiter than normal) on a noncontrast scan in parenchyma (hemorrhage, calcium, or metal)</td>
</tr>
<tr>
<td>increased focal density on contrasted scan in dural, subdural, or subarachnoid spaces (hemorrhage)</td>
</tr>
<tr>
<td>all items above tumor stroke abscess or cerebritis aneurysm or arteriovenous malformation asymmetric gyral pattern mass or edema (causing effacement of sulci) atrophy (seen as very prominent sulci) midline shift ventricular size and position (look at all ventricles) sella for masses or erosion sinuses for fluid or masses soft tissue swelling over skull bone windows for possible fracture</td>
</tr>
</tbody>
</table>
FIGURE 2-6 Normal axial images of the brain at three different levels. Noncontrasted computed tomography (A1, B1, C1), T1 magnetic resonance images (MRI) (A2, B2, C2), and T2 MRI images (A3, B3, C3).
FIGURE 2-6, cont’d
FIGURE 2-7 Normal T1 magnetic resonance imaging anatomy of the brain in sagittal (A) and coronal (B) projection.

Thalamus  Parietal lobe  Occipital lobe  Cerebellum  Medulla  Spinal cord  C2  Temporal lobe  Hippocampus  Pons  Falx cerebri  Septum pellucidum  Third ventricle  Lateral ventricle  External auditory meatus  Skull with marrow  Clivus  Tongue  Nose

FIGURE 2-8 Tuberous sclerosis. Scattered calcifications are seen about the ventricles in the posterior parietal regions. Other diseases that could show this appearance include intrauterine TORCH infections (toxoplasmosis, other agents, rubella, cytomegalovirus, herpes simplex).

TABLE 2-3 Imaging Indications for Headaches

MRI is indicated for the following:
- Sudden onset of the “worst headache of one’s life” (thunderclap headache). CT without contrast also indicated
- A headache that worsens with exertion
- is associated with a decrease in alertness
- is positionally related
- awakens one from sleep
- changes in pattern over time
- A new headache in an HIV-positive individual associated with papilledema
- associated with focal neurologic deficit
- associated with mental status changes
- in a patient >60 years of age with sedimentation rate >55 mm/hr and temporal tenderness
- in a pregnant patient
- Suspected meningitis or encephalitis

MRI, Human immunodeficiency virus.

For most of the above indications, computed tomography (CT) is acceptable if magnetic resonance imaging (MRI) is not feasible or available. MRI is usually not indicated for sinus headaches or chronic headaches with no new features. See Table 2-6 for CT indications in sinus disease.
Sinus headaches can usually be differentiated from other causes because they worsen when the patient is leaning forward or with application of pressure over the affected sinus. Indications for CT use in sinus headaches are presented later in Table 2-6.

**Hearing Loss**

Hearing loss is characterized as conductive, sensorineural, or mixed. Conductive loss results from pathology of the external or middle ear that prevents sound from reaching the inner ear. Sensorineural loss results from abnormalities of the inner ear, including the cochlea or auditory nerve. CT is the best technique for evaluating conductive loss and the bony structures of the middle ear. Not all patients with conductive loss need a CT scan. Indications include complications of otomastoiditis, preoperative and postoperative evaluation of prosthetic devices, cholesteatoma, and posttraumatic hearing loss. Sensorineural hearing loss may be sudden, fluctuating, or progressive and may also be associated with vertigo. It can be due to viral infections, eardrum rupture, acoustic neuroma, and vascular occlusive diseases. Evaluation is best done by MRI with and without intravenous contrast.

**Head Trauma**

On skull x-rays, fractures are dark lines that have very sharp edges and tend to be very straight (Fig. 2-9). If a fracture is present over the middle meningeal area, an associated epidural hematoma may be found. If a depressed fracture is present, the lucent fracture lines can be stellate or semicircular (Fig. 2-10). In either of these cases, substantial brain injury may be present, and a CT scan, including bone windows, is indicated.

Skull x-rays are ordered much too frequently. A skull fracture without loss of consciousness is very rare. Significant brain injury may be found without a skull fracture. The patient should be examined clinically and a decision made as to whether physical findings and the history indicate moderate to severe head injury or mild head injury. CT, MRI, or skull radiography is not needed for low-risk patients. Low risk is defined as those who are asymptomatic or have only dizziness, mild headache, scalp laceration, or hematomas; are older than 2 years; and have no moderate- or high-risk findings.

Patients at moderate risk are those who have any of the following conditions: history of change in the level of consciousness at any time after the injury, progressive or severe headache, posttraumatic seizure, persistent vomiting, multiple trauma, serious facial injury, signs of basilar skull fracture (hemotympanum, “raccoon eyes,” cerebrospinal fluid rhinorrhea or otorrhea), suspected child abuse, bleeding disorder, or age younger than 2 years (unless the injury is trivial).

High-risk patients are those with any of the following conditions: focal neurologic findings, a Glasgow Coma Scale score of 8 or less, definite skull penetration, metabolic derangement, postictal state, or decreased or depressed level of consciousness (unrelated to drugs, alcohol, or other central nervous system [CNS] depressants). If a moderate or severe injury is present and the patient is neurologically unstable, a CT scan should be done to exclude a hematoma. If the patient is neurologically stable, an MR scan is preferable to look for parenchymal shearing injuries. In mild head injury (with no loss of consciousness or neurologic deficit), the patient may be observed. If a persistent headache occurs after trauma, CT scanning should be performed.

**Suspected Intracranial Hemorrhage**

If the presence of acute intracranial hemorrhage is suspected, the study of choice is a CT scan done without intravenous contrast. The scan is done without contrast
because acute hemorrhage appears to be white on a CT scan (Fig. 2-11), and so does intravenously administered contrast. Hemorrhage into the ventricles is usually seen in the posterior horns of the lateral ventricles. Blood is denser than CSF and therefore settles dependently. This settling process is not seen with subarachnoid or intraparenchymal blood. The presence of hemorrhage is a contraindication to anticoagulation.

Intraparenchymal bleeding can result from a ruptured aneurysm, stroke, trauma, or tumor, which are common complications of hypertension. Grave prognostic factors are large size or brainstem location. Most (80%) hypertensive bleeds occur in the basal ganglia. Ten percent occur in the pons, and 10% in the cerebellum. An associated mass effect may be present with compression of the ventricles or midline shift. The findings of acute hemorrhage on a noncontrasted CT scan indicate increased density in the parenchyma (Fig. 2-12). Differentiation from calcification usually is easily made by clinical history and, if necessary, by having the area of interest measured on the scan in terms of density (Hounsfield units).

Subdural hematomas are seen as crescent-shaped abnormalities between the brain and the skull. They can cross suture lines, but they do not cross the tentorium or falx. In some cases, subdural hematomas can be quite difficult to see, because new blood appears denser or whiter than...
brain tissue (Fig. 2-13, A). As the blood ages (over a period of several weeks), it becomes less dense than brain (Fig. 2-13, B). Obviously it follows that a subacute phase occurs during which the blood is the same density as the brain (isodense). In this stage sometimes the only clue that a subdural hematoma is present is effacement of the gyral pattern on the affected side, a midline shift away from the affected side, or ventricular compression on the affected side.

Epidural hematomas follow the same changing pattern of density as do subdural hematomas. The major differential point from an imaging viewpoint is that they are lenticular rather than crescentic (Fig. 2-14) and tend not to cross suture lines of the skull. Epidural hematomas are associated with temporal bone fractures that have resulted in a tear of the middle meningeal artery.

Subarachnoid hemorrhage is usually the result of trauma or a ruptured aneurysm. It is most often accompanied by a very severe sudden-onset headache. Subarachnoid hemorrhage can really be visualized only in the acute stage, when the blood is radiographically denser (whiter) than the CSF. The most common appearance is increased density in the region around the brainstem in a pattern sometimes referred to as a “Texaco star” (Fig. 2-15). Increased density due to the presence of blood also can be seen as a white line in the sylvian fissures, in the anterior interhemispheric fissure, or in the region of the tentorium. In the absence of trauma, a ruptured aneurysm should be suspected. As is discussed in Chapter 9, in infants, both intraventricular and intraparenchymal hemorrhage can be visualized and monitored by using ultrasound. This can be done only if the fontanelles have not closed.

**Pneumocephalus**

Air within the cranial vault is almost always the result of trauma. Even tiny amounts of air are easily seen on CT as decreased density (blackness) (see Fig. 2-11). It is preferable to do a CT scan instead of an MRI examination because of the superior ability of CT to localize skull fractures and fresh hemorrhage. It also is easier to manage an unstable patient in a CT scanner than in an MRI machine.
setting the initial test of choice is a CT scan to differentiate an ischemic event from a hemorrhagic one. A second CT scan can be obtained in 24 to 72 hours if the diagnosis is in doubt, but an MRI is more sensitive in identifying early ischemic damage and may establish the cause of the TIA. If initial vertebrobasilar findings are seen, an MRI provides better evaluation of the posterior fossa than does a CT scan. Regardless of whether a carotid bruit is present in this setting, a duplex Doppler ultrasound examination of the carotid arteries is indicated if the patient would be a surgical candidate for endarterectomy. Magnetic resonance angiography can be used to visualize carotid stenosis.

Stroke

A stroke may be ischemic or associated with hemorrhage. An acute hemorrhagic stroke is most easily visualized on a noncontrast CT scan, because fresh blood is quite dense (white). A diagnosis of stroke cannot be excluded even with normal results on a CT scan taken within 12 hours of a suspected stroke. A purely ischemic acute stroke is difficult to visualize on a CT scan unless mass effect is present. This is noted as compression of the lateral ventricle, possible midline shift, and effacement of the sulci on the affected side. One key to identification of most strokes is that they are usually confined to one vascular territory (such as the middle cerebral artery). An acute ischemic stroke is very easy to see on an MRI study, because the edema (increased water) can be identified as a bright area on T2 images. In spite of this, an MRI scan is not needed in a patient with an acute stroke. Because anticoagulant therapy is often being contemplated, a noncontrast CT scan can be obtained to exclude hemorrhage (which would be a contraindication to such therapy). After about 24 hours, the edema associated with a stroke can be seen on a CT scan as an area of low density (darker than normal brain). If a contrasted CT scan is done 1 day to several days after a stroke, enhancement (increased density or whiteness) may be seen at the edges of the area (so-called luxury perfusion). During the months after a stroke, atrophy of the brain occurs, which can be seen as widened sulci and a focally dilated lateral ventricle on the affected side (Fig. 2-16). Specific different MRI imaging sequences are performed when an acute ischemic, hemorrhagic, or chronic stroke is suspected (Fig. 2-17).

**TABLE 2-4 Imaging Indications With a New Neurologic Deficit**

<table>
<thead>
<tr>
<th>Acute onset or persistence of the following neurologic deficits is an indication for computed tomography or magnetic resonance imaging:</th>
</tr>
</thead>
<tbody>
<tr>
<td>New vision loss</td>
</tr>
<tr>
<td>Cranial neuropathy</td>
</tr>
<tr>
<td>Aphasia</td>
</tr>
<tr>
<td>Mental status change (memory loss, confusion, impaired level of consciousness)</td>
</tr>
<tr>
<td>Sensory abnormalities (hemianesthesia/hypesthesia including single limb)</td>
</tr>
<tr>
<td>Motor paralysis (hemiparesis or single limb)</td>
</tr>
<tr>
<td>Vertigo with headache, diplopia, motor or sensory deficit, ataxia, dysarthria, or dysmetria</td>
</tr>
</tbody>
</table>

**Hydrocephalus**

Dilatation of the ventricles can be either obstructive or nonobstructive. The ventricles are easily seen on a noncontrast CT or MRI study. If the cause is obstructive, both modalities have a good chance of finding the site of obstruction.

**Transient Ischemic Attack**

A transient ischemic attack (TIA) is defined as a neurologic deficit that has an abrupt onset and from which rapid recovery occurs, often within minutes, but always within 24 hours. The imaging indications for patients with a new neurologic deficit are shown in Table 2-4. A TIA indicates that the patient may be at high risk for stroke. In the acute

![Image of brain CT scan](https://example.com/image.png)
Intracranial Aneurysm

Intracranial aneurysms occur in approximately 2% to 4% of the population and are a cause of intracranial hemorrhage. Most aneurysms occur in the anterior communicating artery or near the base of the brain. The best initial way to visualize intracranial aneurysms is with CT or MRI. In a setting of acute headache and suspected acute intracranial bleeding, a noncontrasted CT study should be done. If the noncontrasted CT is negative, it is followed by a contrasted CT. The noncontrasted study will show extravascular acute hemorrhage as denser (whiter) than normal brain. If this is seen, an angiogram is done, and the contrasted CT scan is skipped (Fig. 2-18). A completely thrombosed aneurysm is frequently seen as a hypodense region with a surrounding thin ring of calcium. On the contrasted study a large nonthrombosed aneurysm will fill with contrast, although only partial filling may be seen because of a thrombus. With MRI the aneurysm may be seen as an area signal void (black) on the T1 images. If gadolinium contrast is used, the aneurysm may fill and have an increased signal (white) (Fig. 2-19).

In the acute setting, CT or MR angiogram is usually performed. Patients who have an acute bleeding episode as the result of a ruptured aneurysm may have associated spasm (occurring after a day or so and lasting up to a week). This can make the aneurysm hard or impossible to see on an angiogram. For this reason, if subarachnoid hemorrhage is present and an aneurysm is not seen, the angiogram is often repeated a week or so later. For patients who
have a long history of headache, or a familial history of aneurysms, a noninvasive MR angiogram is probably the procedure of choice.

**Primary Brain Tumors and Metastases**

Many types of brain tumors are found. Meningiomas occur along the surface of the brain. They grow quite slowly and often contain calcium. The study of choice is a CT scan with and without intravenous contrast. The noncontrasted scan may show the calcification, whereas the contrasted scan will show the extent of this typically vascular tumor (Fig. 2-20). Astrocytomas can be high or low grade and typically occur within the brain substance. Low-grade tumors may contain some calcium, but they are low density (dark) on a noncontrasted CT scan and have minimal surrounding low-density edema. The more edema and the more enhancement after administration of intravenous contrast, the more malignant the lesion is likely to be. On MR scans, these tumors are usually low signal (dark) in T1 images and high signal (bright) on T2 images. They also can show enhancement when intravenously administered gadolinium is used as a contrast agent (Fig. 2-21).

Other intracranial tumors, such as pinealomas, papilomas, lipomas, epidermoids, and others, have variable appearances and are not considered here. A reasonable differential diagnosis can be made from the appearance and location of the lesions on either CT or MR scans.

The wide variety of pituitary tumors range from benign microadenomas to malignant craniopharyngiomas. The examination with the best resolution for the pituitary

FIGURE 2-18 Intracerebral aneurysm. An anteroposterior projection from a digital angiogram shows the right internal carotid artery (ICA), the anterior cerebral artery (ACA), and the middle cerebral artery (MCA). A large rounded density seen in the region of the circle of Willis is an aneurysm (large arrow).

FIGURE 2-19 Magnetic resonance image of intracranial aneurysm. A gadolinium contrast–enhanced scan in the coronal projection shows a large area of enhancement (arrow) representing an aneurysm.

FIGURE 2-20 Meningioma. A noncontrasted computed tomography scan (A) shows a very dense, peripherally based lesion in the left cerebellar area. A bone-window image (B) obtained at the same level shows that the density is due to calcification within this lesion.
region is MRI, although relatively large lesions can be imaged with thin-cut (1- to 1.5-mm) CT scans of the sellar region. In either case the studies are usually done with and without intravenous contrast, because differential enhancement of the tumor and the pituitary allows the margins to be delineated (Fig. 2-22).

Metastatic disease is best identified using MRI with intravenous gadolinium (Fig. 2-23). A contrasted CT scan can be used, but it is not as sensitive as MRI. Most metastases enhance with contrast agents. The reason for ordering any study should be carefully considered to determine that the findings would affect the treatment. Usually little reason is found to do a cranial MR or CT scan on a patient who has known metastases elsewhere. Almost all metastases to the brain are quite resistant to all forms of therapy.

Vertigo and Dizziness

Sometimes vertigo and dizziness are confused. Symptoms of vertigo are quite specific and occur in only a small subset
of patients who complain of dizziness. Nystagmus almost always accompanies true vertigo but is usually absent between episodes. The workup of most patients with vertigo rarely involves the use of imaging procedures. If the patient does not respond to conservative measures, imaging studies should be considered in consultation with an ear, nose, and throat specialist. If the patient has vertigo with sensorineural hearing loss or suspected acoustic neuroma or posterior fossa tumor, an MRI is indicated. If conductive hearing loss and vertigo are present, a noncontrasted CT scan of the petrous bone may be indicated. Other types of dizziness may have a wide range of causes ranging from postural hypotension to TIAs. Few, if any, imaging tests are indicated for dizziness until the underlying cause becomes clear.

**Suspected Intracranial Infection**

Most, if not all, suspected intracranial infections are best imaged by MRI. Probably the only exception to this is when a sinus infection is suspected, and then a CT scan should be ordered. It should be remembered that the primary method for diagnosis of meningitis is lumbar puncture. In patients who have acquired immunodeficiency syndrome or are human immunodeficiency virus (HIV) positive, CNS complications such as toxoplasmosis, cryptococcal infection, and lymphoma may develop. These complications are being seen less because of better treatment; however, patients who have neurologic findings or a headache often have a contrasted MRI scan for evaluation. A CT scan also may be used but it is not as sensitive.

**Multiple Sclerosis**

Multiple sclerosis is effectively imaged only by MRI. Often small high-signal (bright) lesions are seen on either T1 or T2 images (Fig. 2-24). These plaques can have contrast
enhancement to varying degrees in the same patient. Whether the enhancement is related to activity of disease remains a matter of debate.

**Dementia and Slow-Onset Mental Changes**

Imaging of the brain in most patients with dementia is usually an unrewarding exercise. Most of the time, a CT scan shows atrophy compatible with age and nothing else. As mentioned, an MR scan can effectively exclude multiple sclerosis, tumor, metastases, and hydrocephalus. Often it is ordered to exclude these rather than to find the true cause of most dementias. It is possible to do a nuclear medicine tomographic brain scan (brain single-photon emission CT [SPECT] or positron emission tomography [PET]) by using radioactive substances that are extracted on the first pass through the cerebral circulation. It appears that these scans show bilateral reduced blood flow to the temporoparietal areas in Alzheimer’s disease and scattered areas of reduced perfusion in multi-infarct dementias. There are also some new radiotracers that bind to amyloid plaque and show increased retention in the brain of Alzheimer’s dementia patients. Such studies may not be cost-effective unless you have effective therapy for these entities.

**Seizures**

Examination of a patient with a seizure should include a thorough medical history, physical examination, and blood and urine evaluation. Particularly pertinent history includes information regarding seizures (personally or in the family), drug abuse, and trauma. Noncontrasted MRI is the imaging procedure of choice, although contrasted CT scanning may be used. Imaging is usually done for persons who are otherwise healthy with a new onset of seizures, those who have epilepsy with a poor therapeutic response, alcoholics with a new onset of seizures, or seizure patients with a neurologic deficit or abnormal electroencephalogram (EEG). Noncontrasted CT scanning is usually used in patients with seizures and acute head trauma or other emergency pathology. Imaging is not usually needed in children who have a suspected febrile seizure and in adults without neurologic deficits who are in chemical withdrawal or who have metabolic abnormalities.

**Psychiatric Disorders**

Imaging studies of most psychiatric patients usually have a low yield for diagnostic information. One must remember that a number of CNS abnormalities may first be seen with apparent psychiatric symptoms, particularly in older adults. For example, common conditions that may be mistaken for a depressive disorder include infections, malignancies, and stroke. Patients treated for chronic alcoholism may have unrecognized subdural hematomas. Obtaining a thorough history and performing a careful physical examination are essential. If associated neurologic findings or disparities are noted between the psychiatric findings and common diagnoses, imaging may be in order. In such circumstances an MRI is the initial study of choice.

Some authors have suggested that neuroimaging studies are unnecessary if the mental status examination, neurologic examination, and EEG findings are normal. If the patient is younger than 40 years, has no history of head injury, and has normal mental status and neurologic examinations but abnormal EEG, the imaging examination is not likely to give additional diagnostic information.

**FACE**

Indicated imaging for face and neck problems is shown in Table 2-5.

**Sinuses and Sinusitis**

The frontal skull x-ray is best used to evaluate the frontal and ethmoid sinuses. The frontal Waters view (done with the head tipped back), is used to evaluate the maxillary sinuses. The lateral view is used for evaluation of the sphenoid sinus (Fig. 2-25). Sinus series are often inappropriately ordered to rule out sinusitis in children. Sinuses are not developed or well pneumatized until children are about 5 to 6 years old. In adults, often hypoplasia of the frontal sinuses is seen (Fig. 2-26).

Most patients with suspected sinusitis do not need sinus imaging for clinical management (Table 2-6). Sinusitis is most common in the maxillary sinuses. Acute sinusitis is diagnosed radiographically if an air/fluid level in the sinus (Fig. 2-27) or complete opacification is found. After trauma, hemorrhage also can cause an air/fluid level. With chronic sinusitis, thickening and indistinctness of the sinus walls appear. CT is vastly superior to either plain x-rays or MRI for evaluation of the paranasal sinuses, mastoid sinuses, and adjacent bone. Malignancy should be suspected if recurrent episodes occur of unilateral epistaxis with no visible bleeding site, constant facial pain, anosmia, recurrent unilateral otitis media, a soft tissue mass, or bone destruction on a sinus or dental x-ray.

**Facial Fractures**

**Zygoma**

Fractures of the zygoma usually result from a direct blow to the arch or to the zygomatic process. The arch and the skull form a rigid bony ring. Just like a pretzel, it cannot be broken in only one place. The view that should be ordered if an arch fracture is suspected is the “jug-handle” view (Fig. 2-28). If only one fracture is seen in the arch, then images of the facial bones should be obtained to exclude a so-called tripod fracture. The tripod fracture results from a direct blow to the zygomatic process. It actually consists of four fractures, not three, as the name suggests. The fractures are of the zygomatic arch, lateral orbital rim, inferior orbital rim, and lateral wall of the maxillary sinus (Fig. 2-29).
TABLE 2-5 Indicated Imaging for Face and Neck Problems

<table>
<thead>
<tr>
<th>SUSPECTED FACE AND NECK PROBLEM</th>
<th>INITIAL IMAGING STUDY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unilateral proptosis, periorbital swelling, or mass</td>
<td>MRI</td>
</tr>
<tr>
<td>Facial fracture</td>
<td>Plain x-ray, CT for complicated cases</td>
</tr>
<tr>
<td>Mandibular fracture</td>
<td>Panorex</td>
</tr>
<tr>
<td>Carotid bruit</td>
<td>Duplex ultrasound</td>
</tr>
<tr>
<td>Epiglottitis</td>
<td>Lateral soft tissue x-ray of neck</td>
</tr>
<tr>
<td>Foreign body</td>
<td>Plain x-ray if calcified or metallic (fish bones not visible)</td>
</tr>
<tr>
<td>Retropharyngeal abscess</td>
<td>Lateral soft tissue x-ray of the neck; if positive, CT to determine extent</td>
</tr>
<tr>
<td>Lymphadenopathy, nontender, single or multiple (or no decrease in size over 4 wk)</td>
<td>CT with IV contrast (preferred) or MRI without contrast</td>
</tr>
<tr>
<td>Solitary neck mass (febrile patient)</td>
<td>CT with IV contrast</td>
</tr>
<tr>
<td>Pulsatile neck mass</td>
<td>CT with IV contrast</td>
</tr>
<tr>
<td>Solitary or multiple neck masses (child)</td>
<td>Ultrasound or CT with IV contrast</td>
</tr>
<tr>
<td>Hyperthyroidism</td>
<td>Serum TSH and free T₄ (no imaging needed)</td>
</tr>
<tr>
<td>Suspected goiter or ectopic thyroid</td>
<td>Nuclear medicine thyroid scan</td>
</tr>
<tr>
<td>Thyroid nodule (palpable)</td>
<td>Fine-needle aspiration (possibly with ultrasound guidance)</td>
</tr>
<tr>
<td>Known thyroid cancer (postoperative)</td>
<td>Nuclear medicine whole body radioiodine scan</td>
</tr>
<tr>
<td>Exclude recurrent thyroid tumor</td>
<td>Serum thyroglobulin</td>
</tr>
<tr>
<td>Suspected hyperparathyroidism</td>
<td>CT or nuclear medicine scan</td>
</tr>
</tbody>
</table>

CT, Computed tomography; IV, intravenous; MRI, magnetic resonance imaging; T₄, thyroxine; TSH, thyroid-stimulating hormone.

FIGURE 2-25 Normal radiographic anatomy of the sinuses. Typical radiographic projections are anteroposterior (A), Waters view (B), and lateral view of the face (C).

Nasal
Nasal bone x-rays are really useful only to look for depressed fractures or lateral deviation. The latter is often clinically obvious. On the lateral view the nasal bone has normal lucent lines that are often mistaken for fractures. If the lucent lines follow along the length of the nose, however, they are not fractures. Fractures are seen as dark lines that are perpendicular or sharply oblique to the length of the nose (Fig. 2-30).

Orbital
Blowout fractures occur from a direct blow to the globe of the eye. The pressure on the eyeball fractures the weak medial or inferior walls of the orbit. The usual blowout fracture is down through the orbital floor. The Waters view affords the best image to look for this. The findings that may be present are discontinuity of the orbital floor, a soft tissue mass hanging down into the maxillary antrum (Fig. 2-31), fluid in the maxillary antrum, and, rarely, air in the orbit (coming up from the sinus). Blowout fractures also can occur medially into the ethmoid sinus (Fig. 2-32). You will see this on the frontal skull view only as opacification (whiteness) in the affected ethmoid sinus.

Le Fort Fractures of the Face
These rare injuries are produced by massive facial trauma. They are associated with many other smaller fractures. A Le Fort I fracture is a fracture through the maxilla, usually
FIGURE 2-26 Hypoplastic frontal sinuses. This adult has had only minimal development of both frontal sinuses (arrows). This is a common normal variant.

TABLE 2-6 Indications for Computed Tomography or Magnetic Resonance Imaging in Sinus Disease

CT scanning is indicated in acute complicated sinusitis if the patient has:
- Sinus pain/discharge and
- Fever and
- A complicating factor such as:
  - mental status change
  - facial or orbital cellulitis
  - meningitis by lumbar puncture
  - focal neurologic findings
  - intractable pain after 48 hr of intravenous antibiotic therapy
  - immunocompromised host
  - sinonasal polyposis
  - possible surgical candidate
  - three or more episodes of acute sinusitis within 1 yr in which the patient has signs of infection
CT scanning is indicated in chronic sinusitis if:
- no improvement is seen after 4 wk of antibiotic therapy based on culture or
- no improvement is seen after 4 wk of intranasal steroid spray
CT or MRI scanning is indicated in cases of suspected sinus malignancy
MRI scanning with and without contrast is indicated in patients with suspected intracranial complications of sinusitis

CT, Computed tomography; MRI, magnetic resonance imaging.

FIGURE 2-27 Sinusitis. A Waters view taken in the upright position (A) may show an air/fluid interface (arrows) in acute sinusitis. In another patient who is a child (B), opacification of the left maxillary antrum (arrows) is seen, and this may represent either acute or chronic sinusitis.
Chapter 2 | Head and Soft Tissues of Face and Neck

FIGURE 2-28 Depressed zygomatic fracture. A view of the skull from the bottom (jug-handle view) shows the zygomatic arches very well. In this patient a direct blow to the zygoma has caused a depressed fracture (arrows).

FIGURE 2-29 Tripod (zygomatic) fracture. In this patient who had a direct blow to the zygomatic process, the anteroposterior Waters view of the skull obtained in the upright position (A) shows an air/fluid level (as a result of hemorrhage) in the right maxillary antrum (small arrows). Discontinuity of the inferior and right lateral orbital walls (large arrows) represents a fracture. A transverse computed tomography view in a different patient (B) shows a tripod fracture on the left caused by a direct blow in the direction indicated by the large arrows. Fractures of the anterior (1) and posterior (2) zygoma, as well as the medial wall of the left maxillary sinus (3), are seen.

FIGURE 2-30 Normal and fractured nasal bones. A normal lateral view (A) of the nose shows normal dark longitudinal lines in the nasal bone. A nasal fracture (B) is seen as a lucent line that is not in the long axis of the nose (arrows). A fracture of the anterior maxillary spine also is seen in this patient.
caused by being hit in the upper mouth with something like a baseball bat. A Le Fort II fracture involves the maxilla, nose, and inferior and medial orbital walls. A Le Fort III fracture is a facial/cranial dissociation or a separation between the face and the skull. Owing to the massive trauma required for the type III fracture, a high fatality rate occurs from the associated brain injury.

**Mandible**

Mandibular fractures should be suspected especially if malocclusion after trauma is present. Occasionally temporomandibular joint dislocation is found. The easiest way to visualize these entities is to order a panorex view of the mandible. This displays the mandible as if it were flattened out (Fig. 2-33). If a panorex machine is not available, standard oblique views of the mandible are satisfactory but harder to interpret.

**SOFT TISSUES OF THE NECK**

For a discussion of cervical fractures and dislocation, refer to Chapter 8.

**Epiglottitis**

Epiglottitis is usually thought of as a childhood disease, but it can occur in adults as well. The best initial imaging modality for upper airway obstruction or suspected foreign body is a lateral soft tissue view of the neck. This is essentially an underexposed lateral cervical spine view, and the airway is usually well seen. With epiglottitis, swelling of the epiglottis is seen easily on the lateral view, and the epiglottis looks somewhat like a thumbprint rather than a thin delicate curved structure (Fig. 2-34). For a discussion of croup and pediatric epiglottitis, refer to Chapter 9.

**Retropharyngeal Abscess**

Retropharyngeal abscess is another cause of upper airway obstruction, as well as a cause of dysphagia. The soft tissue lateral x-ray is the initial imaging procedure of choice, usually showing prevertebral soft tissue swelling. Air may or may not be within these swollen soft tissues (Fig. 2-35). An intravenously contrasted CT scan is often of great value to help discern the lateral and inferior margins of the abscess and the location of the great vessels of the neck. Retropharyngeal abscesses can extend interiorly into the mediastinum or laterally into the region of the carotid artery and jugular vein.

**Subcutaneous Emphysema**

In addition to air within the soft tissues of the retropharynx, you should also be aware of dark vertical lines of air within the anterior and lateral soft tissues of the neck. If you see these, you should look at the concurrent chest x-ray, or order one, to exclude either a pneumothorax or mediastinal emphysema. These are both potentially life-threatening
FIGURE 2-34 Normal epiglottis and epiglottitis. The normal epiglottis is well seen on the lateral soft tissue view of the neck (A) as a delicate curved structure. In a patient with epiglottitis (B), the epiglottis is swollen and significantly reduces the diameter of the airway.

FIGURE 2-35 Retropharyngeal abscess. On a lateral soft tissue view of the neck (A), the normal air column is displaced forward (curved arrows). A large amount of soft tissue swelling occurs in front of the cervical spine; gas, which represents an abscess (ab), is seen in the lower portion. A computed tomography scan through the upper thorax in the same patient (B) shows extension of the abscess (ab) down into the mediastinum between the trachea (T) and the spine.

Thyroid

The thyroid is a symmetric gland that lies lateral and anterior to the trachea just above the thoracic inlet. Large goiters can compress the trachea in a symmetric fashion, although this is unusual. More commonly, asymmetric enlargement occurs, and the trachea is deviated to one side or the other. Before diagnosing tracheal deviation, you must be sure that the patient is not rotated. On a well-positioned posteroanterior or anteroposterior chest x-ray, the medial aspect of the clavicles is equidistant from the posterior spinous processes (Fig. 2-36). The thyroid is usually easily seen on CT scan (Fig. 2-37). Ultrasound can differentiate a cystic from solid thyroid and is commonly used to direct fine-needle aspiration of cells for pathologic examination (Fig. 2-38).

Parathyroid

The most common parathyroid problem requiring imaging is hypercalcemia secondary to a parathyroid adenoma (80%) or to hyperplasia (20%). Because adenomas can be very difficult to locate at surgery, a nuclear medicine scan using radioactive compounds that accumulate in the
FIGURE 2-36 Thyroid mass. A large thyroid adenoma has displaced the trachea to the right (open arrows). This pattern can be simulated if the patient is rotated slightly when the x-ray is taken. In this case, however, the medial aspects of the clavicles (dotted lines) can be seen to be centered over the posterior spinous processes, indicating that the patient was not rotated, and a mass is truly present.

FIGURE 2-37 Normal thyroid on axial contrasted computed tomography scan of the neck. The arteries are well seen because the image was obtained during the arterial phase of an intravenous injection of iodinated contrast. The thyroid appears whiter than other tissues due to the normal content of iodine in the gland.

FIGURE 2-38 Thyroid nodule on axial ultrasound examination. The nodule contains internal echoes, indicating that it is not a cyst. Because it appears solid, it could be either a benign adenoma or a carcinoma. Often ultrasound-guided fine-needle aspiration is done to differentiate these entities.
thyroid or parathyroid or both should be done. The resulting images are very accurate in localizing the adenomas (Fig. 2-39). Parathyroid adenomas can be imaged by CT, MRI, or ultrasound, but the interpretation is more difficult.

**FIGURE 2-39 Parathyroid adenoma.** A nuclear medicine scan done with technetium 99m sestamibi. The initial image (A) shows the thyroid (Th), submandibular glands (S), and a parathyroid adenoma (arrow). On a delayed 2-hour image (B), the radioactivity has faded in the thyroid and submandibular glands.

**Suggested Textbooks on the Topic**
THE NORMAL CHEST IMAGE

Technical Considerations

Exposure
Making a properly exposed chest x-ray is much more difficult than making x-rays of other parts of the body because the chest contains tissues with a great range of contrast. The range stretches from small vessels in air-filled lungs to dense bony structures located behind the heart. A correctly exposed image should allow visualization of vessels to at least the peripheral one third of the lung and at the same time allow visualization of the paraspinous margins and the left hemidiaphragm behind the heart.

Overexposure causes the image to be dark. Under these circumstances the thoracic spine, mediastinal structures, retrocardiac areas, and nasogastric and endotracheal tubes are well seen, but small nodules and the fine structures in the lung cannot be seen (Fig. 3-1, A). If the image was obtained by using either digital or computed radiography, the image can be “windowed” lower on the computer, resulting in an interpretable image.

Underexposure causes the image to be quite white. This is a major problem for adequate interpretation. It will make the small pulmonary blood vessels appear prominent and may lead to thinking that there are generalized infiltrates when none are really present. Underexposure also makes it impossible to see the detail of the mediastinal, retrocardiac, or spinal anatomy (Fig. 3-1, B). Even with digital or computed radiography, nothing can be done to an underexposed image to improve the image.

Male Versus Female Chest
The major difference between male and female chest x-rays is caused by differences in the amount of breast tissue. This is generally relevant only in interpretation of breast tissue. This is of relevance only in the interpretation of a posteroanterior (PA) or an anteroposterior (AP) projection and not of the lateral projection. Breast tissue absorbs some of the x-ray beam, essentially causing underexposure of the tissues in the path. This results in the lung behind the breasts appearing whiter and the pulmonary vascular pattern in the same area appearing more prominent. If the breasts are large, on the PA or AP projection, bilateral basal lung infiltrates may appear to be present.

One common problem is encountered in the woman who has had a unilateral mastectomy. In this circumstance the lung density will be asymmetric. The lung on the side of the mastectomy will appear darker than the lung on the normal side. In these circumstances, recognition of the mastectomy will prevent you from making an erroneous diagnosis of an infiltrate or effusion based on the relatively increased density on the side with the remaining breast (Fig. 3-2).

Visualization on a PA or an AP chest x-ray of a single well-defined “nodule” in the lower lung zone should raise the suspicion that you are seeing a nipple shadow and not a real pulmonary nodule. Nipple shadows are common in both men and women. First, look at the opposite lung to see if a comparable “nodule” appears there. If one does, usually you can stop worrying (Fig. 3-3), but before you completely stop worrying, also look at the lateral image and make sure that the “nodule” is not seen projecting within the lung. If only one “nodule” is found projecting over a lung in the PA projection, and no nodule is seen on the lateral view, a small metallic BB can be taped over the nipples and the single PA view repeated to see whether it was the nipple that was being visualized.

Posteroanterior Versus Anteroposterior Chest X-rays
Chest x-rays on ambulatory patients are usually done with the subject’s chest up against the detector plate. The x-ray tube is behind the patient, and the x-ray beam passes in from the back and exits the front of the chest. This is referred to as a PA (posterior to anterior) projection. If the patient is lying down, it is standard practice to take the image with the x-ray beam entering the front of the chest and to have the detector plate behind the patient. This is called an AP (or anterior to posterior) chest x-ray.

For interpretive purposes the main difference is that the heart will be more magnified on the AP projection (Fig. 3-4). This is because in the AP projection, the heart is farther from the detector plate, and the x-ray beam diverges as it goes farther from the tube. Thus the shadow of the heart appears larger on an AP chest x-ray than on a PA view. Simply remember to make sure that you are looking at a PA view before you interpret an image as showing mild or moderate cardiomegaly. Usually the technician will have written the projection on the x-ray requisition, and occasionally it may be marked on the image.

Upright Versus Supine Chest X-rays
As you can imagine, patients who are able to stand or sit up usually have their chest x-rays done in that position for a number of reasons. The amount of inspiration is greater in these positions, spreading the pulmonary vessels and allowing clearer visualization. It is obviously easier to see a bird in a tree if the branches can be spread out instead of being squashed together. Another reason for preferring
lungs and heart, and the result is that the pulmonary vessels are crowded. In the supine position the blood flow to the upper lungs essentially equals that in the lower lobes, and this will mimic congestive failure. On a supine image the standard AP projection combined with the cephalic push of the abdominal contents will make a normal heart appear large. In addition, with the patient in a supine position, small pleural effusions will layer in the posterior pleural space, whereas small pneumothoraces will go to the anterior pleural surface, and both will easily be missed. As a

an upright examination is that small pleural effusions tend to run down into the normally sharp costophrenic angles, allowing relatively small effusions to be identified. Small pneumothoraces tend to go to the lung apex and can be relatively easy to see on an upright chest x-ray.

Now let us think about a patient lying in bed (supine). The typical chest x-ray will be done with a detector cassette under the patient. No lateral view is done. Under these circumstances, the patient cannot take a full inspiration; the liver and abdominal contents push up on the

FIGURE 3-1 Effect of overexposure and underexposure on a chest x-ray. Overexposure (A) makes it easy to see behind the heart and the regions of the clavicles and thoracic spine, but the pulmonary vessels peripherally are impossible to see. Underexposure (B) accentuates the pulmonary vascularity, but you cannot see behind the heart or behind the hemidiaphragms.

FIGURE 3-2 Left mastectomy. The right breast, which remains, causes the pulmonary vessels at the base of the right lung to be accentuated, and this can be mistaken for a right lower lobe infiltrate. In contrast, the left lung appears darker than the right, and you might mistakenly think there is hyperinflation of the left lung.

FIGURE 3-3 Nipple shadows. Prominent nipple shadows can be seen in both men and women and are seen in the midclavicular line over the lower half of both the right and the left lung (arrows). These should be bilateral and sometimes can be seen on the anterior soft tissue of the chest on the lateral view.
result you must be much more conservative and careful when interpreting the image of a supine, portable examination.

**Inspiration and Expiration Chest X-rays**

The degree of inspiration is important not only for assessing the quality and limitations of the examination but also for diagnosing different diseases. When standing, most adults can easily take an inspiration that brings the domes of the hemidiaphragms down to the level of the tenth posterior ribs. When the patient is sitting or lying down, often the level is between the eighth and tenth ribs. If the image has the domes of the diaphragms at the seventh posterior ribs, the chest should be considered hypoinflated, and you must be very careful before diagnosing basilar pneumonia or cardiomegaly (Fig. 3-5). You should be cognizant of the major differences in the appearance of a chest x-ray as a result of combining all the factors mentioned earlier. Unless you are aware of these issues, you will diagnose cardiomegaly, lung infiltrates, and congestive heart failure (CHF) in a patient who is in fact normal (Fig. 3-6).

Expiration images do have occasional constructive uses.

If a small pneumothorax is present, an expiration view makes the lung smaller and denser, and at the same time, makes the pneumothorax relatively larger and easier to see. Thus if your prime interest is in identification of a small pneumothorax, order an upright expiration image. In the case of a foreign body (such as a peanut) lodged in a major bronchus, both inspiration and expiration examinations should be ordered. Either postobstructive atelectasis or a ball-valve phenomenon may be seen. In the
Chest X-ray Versus Rib Technique

A typical chest x-ray is performed by using an energy of the x-rays that is a compromise for visualizing lung markings, soft tissues, and bones at the same time. Bones can be well seen by using relatively low voltage x-rays, but then the pulmonary markings are hard to see (Fig. 3-7). If you are interested in rib or spine fractures or other abnormalities of bone, order either a “rib” or a “spine” examination rather than a chest x-ray. This will accentuate the detail of the bones.

Normal Anatomy and Variants

Normal anatomy as visualized on a chest x-ray is important to understand, and major structures are shown in Figure 3-8. A method for examining a chest x-ray is given in Table 3-1. The appropriate imaging study to order in various clinical circumstances is shown in Table 3-2. Some circumstances in which a chest x-ray is not indicated are shown in Table 3-3.

Before hyperinflation is diagnosed on a chest x-ray, the lateral image should be examined. With hyperinflation, the diaphragms should be flattened on the lateral view. Many young adults can normally take a very deep inspiration, but on the lateral view they will not have an increased AP diameter or truly flattened hemidiaphragms. In long-standing chronic obstructive pulmonary disease (COPD), additional findings may appear, such as an increased AP diameter and an increase in the clear space between the sternum and the ascending aorta.
finding the farthest right and left portions of the cardiac silhouette. These will not be at the same horizontal level, but that is all right. Find the horizontal distance between the two most lateral cardiac margins. Sometimes patients have either dextrocardia or situs inversus (Fig. 3-10). Before the latter diagnosis is made, it is important to make sure that the technician did not misplace the right or left marker on the image.

The upper mediastinal structures that are visualized on the right are the brachiocephalic vessels, azygos vein, and the left ventricle is on the left and the right ventricle is on the right. Unfortunately, the heart chambers are somewhat twisted in the chest, and on the PA and lateral views the cardiac chambers mostly overlie each other. As a general rule, if the right side of the heart is enlarged more than the left, a right chamber lesion is present. The same holds true for the left side.

On an upright PA chest x-ray the greatest width of the heart should be less than half the width of the thoracic cavity at its widest point (Fig. 3-9). This is determined by finding the farthest right and left portions of the cardiac silhouette. These will not be at the same horizontal level, but that is all right. Find the horizontal distance between the two most lateral cardiac margins. Sometimes patients have either dextrocardia or situs inversus (Fig. 3-10). Before the latter diagnosis is made, it is important to make sure that the technician did not misplace the right or left marker on the image.

The upper mediastinal structures that are visualized on the right are the brachiocephalic vessels, azygos vein, and
Chapter 3 | Chest

<table>
<thead>
<tr>
<th>TABLE 3-1 How to Look at a Chest X-ray</th>
</tr>
</thead>
<tbody>
<tr>
<td>Determine the age, sex, and history of the patient</td>
</tr>
<tr>
<td>Identify the projection and technique used:</td>
</tr>
<tr>
<td>AP, PA, lateral, portable, or standard distance</td>
</tr>
<tr>
<td>Upright, supine, decubitus, lordotic</td>
</tr>
<tr>
<td>Look at the inspiratory effort:</td>
</tr>
<tr>
<td>Adequate, hypoinflated, hyperinflated</td>
</tr>
<tr>
<td>Identify the obvious and common abnormalities:</td>
</tr>
<tr>
<td>Heart size, large or normal</td>
</tr>
<tr>
<td>Heart shape, specific chamber enlargement</td>
</tr>
<tr>
<td>Upper mediastinal contours</td>
</tr>
<tr>
<td>Examine airway, tracheal deviation</td>
</tr>
<tr>
<td>Lung symmetry</td>
</tr>
<tr>
<td>Any mediastinal shift?</td>
</tr>
<tr>
<td>Hilar position</td>
</tr>
<tr>
<td>Lung infiltrates, masses, or nodules</td>
</tr>
<tr>
<td>Pulmonary vascularity</td>
</tr>
<tr>
<td>Increased, decreased, or normal</td>
</tr>
<tr>
<td>Lower greater than upper</td>
</tr>
<tr>
<td>Pleural effusions, blunting of costophrenic angles</td>
</tr>
<tr>
<td>Rib, clavicle, and spine fractures or other lesions</td>
</tr>
<tr>
<td>Check tube placement</td>
</tr>
<tr>
<td>Recheck what you thought was normal anatomy, and look at</td>
</tr>
<tr>
<td>typical blind spots</td>
</tr>
<tr>
<td>Behind the heart</td>
</tr>
<tr>
<td>Behind the hemidiaphragms</td>
</tr>
<tr>
<td>In the lung spicies</td>
</tr>
<tr>
<td>Pneumothorax present?</td>
</tr>
<tr>
<td>Costophrenic angles</td>
</tr>
<tr>
<td>Chest wall</td>
</tr>
<tr>
<td>Lytic rib lesions</td>
</tr>
<tr>
<td>Shoulders</td>
</tr>
<tr>
<td>Look for old images, not just the last one</td>
</tr>
<tr>
<td>Decide what the findings are and their location</td>
</tr>
<tr>
<td>Give a common differential diagnosis correlated with the</td>
</tr>
<tr>
<td>clinical history</td>
</tr>
</tbody>
</table>

AP, Anteroposterior; PA, posteroanterior.

FIGURE 3-9 Measurement of cardiomegaly. The width of the normal heart from its most lateral borders (A) should not exceed the width of half of the hemithorax measured from the middle of the spine to the widest portion of the inner ribs (B).

FIGURE 3-10 Situs inversus. The heart, stomach, and liver are all in reversed positions. Before you make this diagnosis, make sure that the technician has placed the right and left markers correctly.

ascending aorta. The right border of the ascending aorta can be seen beginning below the right hilum. The aortic arch is most commonly seen to the left of the trachea. The descending thoracic aorta can usually be visualized only along its left lateral border, where it abuts the left lung. The trachea should be midline and can be followed down to the carina. The right and left major bronchi are easily seen. The esophagus is not normally seen on a standard chest x-ray.

Hila and Lungs
The hila are made up of the main pulmonary arteries and major bronchi. The right hilum is usually somewhat lower than the left; it should not be at the same level or higher. The pulmonary veins usually are more difficult to see than the arteries. They converge on the atria at a level 1 to 3 inches below the pulmonary arteries. Lymph nodes are not normally seen on a chest x-ray, either in the hilar regions or in the mediastinum.

The lungs are composed mostly of air, and therefore normally not much is seen other than blood vessels. These should be distinct and remain that way as they are traced back to the hila. If you cannot see blood vessels clearly near the hila, a perihilar infiltrate or fluid may be present (such as from CHF). Normal hila are sometimes indistinct on portable x-rays because the exposure takes longer, and the vessels are blurred by motion.

The blood vessels in the lung are usually clearly seen out to within 2 to 3 cm of the chest wall. Some people say that visualization of vessels in the outer third of the lung is abnormal, but this is not true. It depends on the quality of the image and on how hard you look. Lines located within 2 cm of the chest wall are abnormal and probably represent edema, fibrosis, or metastatic disease. Secondary bronchi are not normally visualized except near the hilum, where they can sometimes be seen end-on. The walls of the
<table>
<thead>
<tr>
<th>CLINICAL PROBLEM</th>
<th>IMAGING STUDY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pneumonia</td>
<td>Chest x-ray (confirmatory)</td>
</tr>
<tr>
<td>Diagnosed clinically</td>
<td></td>
</tr>
<tr>
<td>Immunocompromised patient with negative chest x-ray</td>
<td>CT without contrast</td>
</tr>
<tr>
<td>COPD (with acute exacerbation)</td>
<td>Chest x-ray</td>
</tr>
<tr>
<td>CHF (new or worsening)</td>
<td>Chest x-ray, echocardiogram</td>
</tr>
<tr>
<td>Trauma</td>
<td>Chest x-ray, CT</td>
</tr>
<tr>
<td>Chest pain, acute (low probability of CAD)</td>
<td>Chest x-ray (additional studies depend on suspected cause)</td>
</tr>
<tr>
<td>Chest pain, chronic (low to intermediate probability of CAD)</td>
<td>Chest x-ray (possibly US or NM cardiac stress test)</td>
</tr>
<tr>
<td>Chest pain, chronic (high probability of CAD)</td>
<td>NM or US cardiac stress test or coronary angiogram</td>
</tr>
<tr>
<td>Shortness of breath</td>
<td>Chest x-ray</td>
</tr>
<tr>
<td>Severe or long duration or in adult age 40 yr or older</td>
<td>CT chest (high resolution)</td>
</tr>
<tr>
<td>Negative chest x-ray, pulmonary origin suspected</td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td>No imaging needed</td>
</tr>
<tr>
<td>Uncomplicated</td>
<td>Initial chest x-ray</td>
</tr>
<tr>
<td>Moderate or severe</td>
<td></td>
</tr>
<tr>
<td>Asthma (suspected superimposed disease or resistant to therapy)</td>
<td>Chest x-ray</td>
</tr>
<tr>
<td>Interstitial lung disease</td>
<td>Chest x-ray, pulmonary function studies</td>
</tr>
<tr>
<td>Immunosuppressed patient (with fever, cough, or dyspnea)</td>
<td>Chest x-ray</td>
</tr>
<tr>
<td>Foreign body</td>
<td>Inspiration/expiration chest x-ray</td>
</tr>
<tr>
<td>Aspiration pneumonia</td>
<td>Chest x-ray</td>
</tr>
<tr>
<td>Mediastinal mass</td>
<td>Contrasted CT</td>
</tr>
<tr>
<td>Solitary pulmonary nodule</td>
<td>CT without contrast (high resolution); if indeterminate, FDG PET/CT</td>
</tr>
<tr>
<td>Lung tumor or lung metastases screening</td>
<td>Chest x-ray and CT</td>
</tr>
<tr>
<td>Pleural mass or fluid</td>
<td>CT</td>
</tr>
<tr>
<td>Localization of pleural effusion for thoracentesis</td>
<td>Stethoscope, US</td>
</tr>
<tr>
<td>Suspected pneumothorax</td>
<td>Chest x-ray (possibly expiration view as well)</td>
</tr>
<tr>
<td>Hemoptysis</td>
<td>Chest x-ray, CT with IV contrast</td>
</tr>
<tr>
<td>Pericardial effusion</td>
<td>Cardiac ultrasound</td>
</tr>
<tr>
<td>Myocardial thickness</td>
<td>Cardiac ultrasound</td>
</tr>
<tr>
<td>Cardiac wall motion</td>
<td>Cardiac ultrasound</td>
</tr>
<tr>
<td>Cardiac ejection fraction</td>
<td>NM (gated blood pool study) or US</td>
</tr>
<tr>
<td>Pulmonary embolism</td>
<td>Chest x-ray, and CT angiogram or NM lung scan</td>
</tr>
<tr>
<td>Coronary ischemia</td>
<td>Stress ECG, stress nuclear medicine (myocardial perfusion scan) or stress echocardiogram, coronary angiogram</td>
</tr>
<tr>
<td>Aortic aneurysm</td>
<td>CT with IV contrast or transesophageal US</td>
</tr>
<tr>
<td>Aortic tear</td>
<td>CT with IV contrast or CT angiogram</td>
</tr>
<tr>
<td>Aortic dissection</td>
<td>CT with IV contrast or transesophageal US</td>
</tr>
<tr>
<td>Preoperative or admission of patient</td>
<td>Chest x-ray not indicated unless acute or chronic cardiopulmonary disease</td>
</tr>
<tr>
<td>Intensive care unit patient</td>
<td>Chest x-ray upon admission, transfer, and clinical indication only</td>
</tr>
</tbody>
</table>

CAD, Coronary artery disease; COPD, chronic obstructive pulmonary disease; CHF, congestive heart failure; CT, computed tomography; ECG, electrocardiogram; FDG PET/CT, fluorodeoxyglucose positron emission tomography/computed tomography; IV, intravenous; NM, nuclear medicine; US, ultrasound.
Bony Structures

Skeletal structures of interest on a chest x-ray include the ribs, sternum, spine, and shoulder girdle. Twelve ribs should appear, but only the upper ones are completely seen on a PA chest x-ray. Ribs are very difficult to evaluate on the lateral view owing to superimposition of the right and left ribs and the many soft tissue structures. Evaluation should include searches for cervical ribs (Fig. 3-13), fractures, deformity, missing ribs (from surgery), and lytic (destructive) lesions. The upper margin of the ribs is usually well seen, because the rib is rounded here. The lower edge of the ribs is usually very thin, and the inferior cortical margin can be difficult to appreciate. Look for symmetry between the right and left ribs at the same level. If they are symmetric, they are usually normal. At the anterior ends of the ribs, cartilage connects to the sternum. In older individuals, significant calcification of this cartilage may occur; this is a normal finding (Fig. 3-14).

Diaphragms

The diaphragms are typically dome shaped, although many persons have polycarinate diaphragms that look like several domes rather than one. This is an important normal variant and should not be mistaken for a pleural or diaphragmatic tumor; it should not be called an eventration (Fig. 3-12). The right hemidiaphragm is usually higher than the left, and most people believe that this is because the liver is pushing up the right hemidiaphragm. This is nonsense, because the liver, which weighs many pounds, cannot push up into the lungs while the person is standing. The diaphragms are at different levels because the heart is pushing the left hemidiaphragm down. The edges of both hemidiaphragms form acute angles with the chest wall, and blunting of these angles should raise the suspicion of pleural fluid.

Most people have trouble telling the right from the left hemidiaphragm on the lateral view, but several ways exist to tell them apart. The right hemidiaphragm is usually higher than the left and can be seen extending from the anterior chest wall to the posterior ribs. The left side usually can be seen only from the posterior aspect of the heart to the posterior ribs. It also is the hemidiaphragm most likely to have a gas bubble (stomach or colon) immediately beneath it.

TABLE 3-3  Circumstances in Which a Chest X-ray Is Not Indicated

<table>
<thead>
<tr>
<th>Circumstance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prenatal chest x-ray</td>
</tr>
<tr>
<td>Routine admission or preoperative (no cardiac or chest problem) in a patient younger than 65 yr</td>
</tr>
<tr>
<td>Routine preemployment</td>
</tr>
<tr>
<td>Screening for occult lung cancer</td>
</tr>
<tr>
<td>Screening for tuberculosis</td>
</tr>
<tr>
<td>Uncomplicated asthmatic attack</td>
</tr>
<tr>
<td>Chronic obstructive pulmonary disease without acute exacerbation</td>
</tr>
<tr>
<td>Dyspnea of short duration and intensity in an adult younger than 40 yr</td>
</tr>
<tr>
<td>Chest pain in an adult younger than 40 yr with a normal physical examination and no history of trauma</td>
</tr>
<tr>
<td>Uncomplicated hypertension</td>
</tr>
<tr>
<td>Chronic bronchitis</td>
</tr>
<tr>
<td>Acute respiratory illness in an adult younger than 40 yr with a negative physical examination and no other symptoms or risk factors</td>
</tr>
</tbody>
</table>

visualized bronchi normally should not be thicker than a fine pencil point.

A normal variant called an azygos lobe can occasionally be seen in the right upper lung. This is seen on the PA view as a fine, curved line extending from the right lung apex down toward the mediastinum (Fig. 3-11). It has a teardrop shape at its lower edge. This is caused embryologically by the azygos vein migrating inferiorly from the lung apex while trapping some of the lung medially.

Remember that on a PA or an AP chest x-ray the lungs go behind the heart, behind and below the dome of the hemidiaphragms, and behind and in front of mediastinal structures. Forty percent of the lung area and 25% of the lung volume will be obscured by these other structures. If you do not look carefully at these regions, you will miss a significant amount of pulmonary pathology.

Diaphragms

The diaphragms are typically dome shaped, although many persons have polycarinate diaphragms that look like several domes rather than one. This is an important normal variant and should not be mistaken for a pleural or diaphragmatic tumor; it should not be called an eventration (Fig. 3-12). The right hemidiaphragm is usually higher than the left, and most people believe that this is because the liver is pushing up the right hemidiaphragm. This is nonsense, because the liver, which weighs many pounds, cannot push up into the lungs while the person is standing. The diaphragms are at different levels because the heart is pushing the left hemidiaphragm down. The edges of both hemidiaphragms form acute angles with the chest wall, and blunting of these angles should raise the suspicion of pleural fluid.

Most people have trouble telling the right from the left hemidiaphragm on the lateral view, but several ways exist to tell them apart. The right hemidiaphragm is usually higher than the left and can be seen extending from the anterior chest wall to the posterior ribs. The left side usually can be seen only from the posterior aspect of the heart to the posterior ribs. It also is the hemidiaphragm most likely to have a gas bubble (stomach or colon) immediately beneath it.
rhomboid fossa, and it is bilateral. It should not be mistaken for a pathologic bone lesion (Fig. 3-16). The medial aspect of the scapula projects over the upper lateral aspect of the lungs and sometimes can be mistaken for a pathologic line, such as a pneumothorax. When you think that you see a pneumothorax, make sure that it is not the scapular border. Note that the medial scapular border is usually straight rather than curved, and trace the outline of the scapula.

The thoracic spine is seen only incompletely on a standard chest x-ray because, on the frontal view, it is obscured by the heart and mediastinal structures. In older people, substantial degenerative changes or bone spurs may extend laterally from the vertebral bodies. These can often be seen on the PA view (Fig. 3-17), and on the lateral view the spurs can look like pulmonary nodules. A key to differentiating bony spurs from nodules is that spurs project over the vertebral disks on the lateral view and do not look like round nodules on the frontal chest x-ray.

Soft Tissues

The soft tissues also should be examined. We have already seen the problems in interpretation that can arise as a result of a mastectomy or nipple shadows, but other soft tissues also are important. It is important to look for asymmetry of soft tissues or for air or calcium within them. Calcification may be seen in the carotid arteries or great vessels in older persons (Fig. 3-18). A common confusing artifact can be caused by hair (especially braids). If the hair is greasy and braided, strange artifacts (Fig. 3-19) that may be mistaken for apical lung infiltrates can be seen.

Normally, not much soft tissue or water density should exist between the peripheral aerated lung and the ribs. The pleura are not normally seen at the lung margins. In some adults a collection of fat appears along the chest wall between the lung and the ribs. This is extrapleural fat, which is usually seen only on the PA view of the chest and almost always in the upper outer portion of the thoracic cavity (Fig. 3-20). The biggest pitfall is mistaking this for bilateral pleural effusions. If no other sign of effusion (such as costophrenic angle blunting) is noted and if the finding is bilateral, is seen near the upper lateral lung zones, and does not exceed 3 to 4 mm in thickness, it is almost certainly extrapleural fat rather than pleural fluid.

Computed Tomography Anatomy

The cross-sectional anatomy of the chest is important to understand, because CT is commonly used for evaluation of thoracic pathology. CT scanning of the chest may be done with or without intravenous contrast. Most standard CT scanning techniques provide CT “slice” images that are 5 mm thick. To evaluate a lung nodule, use thinner cuts, and intravenous contrast is not needed. For evaluation of a potential dissecting aortic aneurysm, a bolus of intravenous contrast is essential. Consult a radiologist if you are in doubt about what to order. The radiologist usually will use the correct technique, provided you have supplied complete clinical information. With current spiral multidetector CT technology the entire chest can be scanned in several seconds while the patient holds his or her breath. After the scan is done, the data can be manipulated on almost any computer to show bone, mediastinal windows, or pulmonary parenchymal windows.
FIGURE 3-15 Pectus excavatum. A congenital abnormality in which the sternum is depressed. Because the heart is squashed between the sternum and spine, it appears big in the frontal view (A) of the chest, and the right heart border is indistinct, suggesting a right middle lobe infiltrate. A lateral view (B) clearly shows the depressed position of the sternum (arrows).

FIGURE 3-16 Rhomboid fossa. A normal finding in which an indentation appears along the medial and inferior aspects of the clavicles (arrows). This should be bilateral and is of no clinical significance.

FIGURE 3-17 Degenerative spurs or osteophytes. These projections occur at the level of the disks and can cause an unusual appearance along the lateral aspect of the thoracic spine (arrows). On the lateral chest x-ray, these bony spurs can simulate nodules projecting near or over the thoracic spine.

This affords a good look at the pulmonary parenchyma and still allows differentiation of mediastinal structures (Fig. 3-21).

In some special circumstances you will want to look at the fine detail of the lung. In these circumstances, high-resolution CT (HRCT) can be performed. The “slices” that are obtained are 1 to 2 mm thick. This usually is not done for the whole lung, because it would involve too many images and it is not necessary to make most diagnoses. For this reason, a regular CT scan is often done with thin cuts at selected levels (Fig. 3-22). Repeated chest CT scans for follow-up of pulmonary nodules should be performed using a low-dose protocol.

THE ABNORMAL CHEST IMAGE

Admission, Preoperative, and Prenatal Chest X-rays

Routine admission chest x-rays have a low yield and are not indicated. If a patient is being admitted with a cardiothoracic problem, cancer, or a febrile illness, a chest x-ray is appropriate. In a similar fashion, routine preoperative chest x-rays are not indicated (e.g., before foot or knee surgery). Preoperative chest x-rays are indicated in patients undergoing neck or chest surgery, in those who have a history of respiratory or cardiac problems,
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FIGURE 3-18 Carotid calcification. In older patients, as a result of atherosclerosis, calcification of the aortic arch and great vessels often is seen. In this case, calcification is seen in the carotid arteries (arrows).

FIGURE 3-19 Braid artifacts. Tightly woven or greasy hair can cause streaky artifacts that may resemble an upper lobe infiltrate. A key finding is that these artifacts can be seen extending above the apex of the lung and projecting over the cervical soft tissue region (arrows).

FIGURE 3-20 Extrapleural fat. This normal finding in the upper and lateral hemithorax (arrows) is symmetric between right and left and should not be mistaken for a pleural effusion.

and in patients who are febrile, immunocompromised, have altered mental status, an acute abdomen, a known or suspected cancer, or are older than 65 years. A chest x-ray also is appropriate for children who are admitted to an intensive care unit for any reason.

Chest X-ray Examinations in Occupational Medicine

Preemployment and preplacement chest x-rays should be done selectively based on pertinent factors in the medical history, clinical examination, and proposed work assignment. Surveillance of persons who work with or may be exposed to substances that adversely affect pulmonary function or cause pulmonary disease should be done if this is the diagnostic procedure with the greatest accuracy and earliest detection. The periodicity of such testing would vary with the particular circumstance.

Silhouette Sign

The silhouette sign is one of the most useful signs in interpreting a chest x-ray. It helps determine the location of an abnormality in relation to normal structures. Loss of a normal border occurs if an abnormality is contiguous with that structure. For example, if an infiltrate is identified on the PA or AP image in the lower right lung zone, it could be in either the right middle or the right lower lobe. If a loss of the normally distinct right heart border is found, then the infiltrate must abut the heart and can be only in the medial segment of the right middle lobe. If, however,
FIGURE 3-21 Normal anatomy of the chest on transverse (axial) computed tomography scans. Identical anatomy has been imaged using pulmonary parenchymal windows and soft tissue windows (A to L).
FIGURE 3-21, cont'd
FIGURE 3-21, cont'd
TUBES, WIRES, AND LINES

Evaluation of the placement and associated complications of various tubes, wires, and lines is a common reason for ordering a chest x-ray. On patients who are extremely sick and in intensive care units, the portable chest x-ray often resembles a plate of spaghetti with tubes, lines, and wires everywhere. Your job is to figure out which parts of the tubes and wires are inside the patient and which are simply lying on the patient. In addition, you need to know if the lines and tubes that are inside the patient are going to the right place or are at the correct level.

Endotracheal Tube

An endotracheal tube (ET) is probably the easiest item to identify, because it is within the air shadow of the trachea. In an adult or child the ET tip should be at least 1 cm above the carina, and preferably slightly more. A tube in a lower position can obstruct airflow to one side and cause atelectasis (collapse) of a lung or a portion of a lung. An ET tube in low position usually will go into the right main stem bronchus because it is more vertically oriented than the left main stem bronchus (Fig. 3-23). The highest that an ET tube tip should be is at the level of the suprasternal notch (which is midway between the proximal clavicles).

Nasogastric Tube

A nasogastric (NG) tube should follow the course of the esophagus on the frontal chest x-ray, and on the lateral view it should pass behind the trachea and then along the posterior aspect of the heart (Fig. 3-24). You must ascertain the position of the tip of an NG tube before putting any liquid through the tube. The position often can be determined by clinical means without resorting to a chest x-ray. The most common method is to put air into the tube and listen over the stomach with a stethoscope.

TABLE 3-4 Abnormalities to Look for on a Postsurgical or Posttraumatic Chest X-ray Examination

<table>
<thead>
<tr>
<th>Abnormality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position of the endotracheal tube, pleural tubes, venous catheters</td>
</tr>
<tr>
<td>Upper mediastinal widening</td>
</tr>
<tr>
<td>Left apical pleural cap</td>
</tr>
<tr>
<td>Ill-defined aortic knob or anteroposterior window (signs of aortic tear)</td>
</tr>
<tr>
<td>Pneumothorax</td>
</tr>
<tr>
<td>Apical</td>
</tr>
<tr>
<td>Loculated or basilar</td>
</tr>
<tr>
<td>Mediastinal emphysema</td>
</tr>
<tr>
<td>Subcutaneous emphysema</td>
</tr>
<tr>
<td>Infiltrates (? changing)</td>
</tr>
<tr>
<td>Mediastinal shift</td>
</tr>
<tr>
<td>Atelectasis</td>
</tr>
<tr>
<td>Lobar</td>
</tr>
<tr>
<td>Focal</td>
</tr>
<tr>
<td>Pleural fluid collection</td>
</tr>
<tr>
<td>Rib or sternal fractures</td>
</tr>
<tr>
<td>Spine fractures (including paraspinous soft tissue widening)</td>
</tr>
<tr>
<td>Shoulder fractures and dislocations</td>
</tr>
<tr>
<td>Free air under the diaphragms</td>
</tr>
</tbody>
</table>

Portable Chest Radiography in the Intensive Care Unit

Much has been written about the utility or overuse of chest x-rays in intensive care units. In general, standing or routine orders for chest x-ray should be avoided. However, by definition, patients in intensive care units are very sick, are usually lying supine all day, and are not ventilating normally. Almost all these patients have supporting tubes or lines that are changed or repositioned frequently. Daily chest x-rays are indicated for patients with endotracheal tubes or a recently placed tracheostomy tube. In such patients about 60% of daily chest x-rays do not disclose either new major or minor findings, and about 20% have new minor findings. However, about 20% of the time, new major findings are clinically unsuspected and are seen only on the x-ray. Chest x-rays also are indicated after a chest tube or central venous line has been placed, to assess the position and potential presence of a pneumothorax. Abnormalities to look for on a postsurgical or posttraumatic chest x-ray are shown in Table 3-4.

FIGURE 3-22 Normal and high-resolution computed tomography (CT) of the lungs. The normal slice thickness (A) of a CT scan of the chest is 0.5 cm. A high-resolution slice (B) taken at exactly the same level is 1.0 mm in thickness and shows much greater detail of the vessels and bronchi.

NG tubes have two favorite abnormal positions. The most common is with the NG tube only partway down the esophagus or coiled in the esophagus. Fluid placed down the tube can reflux and be aspirated into the lungs. Less commonly during insertion, the NG tubes can pass into the trachea instead of going into the esophagus. When this happens, they tend to go down the right main stem bronchus (just as do ET tubes that are advanced too far). Because NG tubes can be stiff and have a rigid end, if pushed hard enough, they can perforate the lung and go out into the pleural space (Fig. 3-25). Many patients require alimentation via NG tube; this works best if the tube tip is in the distal aspect of the duodenal loop near the ligament of Treitz.

**Jugular or Subclavian Venous Line**

This is a common route of venous access. The tip of the catheter should optimally be placed in the superior vena cava (SVC). On the frontal chest x-ray, the catheter tip should be about 1 to 4 cm below the medial aspect of the right clavicle (Fig. 3-26). The favorite abnormal positions of subclavian catheter tips are those that have turned up into the jugular vein rather than down into the SVC (Fig. 3-27, A), and those that have crossed the midline and extended into the opposite subclavian vein (Fig. 3-27, B).

**Swan-Ganz or Pulmonary Artery Catheter**

Central lines are usually placed to monitor cardiac or pulmonary arterial pressures. The normal course is almost circular: down the SVC, through the right atrium and right ventricle, and out into the main pulmonary and peripheral pulmonary arteries. The most common natural course that the catheter follows leads it into the right rather than the left main pulmonary artery (Fig. 3-28). Some venous catheters are placed from the inguinal region. In this case the catheter usually follows a gentle “S” curve from the inferior vena cava (IVC) into the right atrium and right ventricle and into the pulmonary artery (Fig. 3-29). A central venous catheter placed too far out into a pulmonary artery will obstruct blood flow and can result in pulmonary infarction (Fig. 3-30). The tip of a central venous pressure line should not extend more than halfway between the hilum and the lung periphery, or lung infarction can occur. Another problem encountered can be the passage of such a catheter from the SVC into the IVC instead of into the right heart (Fig. 3-31).

**FIGURE 3-23 Left lung atelectasis.** The endotracheal tube is down too far, and the tip is located in the right main stem bronchus. The left main stem bronchus has become totally obstructed, the air in the left lung has been resorbed, and volume loss is seen in the left lung with shift of the mediastinum to the left.

**FIGURE 3-24 Normal course of a nasogastric (NG) tube.** In the posteroanterior projection of the chest (A), the NG tube passes directly behind the trachea until it gets past the carina and then curves slightly to the left at the gastroesophageal junction (arrows). On the lateral view (B), the NG tube can be seen behind the trachea (T) and going down behind the heart.
FIGURE 3-25 Nasogastric (NG) tube in right main stem bronchus. If the NG tube gets into the trachea, it will usually go down the right main stem bronchus (arrows) (A). These tubes are quite rigid and, if pushed, can perforate the lung and go out into the pleural space (arrows) (B).

FIGURE 3-26 Normal subclavian catheter course. The subclavian catheter (Sc) should progress medially and then inferiorly to the medial clavicle, with the tip located in the superior vena cava. An endotracheal tube (ET) and nasogastric (NG) tube also are present. The remainder of overlying and coiled wires are electrocardiogram leads.

**Pleural Tubes**

Pleural tubes are typically placed to evacuate a pneumothorax or drain a pleural fluid collection. They can be small pigtail catheters or large bore and are inserted between the ribs in the midlateral or lower-lateral chest. One common question about these tubes concerns the location of the tip and side port. The tip should not abut the mediastinum. The side port on a large-bore tube can be seen as a discontinuity in the radiodense marker line, and it should be inside the chest cavity and not out in the soft tissues of the chest (see Fig. 3-27, B). Another question relates to whether the tube has kinked and whether it is working to reduce the pneumothorax or fluid collection. Remember, a posteriorly placed tube will have a hard time removing a pneumothorax if the patient is supine and the air collection is located anteriorly.

**Cardiac Pacers and Defibrillators**

Cardiac pacers are most commonly bipolar (and sometimes tripolar) wires that extend from a pacing source, down the SVC, through the right atrium, and to the right ventricular apex (Fig. 3-32). Not much that can go wrong with these can be identified on a conventional chest x-ray; however, in the case of pacemaker failure, look for a broken wire. The batteries and electronics are typically placed outside the ribcage just under the skin on the left side of the chest. Automatic implantable cardioverter-defibrillators are placed in a similar location but can be recognized by a fat section of wire both at the tip and about midway between the tip and the electronics. Because strong magnetic fields can interfere with electronics, pacers and defibrillators are generally regarded as a contraindication to use of magnetic resonance imaging scans.

**Overlying Electrocardiogram Wires and Tubes**

Electrocardiogram (ECG) leads are metallic wires and therefore are denser than most tubes and catheters. They also can be recognized because they usually have a button or snap on the end, usually are over the upper chest, and do not follow any reasonable internal anatomic pathway.
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| Chest (such as venous structures) (see Fig. 3-27, B). Other overlying objects that are often confusing are oxygen supply lines to nasal cannulas and masks. These can look like catheters, but they too do not follow normal vascular or anatomic pathways and are seen mostly over the upper chest and neck. If an unsolved issue appears, perform a visual examination of the patient rather than ordering another x-ray.

**Trauma**

A chest x-ray is often obtained in the emergency department in patients with major trauma. This allows rapid identification of moderate to large pneumothoraces and pleural fluid collections. Because the patients are usually supine, a small anterior pneumothorax or posterior fluid collection can easily be missed. These are often incidentally noted on a chest CT obtained later (see Fig. 3-75). With major chest trauma, consideration of spine and sternal injuries may require additional x-rays. Dedicated rib images are usually not needed because no change in treatment would occur as the result of an uncomplicated rib fracture. A widened mediastinum on a chest x-ray raises the question of vascular injury, and a contrasted CT scan is indicated. Plain x-ray examinations often underestimate the extent of soft tissue injuries, and as a result, it is common for trauma surgeons to order a CT scan of the chest, abdomen, and pelvis. This is done to identify life-threatening injuries that require prompt surgical intervention.

Pulmonary infiltrates are common after lung trauma. Pulmonary contusions can occur without rib fractures and are seen within hours of an accident. About 50% of such
The latter indicates a high probability of rib fracture, pneumothorax, or penetrating injury. The various entities related to trauma are discussed and shown with examples later in this chapter.

A posttraumatic abnormality that can produce bilateral, ill-defined infiltrates is fat embolism. This is not seen except with fracture of a large bone (such as the femur) patients will have hemoptysis. Contusions are seen radiographically as ill-defined pulmonary parenchymal infiltrates caused by hemorrhage and edema. If uncomplicated, they normally resolve over a period of 4 to 5 days. Pulmonary hematomas are caused by bleeding as a result of shearing injuries of the lung parenchyma. These can appear as nodules or masses, and they may cavitate. They take weeks to resolve completely. Pneumomediastinum or subcutaneous emphysema also should be identified. The latter indicates a high probability of rib fracture, pneumothorax, or penetrating injury. The various entities related to trauma are discussed and shown with examples later in this chapter.

A posttraumatic abnormality that can produce bilateral, ill-defined infiltrates is fat embolism. This is not seen except with fracture of a large bone (such as the femur)
Foreign bodies are usually the result of aspiration or swallowing an object that was in the mouth. In the case of aspiration, depending on the density of the offending object, it may or may not be seen on a chest x-ray. Metal objects are easily seen (Fig. 3-34), whereas items such as plastic toys and peanuts do not differ in density from soft tissues. The typical location of aspirated foreign bodies is in the right main stem or right lower lobe bronchus because of the more vertical direction compared with the left side.

As mentioned earlier, in cases in which a nonmetallic obstructing foreign body is suspected, you should order an imaging study that has undergone surgical manipulation. These patients usually initially have a clear chest on images and have a sudden onset of dyspnea some time afterward. The diagnosis is made by looking for fat globules in the urine.

### The Airways

Issues related to epiglottitis and retropharyngeal abscesses were discussed in Chapter 2. You should be able to recognize several major problems related to airways.

#### Occlusion

Lung cancer can narrow or totally occlude a bronchus. If the airway is only partially occluded, difficulty will occur in clearing mucus, and a postobstructive pneumonia may be found. In any older adult who has a focal pneumonia, you should look carefully at the nearby bronchi. In an adult with recurrence of pneumonia in a particular location, you should suspect a lung tumor, and bronchoscopy may be indicated.

If a tumor or mucous plug totally obstructs an airway, resorption of air distally will be accompanied by volume loss. If the obstruction is of a major bronchus, rapid opacification (whiteness) of the lung may be found, accompanied by shift of the trachea and mediastinal structures toward the affected side as a result of volume loss. A major bronchus obstruction can often be identified on the frontal chest x-ray. Additional studies, such as CT, can be useful to determine the extent of tumor, the presence of enlarged lymph nodes, and so forth (Fig. 3-33). If the patient is young or very sick, a mucous plug is a more likely cause of obstruction and volume loss than is a tumor. Bronchoscopy or respiratory therapy should be suggested rather than a CT scan of the chest.
On the PA x-ray the superior portions of the hemidiaphragms may be down to the level of the posterior twelfth ribs, and often blunting of the costophrenic angles is seen. With COPD an increase in the AP diameter of the chest on the lateral view, a large anterior clear space between the sternum and ascending aorta, and marked flattening or even inversion of the hemidiaphragms are seen (Fig. 3-35). An associated finding may be the presence of bullae or large air cavities within the lungs as a result of destruction of alveoli. In advanced COPD, what is known as a saber sheath trachea may be seen. This refers to a trachea that is

**FIGURE 3-34** Aspiration of a nonobstructing foreign body. A metallic straight pin can be seen in the right lower lobe on both the posteroanterior (A) and the lateral (B) chest x-rays.

**FIGURE 3-35** Chronic obstructive pulmonary disease (COPD). The posteroanterior view (A) shows that the superior aspect of the hemidiaphragms is at the same level as the posterior aspect of the twelfth ribs. Hyperinflation also is seen on the lateral view (B) as an increase in the anteroposterior diameter and flattening of the hemidiaphragms.

inspiration and expiration PA chest views. In uncooperative children, right and left decubitus chest views are sometimes used. The side that does not decrease in volume during expiration or when placed dependently is abnormal.

**Chronic Obstructive Pulmonary Disease**
A chest x-ray can detect only moderate or advanced COPD. In early stages the chest x-ray is normal, and you must rely on pulmonary function tests to make this diagnosis. In advanced stages, obvious signs of hyperinflation are noted. On the PA x-ray the superior portions of the hemidiaphragms may be down to the level of the posterior twelfth ribs, and often blunting of the costophrenic angles is seen. With COPD an increase in the AP diameter of the chest on the lateral view, a large anterior clear space between the sternum and ascending aorta, and marked flattening or even inversion of the hemidiaphragms are seen (Fig. 3-35). An associated finding may be the presence of bullae or large air cavities within the lungs as a result of destruction of alveoli. In advanced COPD, what is known as a saber sheath trachea may be seen. This refers to a trachea that is
compressed from the sides by the lungs, with the trachea appearing narrow on the PA x-ray and wide on the lateral image. I do not see this often. Because most COPD is associated with smoking, also look for an occult lung cancer.

**Atelectasis**

Atelectasis refers to collapse of a lung or portion of the lung with resorption of air from the alveoli. This can result from an obstructing bronchial lesion, extrinsic compression (from pleural effusions or bullae), fibrosis, or a loss of surface tension in the alveoli (as in hyaline membrane disease). Atelectasis can involve a small subsegmental region of a lung or the entire lung. Because atelectasis is a common finding and has clinical implications, you should be familiar with the various appearances and progressions that are associated with focal or generalized volume loss in the lung.

Linear (discoid or platelike) atelectasis is almost always seen in the middle or lower lung zones as a horizontal or near-horizontal line of increased density (whiteness). This is visualized on a plain chest x-ray by the associated bronchial wall thickening, which is the result of infection.

**Bronchiectasis**

Bronchiectasis refers to diffuse or focal dilatation of the bronchi. This is usually the result of chronic or childhood infection and subsequent cartilage damage. It also is seen in patients with rare entities such as cystic fibrosis and allergic bronchopulmonary aspergillosis. Symptoms are chronic cough, purulent sputum, and sometimes hemoptysis. Bronchiectasis typically involves the medial aspects of both right and left lower lobes. This is visualized on a plain chest x-ray by the associated bronchial wall thickening, which is the result of infection.

Early bronchiectasis may be associated with a normal chest x-ray, although in later stages the bronchial wall thickening causes the appearance of a stringy or honeycomb (coarse mesh) infiltrate at both lung bases. In addition, sometimes “tram-tracking” can be seen. This refers to two parallel linear densities seen as white lines that represent the thickened bronchial walls. Usually this is seen for only 2 or 3 cm before it disappears (Fig. 3-37, A and B). Late bronchiectasis is seen as cavities or a honeycomb appearance at the lung bases. Although it is difficult to see bronchiectasis on a plain chest x-ray, it is quite easy to identify by using thin-slice or high-resolution CT scanning (Fig. 3-37, C). You should not order a CT study unless it will make a difference in therapy or outcome.

**Asthma**

Imaging studies are usually not necessary in an uncomplicated asthma attack. A chest x-ray is ordered only with the suspicion of superimposed disease or if the attack is resistant to therapy. The findings of asthma on chest x-ray range from a normal appearance (about three fourths of the time) to signs of mild hyperinflation, such as slightly increased AP diameter or hemidiaphragms with the superior aspect level with the posterior tenth to eleventh ribs (Fig. 3-36). With asthma it is unusual to have enough hyperinflation either to drive the diaphragms lower than this or to significantly flatten them (as seen on the lateral view). An acute asthma attack can result in a pneumomediastinum but rarely in a pneumothorax. Patients with recurrent asthmatic attacks may have a prominent interstitial pattern due to scarring, and they may have slightly thickened bronchial walls. Also look for a focal infiltrate or pneumonia as the precipitating cause of the asthmatic attack.
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Along the right lateral aspect of the superior mediastinum and then curving out over the apex. In this late stage (complete right upper lobe collapse), the diagnosis can be difficult to make. Usually, however, other signs of volume loss point toward the right upper lobe. These include shift or pulling of the trachea to the right and elevation of the right hilum. Remember that the right hilum should normally be slightly lower than the left; if both right and left hila appear at the same level, think about right upper lobe volume loss as one possible cause for this finding.

Atelectasis of the right middle lobe is often difficult to appreciate on an AP x-ray, but it appears as a slightly increased density (whiteness) over the lower portion of the right lung, and loss of the normally distinct right cardiac margin is seen. On the lateral chest x-ray a narrow white triangle will project over the heart, formed by the approximation of the minor fissure and the lower half of the major fissure.

Minimal form of subsegmental collapse is most commonly seen in patients who have difficulty breathing, such as after recent surgery or rib fractures. The atelectasis may appear quickly (within hours) and can disappear just as quickly after the patient has been encouraged to breathe deeply or after respiratory therapy (Fig. 3-38).

Atelectasis, or collapse of entire lung segments, occurs typically as a result of a mucous plug, tumor, or malplacement of ET tubes. Early right upper lobe atelectasis is seen on the AP or PA x-ray as a hazy white density in the right upper lung zone. As air is resorbed from the right upper lobe, increasing density but decreasing right upper lobe volume may be seen. During this process the right minor fissure moves from its normal horizontal position and becomes bowed upward. This looks like an upside-down white triangle at the right lung apex. With complete collapse of the right upper lobe, only a whitish density may appear, beginning at the right hilum and extending up along the right lateral aspect of the superior mediastinum and then curving out over the apex. In this late stage (complete right upper lobe collapse), the diagnosis can be difficult to make. Usually, however, other signs of volume loss point toward the right upper lobe. These include shift or pulling of the trachea to the right and elevation of the right hilum. Remember that the right hilum should normally be slightly lower than the left; if both right and left hila appear at the same level, think about right upper lobe volume loss as one possible cause for this finding.

Atelectasis of the right middle lobe is often difficult to appreciate on an AP x-ray, but it appears as a slightly increased density (whiteness) over the lower portion of the right lung, and loss of the normally distinct right cardiac margin is seen. On the lateral chest x-ray a narrow white triangle will project over the heart, formed by the approximation of the minor fissure and the lower half of the major fissure.

FIGURE 3-37 Bronchiectasis. A posteroanterior chest x-ray in a patient with bronchiectasis demonstrates bronchial wall thickening, most pronounced at the lung bases (A). This is often referred to as tram-tracking or linear parallel lines that represent thickened bronchial walls (arrows). In advanced bronchiectasis (B), coarse basilar lung infiltrates may appear cavitary. Bronchiectasis is much better seen on a computed tomography scan (C) than on a chest x-ray. The findings are of dilated bronchi with thickened bronchial walls (arrow).
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Chest can be done by looking at the cardiophrenic angles on an upright frontal view of the chest to see if blunting or pleural fluid tracking up along the sides of the chest wall is present. If volume loss is seen (indicated by pulling down of the hilum or mediastinal shift toward the affected side), collapse should be suspected. With a large pleural effusion, often associated underlying lung atelectasis occurs as a result of direct compression, so do not be fooled into assuming that only one entity can exist at a given time.

Left upper lobe atelectasis is seen on the frontal chest x-ray as a generalized density in the left upper lung. In the early stages, increased density occurs anterior to the major fissure on the lateral chest x-ray. As atelectasis of the left upper lobe progresses and becomes complete, the collapsed left upper lobe becomes pancaked along the anterior chest wall and may be visualized only as a dense white line 1 or 2 cm thick in the retrosternal region (Fig. 3-40).

With right lower lobe collapse, there is increasing density at the right lung base, loss of the right hemidiaphragm margin, and pulling down of the right hilum. On the lateral chest x-ray, posterior and inferior displacement of the major fissure and increasing density (or whiteness) over the lower thoracic spine appear (Fig. 3-39).

Lobar atelectasis, or collapse of left lung lobes, can be more difficult to appreciate than you might suspect. On an AP or a PA chest x-ray, left lower lobe collapse appears as a haziness or increasing density at the left lung base and retrocardiac region. A retrocardiac density is more likely to be atelectasis than a pneumonia, particularly immediately after thoracic surgery. With left lower lobe atelectasis, the left hilum may be pulled down and level with the right one, and the left hemidiaphragm will be hard to see. On the lateral view, posterior and some inferior displacement of the major fissure are noted. As in right lower lobe collapse, increasing density over the lower thoracic spine is seen.

Both right and left lower lobe collapse can mimic or be mimicked by pleural effusions. The way to differentiate the two is to exclude the presence of a pleural effusion. This can be done by looking at the cardiophrenic angles on an upright frontal view of the chest to see if blunting or pleural fluid tracking up along the sides of the chest wall is present. If volume loss is seen (indicated by pulling down of the hilum or mediastinal shift toward the affected side), collapse should be suspected. With a large pleural effusion, often associated underlying lung atelectasis occurs as a result of direct compression, so do not be fooled into assuming that only one entity can exist at a given time.

Left upper lobe atelectasis is seen on the frontal chest x-ray as a generalized density in the left upper lung. In the early stages, increased density occurs anterior to the major fissure on the lateral chest x-ray. As atelectasis of the left upper lobe progresses and becomes complete, the collapsed left upper lobe becomes pancaked along the anterior chest wall and may be visualized only as a dense white line 1 or 2 cm thick in the retrosternal region (Fig. 3-40).

The most severe form of volume loss occurs after surgical removal of one lung. After a pneumonectomy, empty space fills with fluid over several weeks. As this progresses, the hemidiaphragm will elevate, the mediastinum will move toward the affected side, and the remaining lung will hyperinflate and often will herniate across the midline. If the mediastinal structures are displaced away from the resected lung, you should be suspicious of a postoperative malignant effusion or an empyema.

**Blebs and Bullae**

Both blebs and bullae refer to a portion of lung in which an air space is found without alveoli. Although I have never known a clear distinction to be made between these two entities, most people consider a bleb to be a relatively small air cavity, usually on the order of 1 cm or less. A bulla is greater than 1 cm and often significantly larger, measuring several inches in diameter. Both a bleb and a bulla should have walls that are very thin and well defined (if they can...
Infiltrates and Pneumonias

For appropriate diagnosis of a patchy or diffusely increased density in the lungs, you need to characterize the x-ray appearance and correlate this with the clinical history. Most radiologists will report an infiltrate as alveolar, interstitial, nodular, or mixed, and they will tell you what they see at all (Fig. 3-41). If a thick wall is present, think in terms of an inflammatory or cavitary neoplastic lesion. Because the walls of blebs and bullae are so thin, the sensitivity of a chest x-ray for detection of these lesions is quite poor, although they are easily seen on a CT scan. The presence of a bulla can sometimes be inferred on a chest x-ray by noting a region of lung that does not seem to have pulmonary vessels.

**Air-Space Pathology**

**Infiltrates and Pneumonias**

For appropriate diagnosis of a patchy or diffusely increased density in the lungs, you need to characterize the x-ray appearance and correlate this with the clinical history. Most radiologists will report an infiltrate as alveolar, interstitial, nodular, or mixed, and they will tell you...
whether it is focal (e.g., in the right upper lobe) or diffuse. The terms \textit{alveolar} and \textit{interstitial} are often difficult for the novice and the expert radiologist to differentiate and agree on.

Alveolar simply means that the alveolar spaces are filled with some material. In simple terms this means that the alveoli are filled with pus, blood, fluid, or cells. Given this, it is not possible radiographically to tell whether an alveolar infiltrate is due to a pneumonia (pus), pulmonary hemorrhage (blood), pulmonary edema (fluid), or alveolar tumor (cells) (Fig. 3-42). Most alveolar infiltrates either are somewhat fluffy or represent areas of complete consolidation. As filling of the alveoli progresses, the only things left with air in them are the bronchi, and thus “air bronchograms” can be seen (Fig. 3-43, A). If you see a bronchus filled with air and outlined by increased density, you can be certain that you are dealing with an alveolar process.

Interstitial infiltrates are caused by disease processes that affect tissues outside the alveoli. Interstitial processes are usually diffuse and are seen as thin white lines (Fig. 3-43, B). Occasionally they may be somewhat honeycombed in appearance, and the differential diagnosis of these processes often depends on whether the interstitial infiltrate is acute or chronic. Again, the finding of an interstitial infiltrate is nonspecific. Increased fluid in the interstitium and interlobular septa can be seen in CHF. Interstitial changes also can be seen with what is commonly referred to as \textit{lymphangitic spread of tumor} as well as idiopathic pulmonary fibrosis, collagen vascular diseases, and other entities. Do not be surprised if you think you see both interstitial and alveolar signs on the same chest x-ray. Many processes, such as CHF, can cause both findings (e.g., interstitial edema and pulmonary edema with alveolar filling).

\textbf{Community-Acquired Pneumonia in Adults}

The diagnosis of pneumonia should be made clinically, based on fever, cough, dyspnea, pleuritic chest pain, rales, localized diminished breath sounds, percussion dullness, or egophony on auscultation. A chest x-ray is confirmatory and helps differentiate pneumonia from other conditions that may have similar symptoms (e.g., bronchial obstruction) and may demonstrate findings that suggest a complicated course or prolonged recovery, such as multilobar distribution and pleural effusions.
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Medial segment of the right middle lobe will obscure the right heart border on the frontal view, and on the lateral view the infiltrate is seen as a triangular density radiating from the hilum toward the anterior and lower part of the chest (Fig. 3-45).

Right and left lower lobe infiltrates can be visualized by one of three methods. They may obscure the right or left hemidiaphragm on the frontal view. Remember, on an AP or a PA chest x-ray, you should normally be able to see the hemidiaphragms from the lateral costophrenic angles almost all the way to the spine (even behind the heart) (Fig. 3-46, A). On the lateral view, lower lobe infiltrates can be identified as being behind the location of the major fissure.

Most bacterial pneumonias produce lobar, segmental, or patchy infiltrates. Although this is an alveolar infiltrate, the alveolar filling and consolidation are usually not enough to be able to see distinct air bronchograms. Accurate localization of a pneumonia to a segment of the lung usually requires both PA and lateral chest x-rays. When the consolidation is fairly dense, the infiltrate is quite easy to localize. A right or left upper lobe infiltrate is usually seen as increased density in the upper portions of the lung on the AP or PA view. The lateral image generally is unnecessary for this diagnosis (Fig. 3-44).

A right middle lobe infiltrate or pneumonia can be in the medial or lateral segment, or both. An infiltrate in the medial segment of the right middle lobe will obscure the right heart border on the frontal view, and on the lateral view the infiltrate is seen as a triangular density radiating from the hilum toward the anterior and lower part of the chest (Fig. 3-45).

Right and left lower lobe infiltrates can be visualized by one of three methods. They may obscure the right or left hemidiaphragm on the frontal view. Remember, on an AP or a PA chest x-ray, you should normally be able to see the hemidiaphragms from the lateral costophrenic angles almost all the way to the spine (even behind the heart) (Fig. 3-46, A). On the lateral view, lower lobe infiltrates can be identified as being behind the location of the major fissure.

**FIGURE 3-44** Right upper lobe pneumonia. On the posteroanterior chest x-ray (A), note that the right cardiac border is well seen. The alveolar infiltrate is seen in the right midlung. Localization is quite easy on the lateral view (B) by noting where the major and minor fissures should be (dashed lines). The infiltrate (arrows) can be seen above the minor fissure, indicating that it is in the upper lobe.

**FIGURE 3-45** Right middle lobe pneumonia. On the posteroanterior chest x-ray (A), the alveolar infiltrate obscures the right cardiac border. This silhouette sign means that the pathologic process is up against the right cardiac border and therefore must be in the middle lobe. This is confirmed on the lateral view (B) by noting that the consolidation is anterior to the major fissure but below the minor fissure.
ment, or no improvement is found after two separate trials of antibiotic therapy based on Gram stain sputum and blood cultures. CT is indicated in a patient with recurrent pneumonia at the same site within 6 months.

**Pneumonia in Immunocompromised Patients**

In immunocompromised patients with a fever, a chest x-ray is indicated. If the x-ray is positive, the patient is treated and followed up clinically. If the chest x-ray is negative and the patient is symptomatic or hypoxic, and the rest of the examination is negative, a CT scan may be indicated, but bronchoscopy usually provides sufficient information for diagnosis and management. In patients with acquired immunodeficiency syndrome (AIDS), it is best to characterize the air-space disease as diffuse, localized, or multiple nodules.

Lobar or segmental infiltrates in immunocompromised adults are most likely bacterial or fungal in origin. A chest x-ray in such a patient may reveal infiltrates (Fig. 3-47, A), although a patient who has PCP can have a relatively normal chest x-ray. In these circumstances a CT scan may show “mosaic ground glass” densities in the lungs. Diffuse air-space disease in immunocompromised patients is due to *Pneumocystis* with or without cytomegalovirus infection. Early *Pneumocystis* infection can be seen as an interstitial infiltrate, although a more advanced condition may cause diffuse alveolar disease with air bronchograms. This can progress to consolidation within several days. Occasionally upper lobe air-filled cysts progress to pneumothorax or bronchopleural fistula. These latter findings mimic tuberculosis, but with PCP, adenopathy and pleural effusions are rare. Fungal infections in AIDS patients are uncommon.

In patients with AIDS, diffuse or nodular pulmonary involvement may be found with lymphoma or Kaposi’s sarcoma (Fig. 3-47, B). A nuclear medicine gallium scan will not be positive in patients with Kaposi’s sarcoma but will be positive in PCP, most other infections, and lymphoma. Isolated hilar adenopathy in AIDS patients is more likely due to lymphoma than to mycobacterial infections.

**FIGURE 3-46 Right lower lobe pneumonia.** On the posteroanterior chest x-ray (A), an alveolar infiltrate can easily be seen at the right lung base. The fact that the right heart border is clearly identified suggests that this is not in the right middle lobe but is probably in the lower lobe. The lateral view (B) shows that the infiltrate is behind the major fissure and is in the anterior segment of the right lower lobe. The lateral view in a different patient (C) also shows a right lower lobe infiltrate. In this case, the “spine sign” is used to detect an early infiltrate. The vertebral bodies of the spine should become darker as one goes from upper to lower thoracic spine, but those marked with black arrows are getting whiter rather than darker, indicating that an overlying infiltrate is present.
Acquired immunodeficiency syndrome (AIDS) complications.

A posteroanterior chest x-ray in a human immunodeficiency virus–positive patient shows a diffuse bilateral perihilar infiltrate due to *Pneumocystis pneumonia* (A). In many patients with AIDS the chest x-ray may be negative when *Pneumocystis* is present. A chest x-ray in a different patient with AIDS (B) shows bilateral dense patchy alveolar infiltrates, in this case representing Kaposi's sarcoma.

**Aspiration Pneumonia**

A common indication for ordering a chest x-ray is to exclude aspiration pneumonia. The question of aspirated gastric contents may occur as the result of a seizure, cardiac resuscitation attempt, or alcoholic binge. In the case of aspiration the chest x-ray is often normal within the first hour or so. If you get a normal chest x-ray interpretation after a recent suspected aspiration, a follow-up image should be obtained in approximately 12 hours. It often takes several hours for the gastric contents to react with the lung to cause fluid exudate and an alveolar infiltrate (Fig. 3-48). A number of other toxic agents, such as water (drowning), hydrocarbons, chlorine, smoke, heroin, and aspirin, as well as radiation therapy, can produce alveolar infiltrates. Some drugs, such as busulfan, bleomycin, and cyclophosphamide, produce toxic interstitial disease. Amiodarone can cause a wide variety of pulmonary abnormalities, but the characteristic finding seen on CT scan is increased lung density due to the iodine content of the drug.

**Tuberculosis**

Routine screening chest x-rays to detect TB are not indicated. Chest x-rays are often done on persons who have had a positive purified protein derivative (PPD) skin test, and 99% or more are normal. Guidelines exist for the use of chest x-rays in TB detection in asymptomatic patients. One should ascertain the results of a recent chest x-ray on elderly persons being admitted to nursing homes (and who may not react to skin tests). A chest x-ray also is indicated in a person with a first-time positive PPD skin test or a converter to determine if prophylaxis or multiple-drug therapy should be initiated. It should be pointed out that a normal chest x-ray does not exclude active TB, because the TB that results in a positive skin test need not be in the lungs but can be in the kidneys or even in the spine.

Primary TB is most commonly seen as a focal middle or lower lobe consolidation with lymphadenopathy and
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Fungal Lesions
A wide variety of fungal lesions can affect the lung. These may be seen as focal infiltrates or as discrete lesions. Occasionally a fungus ball or a mycetoma can be seen within a pulmonary cavitary lesion (Fig. 3-50). Cryptococcus can be seen as a small cavitary lesion within the lung, and small satellite nodules are sometimes nearby.

Lung Abscess
Inhaled particulate matter or necrotic pneumonias can result in a lung abscess. A typical appearance is that of a lesion several centimeters in diameter that either looks solid (Fig. 3-51) or has a lucent (dark) air-filled center and a shaggy, thick wall. The wall typically is about 5 mm in thickness. The major differential diagnosis of a thick-walled cavitary lesion in the lung is a lung abscess or a cavitating neoplasm (usually squamous cell carcinoma). Lung abscesses may have an air/fluid level in the central portion, but so may infected cavitary neoplasms. CT scanning is commonly used to direct a needle biopsy of such lesions to obtain cultures and cytologic studies. Sometimes a lung abscess can be confused with an empyema, but abscesses are typically round, with the lung and blood vessels in normal position; if there is an air/fluid level, it is the same length on PA and lateral images. An empyema is usually elliptical, and the lung and blood vessels are displaced or compressed; if there is an air/fluid level, it often is of a different length on frontal and lateral images.
Diagnosis is probably best made on clinical grounds, although if an alveolar infiltrate changes rapidly (within several hours or within 1 day), the infiltrates most likely represent CHF or fluid overload. In patients with CHF, usually Kerley B lines, pleural effusions, increased heart size, and perihilar or basilar infiltrates occur. With ARDS, Kerley B lines should not be present, pleural effusions occur only late, heart size is often normal, and alveolar infiltrates often extend to the lung periphery.

Bacterial pneumonias often take a day or more to change appearance, and patients with ARDS often have a relatively stable appearance over many days. The diagnosis of pneumonia is often made on the basis of bacterial cultures. Be aware that changes in the x-ray technique or in the amount of positive-pressure respiratory therapy may cause significant changes in the appearance of the infiltrates in patients with ARDS.

**Chronic Interstitial Lung Diseases**

A wide variety of chronic lung abnormalities can occur. Bronchiectasis and COPD have already been described. Given the nonspecificity of the radiographic findings and the varied appearance of interstitial lung diseases, the diagnosis is best made by medical history and clinical findings. If the patient is not acutely ill, often no imaging needs to be done. If symptoms or decreased diffusing capacity, restrictive lung disease by pulmonary function tests, and interstitial prominence are seen on the chest x-ray, then an HRCT scan of the chest can be done to look for early infiltrative lung disease (such as unusual interstitial pneumonitis). If the patient is acutely ill, and atypical pneumonia or heart disease is suspected, a CT scan is not needed.

Diseases that preferentially affect the upper lobes are silicosis, sarcoidosis, and eosinophilic granuloma. Silicosis may have “eggshell” calcifications in the hilar nodes in addition to uniformly distributed small (1- to 10-mm)
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Chest (or other collagen vascular diseases). For upper lobe diseases, they use CASSET P, which stands for cystic fibrosis, ankylosing spondylitis, silicosis, sarcoid, eosinophilic granuloma, tuberculosis, and *P. carinii*. For diffuse chronic interstitial disease, they use LIFE, which refers to lymphangitic spread of tumor, inflammation (infection), fibrosis, and edema. For acute interstitial infiltrates, they use HEP, referring to hypersensitivity (allergic alveolitis), edema, and pneumonia (viral).

Lymphangitic carcinoma and sarcoid can have extremely small nodules that are concentrated about the bronchi and blood vessels, whereas most of the other conditions have nodules that extend to the periphery of the lung. Most collagen vascular diseases can cause interstitial (fine lines), reticular (meshlike), or honeycombing (coarse mesh–like) pulmonary parenchymal abnormalities. These can be seen with rheumatoid arthritis and systemic lupus erythematosus and with a number of other entities.

Some chronic lung disease can cause diffuse interstitial changes, honeycombing, or focal patchy infiltrates. Sarcoid

![FIGURE 3-53 Silicosis](image1)

Silicosis. Chest x-rays on the same person 20 years apart. The initial chest x-ray (A) shows an unremarkable left upper lobe. After many years of hard-rock mining, rounded calcifications are seen about the left hilum, a nodular appearance is seen in the lung parenchyma, and fibrosis is seen at the left apex (B).

![FIGURE 3-54 Late stage of silicosis](image2)

Late stage of silicosis. The chest x-ray (A) shows significant parenchymal disease, predominant in the upper lobes, as a result of progressive massive fibrosis. The regular (B) and high-resolution (C) computed tomography scans show both coarse interstitial and nodular changes.
already was mentioned. Other diseases that produce these varied findings include extrinsic allergic alveolitis (caused by a number of antigens such as mold or avian proteins), eosinophilic granuloma, bronchiolitis obliterans, and eosinophilic lung disease. Given the nonspecificity of the radiographic findings and the varied appearance of these diseases, the diagnosis is best made by history and clinical findings. The chest x-ray or high-resolution CT can provide supporting information and be used to monitor progress of a given disease.

Bioterrorist Agents

Bioterrorist agents do not fit neatly into any specific imaging category. They are included here because they are infectious and many cause lung abnormalities, particularly air-space findings. A few of the agents (such as inhalational anthrax) have characteristic radiologic findings. Other agents, such as smallpox or viral hemorrhagic fevers, have striking clinical presentations. Regarding the imaging findings, anthrax has mediastinal adenopathy but not interstitial edema, focal consolidation, or diffuse air-space disease. Smallpox can have segmental or lobar consolidation after the skin lesions appear, and it occasionally exhibits pulmonary nodules in immunized hosts, but interstitial edema and adenopathy do not occur, and diffuse air-space disease is uncommon. Plague commonly has segmental or lobar consolidation and sometimes has adenopathy and diffuse air-space disease. Cavitation is rare. Tularemia commonly has segmental or lobar consolidation, occasional adenopathy, and cavitation. Interstitial edema and diffuse air-space disease is rare. Q fever commonly has segmental or lobar consolidation but not other thoracic imaging manifestations. American hantavirus commonly has interstitial edema and diffuse air-space disease but not adenopathy or segmental or lobar consolidation. Viral hemorrhagic fevers may have mild interstitial edema but no other thoracic imaging manifestations.

Hemoptysis

Bleeding from the gastrointestinal tract and nasopharynx is more common than is true hemoptysis, and these sites should be excluded as a cause of the patient’s complaints. The initial imaging studies for hemoptysis are standard PA and lateral chest x-rays. The most common cause is bronchitis, although an endobronchial lesion or pulmonary embolism also should be considered. If the chest x-ray is normal and the patient is at low risk for bronchogenic carcinoma, an HRCT scan to exclude bronchiectasis is the most useful imaging study. If the chest x-ray is normal and the patient is at high risk for lung cancer (>10 pack-years of smoking) or has a malignancy elsewhere, bronchoscopy is usually performed, although CT also may be used. If an abnormality is seen on the chest x-ray, whether CT or bronchoscopy is used often depends on the nature of the abnormality. If it is peripheral, CT may be more helpful than bronchoscopy. If hemoptysis is present in a traumatized patient, a transected bronchus requiring surgery should be considered. In these latter cases a chest x-ray usually reveals an associated pneumomediastinum.

Lung Cancer and Nodules

Solitary Pulmonary Nodule

A pulmonary nodule is really a small mass. I think of a nodule as being smaller than 3 cm in diameter, and when something in the lung is larger than 3 cm, I call it a mass. To me, anything approaching the size of a golf ball is strongly suggestive of a neoplasm; anything that is only 0.5 cm in diameter that you can see easily on a chest x-ray and is probably very dense is most likely a granuloma. Age also is a useful discriminating factor. In a patient younger than 40 years, a lung cancer may occur, but it is extremely rare.

A solitary pulmonary nodule can represent practically anything. As already mentioned, it may be due to a granuloma or lung cancer, but other causes include a single metastatic lesion, septic embolus, arteriovenous malformation, hamartoma, or even a small area of rounded

![FIGURE 3-55 Sarcoidosis. In the pulmonary parenchymal form, diffuse infiltrates are seen throughout both lungs (A). Many of these patients also have associated lymphadenopathy about the hilum or in the paratracheal region. A high-resolution computed tomography scan (B) shows marked thickening of the bronchial walls (arrows).](image-url)
The second step is to characterize the nodule. If it is well defined and round, it is much more likely to be benign than if it is irregular or indistinct in its margins. Calcification that is dense (Fig. 3-56) or within a nodule suggests that it is most likely a granuloma (Fig. 3-57). The calcification, however, should be centrally located in the nodule. If calcification is eccentrically located in a nodule, consider a neoplasm.

The third step of importance is to determine whether the nodule is new or old. A careful review of all available chest x-rays should be performed and phone calls to pertinent hospitals should be made before expensive or invasive studies are ordered. A nodule that has remained unchanged in size for 2 years can be considered benign. Stability for a period of 1 year is not enough, because slow-growing tumors may not change appreciably in a 12-month interval. If a 1-cm nodule doubles the number of cells that

TABLE 3-5 Common Differential Diagnosis of Pulmonary Nodule(s)

<table>
<thead>
<tr>
<th>Solitary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less Than 3 cm</td>
</tr>
<tr>
<td>Granuloma (especially if calcified)</td>
</tr>
<tr>
<td>Lung cancer</td>
</tr>
<tr>
<td>Single nipple shadow</td>
</tr>
<tr>
<td>Wart on the skin</td>
</tr>
<tr>
<td>Benign lung tumors</td>
</tr>
<tr>
<td>Metastasis</td>
</tr>
<tr>
<td>Rounded atelectasis</td>
</tr>
<tr>
<td>Septic emboli</td>
</tr>
<tr>
<td>Large</td>
</tr>
<tr>
<td>Lung cancer</td>
</tr>
<tr>
<td>Round pneumonia</td>
</tr>
<tr>
<td>Large solitary metastases</td>
</tr>
<tr>
<td>Lung abscess</td>
</tr>
<tr>
<td>Multiple</td>
</tr>
<tr>
<td>Granulomas</td>
</tr>
<tr>
<td>Metastases</td>
</tr>
<tr>
<td>Septic emboli</td>
</tr>
<tr>
<td>Cavitory</td>
</tr>
<tr>
<td>Septic emboli</td>
</tr>
<tr>
<td>Tuberculosis</td>
</tr>
<tr>
<td>Fungal</td>
</tr>
<tr>
<td>Squamous cell cancer</td>
</tr>
<tr>
<td>Benign Characteristics</td>
</tr>
<tr>
<td>Small (&lt;3 cm)</td>
</tr>
<tr>
<td>Round</td>
</tr>
<tr>
<td>Well-defined edges</td>
</tr>
<tr>
<td>Slow growing (no appreciable change in 2 yr)</td>
</tr>
<tr>
<td>Central calcification</td>
</tr>
<tr>
<td>Solid (not cavitated)</td>
</tr>
<tr>
<td>Malignant Characteristics</td>
</tr>
<tr>
<td>Large (&gt;3 cm)</td>
</tr>
<tr>
<td>Irregular shape</td>
</tr>
<tr>
<td>Poorly defined edges</td>
</tr>
<tr>
<td>Obvious growth in &lt;2 yr</td>
</tr>
<tr>
<td>Asymmetric or no calcification</td>
</tr>
<tr>
<td>Cavitated</td>
</tr>
<tr>
<td>Active accumulation of FDG on a PET scan</td>
</tr>
</tbody>
</table>

FDG, Fluorodeoxyglucose; PET, positron emission tomography.

atelectasis (Table 3-5). Several challenges appear when you have identified what you think is a solitary pulmonary nodule. The first is to determine that the nodule is within the lung and that you are not looking at a nipple shadow or wart that is on the skin surface. A nipple shadow is seen projecting within the lung only on the frontal chest x-ray, is usually in the midclavicular line, and projects over the lower half of the lung. Small nipple markers (BBs) with a repeated chest x-ray may be of some use.

Locate the “nodule” in a horizontal plane on the frontal chest x-ray (for example, at the level of the aortic arch), and then look at the lateral chest x-ray (again at the horizontal plane of the aortic arch) and see whether you can find the nodule at the same level projecting within the chest on both views. If there is any doubt, you can obtain shallow oblique views; if the nodule is truly within the thoracic cavity, it should rotate less than the anterior and posterior ribs.

Figure 3-56 Solitary calcified granuloma. A very dense pulmonary nodule (arrow) is seen on both posteroanterior (A) and lateral (B) chest x-rays. This can be confidently called a granuloma; it needs no further workup, because it is much denser than even the surrounding ribs and therefore is clearly densely calcified.
Screening for Lung Cancer

Many years ago it was clear that annual chest x-rays did little or nothing to reduce mortality from lung cancer, even in smokers. By the time lesions were clearly identified, they were advanced enough that many had metastasized. Recent research using periodic low-dose CT for lung cancer screening of current (30 pack-years or more) or former smokers (quit <15 years ago) and who were ages 55 to 74 indicates that CT screening may confer a 20% reduction in lung cancer mortality. Guidance from the American Society of Clinical Oncology is as follows:

1. For smokers and former smokers ages 55 to 74 who have smoked for 30 pack-years or more and either continue to smoke or have quit within the past 15 years, annual screening with low-dose computed tomography (LDCT) should be offered over both annual screening with chest radiograph or no screening, but only in settings that can deliver the comprehensive care.

2. For individuals who have accumulated fewer than 30 pack-years of smoking, are either younger than 55 or older than 74, or quit smoking more than 15 years ago, and for individuals with severe comorbidities that would preclude potentially curative treatment and/or limit life expectancy, CT screening should not be performed.

It is clear that extremely small lesions can be detected with CT; however, the experience to date has shown that, if smokers are screened, about 70% will have one or more
Nothing could be further from the truth. A 1-cm-diameter nodule has about 10 billion cells in it. In terms of doubling times, it is already two thirds of the way toward filling the entire hemithorax.

Primary lung cancers have a number of appearances. Adenocarcinoma generally occurs peripherally, whereas squamous cell types tend to be central or peripheral. Squamous cell tumors of any origin may cavitate. Small cell carcinomas often initially appear as an indistinct hilar or perihilar mass. A unilateral hilar mass or persistent infiltrate in an adult older than 40 years should always raise the suspicion of a lung cancer.

A CT scan is the most valuable imaging method for initially and locally staging lung cancers. Intravenous contrast often is used with the CT scan, so that the tumor, adenopathy, and pulmonary vessels can be differentiated. However, if you have a good knowledge of anatomy, it is not necessary to use intravenous contrast. Analysis of a CT scan should include not only location and size of the pulmonary lesion but also whether it has a pleural or chest wall involvement and whether hilar or mediastinal lymphadenopathy is present (Fig. 3-60). The accuracy of CT in determining chest wall invasion is only about 50%, but invasion is suggested by pleural thickening, more than 3 cm of contact between pleura and tumor, obtuse angles between tumor and pleura, or an increased density of the extrapleural fat. A pleural effusion usually indicates a poor prognosis; however, only aspiration and cytologic confirmation of malignant cells in the effusion make the tumor unresectable. Staging of non–small cell lung cancers with regard to mediastinal and distant spread is best done with nuclear medicine whole-body FDG PET/CT scans.

Two classic, although uncommon, appearances of lung carcinoma are seen on the chest x-ray. The first of these is the Golden S sign, from a hilar tumor that has caused peripheral atelectasis (most commonly of the right upper lobe). Normally, as the right upper lobe collapses, an visible “nodules.” In some of the better-designed longitudinal studies, about 99% of these abnormalities are not cancer. This leaves the perplexing question of how to manage these patients. Many of the lesions are too small to perform an accurate percutaneous biopsy with a fine needle, and segmental resection carries at least a percentage or so mortality (Fig. 3-59). Usually the abnormalities are followed up using criteria developed by the Fleischner Society (Table 3-6).

### Lung Cancer

The pathology of lung cancers is a bit confusing. Some confusion arises because a number of tumors exhibit more than one type of pathology, a number are undifferentiated, and the incidence of cell types varies depending on the type of series (surgical versus autopsy) quoted. About 40% of lung cancers are adenocarcinomas, and 30% or so are squamous. Most of the remainder are small cell carcinomas (which includes oat cell types).

You may erroneously think that a 1-cm lung nodule, which turns out to be a lung cancer, is an early lesion.

**TABLE 3-6 Fleischner Society Recommendations for Newly Detected Incidental Pulmonary Nodule Follow-up**

<table>
<thead>
<tr>
<th>NODULE SIZE (MM)</th>
<th>LOW-RISK PATIENT*</th>
<th>HIGH-RISK PATIENT†</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤4</td>
<td>No follow-up needed</td>
<td>CT at 12 mo; if unchanged, no further follow-up¹</td>
</tr>
<tr>
<td>&gt;4-6</td>
<td>CT at 12 mo; if unchanged, no further follow-up¹</td>
<td>CT at 6-12 mo, then at 18-24 mo if no change</td>
</tr>
<tr>
<td>&gt;6-8</td>
<td>CT at 6-12 mo, then at 18-24 mo if no change</td>
<td>CT at 3-6 mo, then 9-12 and 24 mo if no change</td>
</tr>
<tr>
<td>&gt;8</td>
<td>CT at 3, 9, 24 mo, dynamic contrast-enhanced CT, PET/CT, CT, and/or biopsy</td>
<td>Same as for low risk patient</td>
</tr>
</tbody>
</table>

*Minimal or absent history of smoking and of other risk factors.
†History of smoking or other risk factors.
²Nonsolid (ground-glass) or partly solid nodules may require longer follow-up. CT, Computed tomography; PET/CT, positron emission tomography/computed tomography.


A CT scan is the most valuable imaging method for initially and locally staging lung cancers. Intravenous contrast is often used with the CT scan, so that the tumor, adenopathy, and pulmonary vessels can be differentiated. However, if you have a good knowledge of anatomy, it is not necessary to use intravenous contrast. Analysis of a CT scan should include not only location and size of the pulmonary lesion but also whether it has a pleural or chest wall involvement and whether hilar or mediastinal lymphadenopathy is present (Fig. 3-60). The accuracy of CT in determining chest wall invasion is only about 50%, but invasion is suggested by pleural thickening, more than 3 cm of contact between pleura and tumor, obtuse angles between tumor and pleura, or an increased density of the extrapleural fat. A pleural effusion usually indicates a poor prognosis; however, only aspiration and cytologic confirmation of malignant cells in the effusion make the tumor unresectable. Staging of non–small cell lung cancers with regard to mediastinal and distant spread is best done with nuclear medicine whole-body FDG PET/CT scans.

Two classic, although uncommon, appearances of lung carcinoma are seen on the chest x-ray. The first of these is the Golden S sign, from a hilar tumor that has caused peripheral atelectasis (most commonly of the right upper lobe). Normally, as the right upper lobe collapses, an
FIGURE 3-60 Lung cancer. An ill-defined mass is noted on the posteroanterior chest x-ray (arrows) (A). Although this appears to be located near the right hilum, the lateral chest x-ray (B) clearly shows the mass to be posterior to the hilum. Its shaggy appearance is suggestive of carcinoma. Further evaluation by computed tomography scan (C) clearly shows the mass in relation to the mediastinal structures, such as the pulmonary artery (PA) and aorta (Ao).

upward bowing of the minor fissure appears from the hilum out to the lateral aspect of the chest. With the presence of the hilar mass, now inferior and lateral bowing are seen near the hilum, and this creates an “S” shape to the inferior margin of the collapsing right upper lobe (Fig. 3-61). The second classic appearance is that of the Pancoast tumor, an upper lobe carcinoma that has eroded into the pleura and adjacent structures, such as the ribs (Fig. 3-62).

Lung cancers commonly metastasize to the opposite lung, liver, bones, brain, and adrenal glands. The liver is the most common site, and the adrenal glands are involved in about 30% of patients. For this reason any chest CT scan done for a suspected lung cancer should be extended far enough down to visualize these organs. When bony metastases are present, these are usually purely lytic or destructive. For peripheral lesions (that cannot be reached with a bronchoscope), a percutaneous biopsy can be performed with a thin needle guided by either fluoroscopy or a CT scan. The most common complication of this procedure is a pneumothorax (about 25% of cases); about 5% to 10% of patients will need a chest tube to correct this.

FIGURE 3-61 The Golden S sign of lung cancer. Where a mass in the region of the hilum obstructs the upper lobe bronchus, the minor fissure collapses superiorly. With uncomplicated atelectasis, the minor fissure is simply bowed up, but with a mass near the hilum, the inferior margin of the upper lobe takes on an “S” shape as it goes around the mass (M).
Chest Metastatic Disease

The pulmonary parenchyma is a common site for metastatic deposits because the lungs act as a filter for large particles or cells that are circulating in the bloodstream. Most metastatic disease has two predominant patterns in the lung. One is the relatively familiar nodular lesion. Lesions are typically referred to as hematogenous metastases. Metastatic lesions in the pulmonary parenchyma vary from extremely small nodules to extremely large (cannonball) masses. The pulmonary metastases of thyroid cancer typically create a snowstorm of very small nodular lesions. Other tumors, such as colon and renal cell carcinomas, typically produce metastatic lesions that range from approximately 1 cm to several centimeters in diameter. When extremely large multiple masses (about the size of a tennis ball) are present, metastases from a sarcoma should be suspected. CT scans will show many more metastases than are suspected from the chest x-ray (Fig. 3-64).

A second variety of metastases is seen in which streaky or linear infiltrates appear throughout the lungs. This is referred to as lymphangitic spread of tumor. It is not really lymphangitic spread, but another appearance of hematogenously spread disease. This particular “lymphangitic” pattern occurs quite commonly with stomach cancer (Fig. 3-65). Breast cancer can produce either the rounded hematogenous metastases or the “lymphangitic” pattern. Of course, remember that, if you are looking for metastatic disease, you should carefully examine the mediastinum and hilar regions for evidence of lymphadenopathy, and you should examine the bony structures for evidence of lytic lesions (holes) as well as for sclerotic lesions (areas of ill-defined dense bone).

Clinicians commonly ask how often to get a periodic chest x-ray on a patient with a known cancer to exclude pulmonary metastases. It is rarely efficacious to order x-rays monthly, and most oncologists will order chest x-rays only on a 6-month or annual basis and only if the results may affect therapy.

Hypertension

Most hypertension is idiopathic in origin. A small percentage is due to renal artery stenosis. Chest x-rays are not indicated on uncomplicated patients with mild hypertension because the yield of positive findings is extremely low. In patients with moderate or severe hypertension who have cardiorespiratory symptoms, a chest x-ray may be helpful. Chest pain in a hypertensive patient should suggest either a thoracic aneurysm or coronary artery disease. These conditions, in addition to an investigation of hypertension caused by renal artery stenosis, are discussed in Chapter 5.

Chest Pain and Dyspnea

Both chest pain and dyspnea can be due to a wide variety of causes, including traumatic, infectious, neoplastic, and circulatory. A chest x-ray is almost always indicated if the patient has an abnormal physical examination; has acute
nonspecific chest pain; has been traumatized; or has a fever, weight loss, or a cardiac condition. In a patient older than 40 years, a chest x-ray is usually done even if the physical examination is normal. For patients younger than 40 years who have a normal physical examination, no consensus exists about whether a chest x-ray is indicated. Issues related to cardiac conditions and angina are discussed in Chapter 5 (see also Table 3-2).

**Congestive Heart Failure and Pulmonary Edema**

In the upright position, substantially more blood flows to the lung bases than to the apices. When you look at an upright chest x-ray, assess this normal difference in the pulmonary vascularity. The vessels should be distinct from the peripheral one third of the lung back centrally to the hila, and they should be much more apparent in the lower lung zones than in the upper lung zones.

With CHF a spectrum and a progression of findings are normally identified on an upright chest x-ray. In the early stages, minimal cardiomegaly and redistribution of the pulmonary vascularity may be seen, with almost equal flow to upper and lower lung zones (with mean capillary wedge pressures of 15 to 25 mm Hg). At this time the diameter of upper lobe vessels will be equal to or greater than that of lower lobe vessels at the same distance from the hilum. Another way to tell is by the presence in the first intercostal space of pulmonary vessels that are greater than 3 mm in diameter. These are referred to as Kerley B lines. They are always located just inside the ribs and are horizontal in orientation (Fig. 3-66). Remember, these cannot be blood vessels, because you should not normally see lung markings in the peripheral one fourth of the lungs.

As CHF increases, fluid may be seen in the interlobular septa at the lateral basal aspects of the lung (25 to 30 mm Hg). These are referred to as Kerley B lines. They are always located just inside the ribs and are horizontal in orientation (Fig. 3-66). Remember, these cannot be blood vessels, because you should not normally see lung markings in the peripheral one fourth of the lungs.

As CHF becomes more pronounced, vessels near the hila become indistinct because of fluid accumulating in the interstitium. Symmetric and bilateral hilar indistinctness should immediately raise the possibility of CHF.

**FIGURE 3-63** Hodgkin’s disease. In this 20-year-old man with low-grade fevers, a posteroanterior chest x-ray (A) shows marked widening of the middle and superior mediastinum (arrows). On the lateral chest x-ray (B), filling in of the retrosternal space by an ill-defined anterior mediastinal mass is seen (arrows). The transverse contrast-enhanced computed tomography scan (C) through the upper portion of the chest shows the innominate vein (In V), ascending and descending aorta (Ao), and trachea (T). They are all enveloped by a mass of nodes (arrows).
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FIGURE 3-64 Hematogenous metastases from renal cell carcinoma. The chest x-ray (A) shows a few nodules, but the computed tomography scan (B) shows many more metastases than are suspected (some are labeled with arrows).

FIGURE 3-65 Lymphangitic metastases. The streaky appearance in the lung parenchyma is due to metastatic disease, in this case, stomach carcinoma. The term lymphangitic is really a misnomer, because these actually do represent hematogenous metastases in the pulmonary interstitium.

FIGURE 3-66 Early findings of congestive heart failure. The major signs on upright posteroanterior chest x-ray (A) are cardiomegaly and redistribution of the pulmonary vascularity. Normally the vessels to the lower lobes are more prominent than those in the upper lobes; however, here they appear at least equally prominent. On a close-up view (B), small horizontal lines can be seen at the very periphery of the lung (arrows). These are known as Kerley B lines and represent fluid in the interlobular septa.
FIGURE 3-67 Pulmonary edema. Pulmonary edema, or fluid overload, can be manifested by indistinctness of the pulmonary vessels as they radiate from the hilum (arrows) (A). This is sometimes termed a bat wing infiltrate. As pulmonary edema worsens (B), fluid fills the alveoli, and air bronchograms (arrows) become apparent.

Pleural effusions may be present, as evidenced by blunting of the lateral or posterior costophrenic angles. With pronounced CHF, fluid accumulates in the alveolar spaces, and frank pulmonary edema becomes apparent (Fig. 3-67, B). This is seen as bilateral, predominantly basilar and perihilar alveolar infiltrates (>30 mm Hg). A note of caution is inserted here, because the changes of minimal cardiomegaly and the equalization of the pulmonary vasculature are essentially normal findings on a supine AP chest x-ray, do not be fooled into making the diagnosis of minimal CHF on a supine chest x-ray.

Some common variations of CHF may be seen. In patients who have been lying down, on either their right or left side, relatively more accumulation of pulmonary edema occurs on the dependent side, because the fluid pressure is greater (Fig. 3-68). Patients who are in renal failure often look as though they are in CHF, particularly with a perihilar indistinctness and a sort of butterfly or bat-wing infiltrate centered about the hila. Typically, this is seen before dialysis, and after dialysis the infiltrate resolves almost immediately (Fig. 3-69). Remember that pulmonary edema may occur from noncardiogenic causes. In the absence of cardiomegaly, consider drug overdose, head injury (with central nervous system depression), and acute inhalations of noxious agents as possible causes.

FIGURE 3-68 Dependent pulmonary edema. In debilitated patients who are lying on one side, the increased hydrostatic pressure in the lung that is lower can produce pulmonary edema only in that one lung. In this intensive care unit patient, a right-sided alveolar infiltrate is due to dependent pulmonary edema.

PLEURAL PATHOLOGY

Pneumothorax

Pneumothorax refers to air in the pleural space. This is most often caused by trauma (such as a stabbing or motor vehicle accident). It also commonly results from attempted introduction of subclavian venous catheters or after liver biopsy (the pleural space extends down quite far between the liver and the lateral and posterior abdominal wall). A pneumothorax may occur spontaneously (as a result of bleb rupture) or even as a result of some unusual tumors, such as histiocytosis X or metastatic osteogenic sarcoma.

Because the pleural space is continuous around each lung, if the patient is in an upright or semiupright position, air in the pleural space will typically go toward the apex. Thus the first place to look for a pneumothorax is in the right and left upper hemithorax (Fig. 3-70). The most common appearance is an area adjacent to the ribs where no lung vascularity is seen and where a very thin white line represents the visceral pleura that has been separated from the parietal pleura by air. Look carefully for this line, because it is often difficult to distinguish from the bony cortex of nearby ribs. If the pneumothorax is small and the pleural line is behind the rib, it can be almost impossible to see. In such circumstances, it may be useful to obtain an expiration chest x-ray in addition to the usual inspiration chest x-ray. On an expiration view the lung becomes somewhat denser and smaller as expiration occurs. The amount of air in the pleural space will not change in size or density, and thus the pneumothorax will appear relatively larger during expiration (Fig. 3-71).

How much the lung collapses with a pneumothorax is a function of how much air can get into the pleural space. In patients who have adhesive pleural changes between the visceral and parietal pleura as a result of previous inflammatory disease or scarring, complete collapse of the lung
Quite commonly a skin fold may cause an artifact that looks much like a pneumothorax. This artifact is caused by the patient’s skin being folded over and pressed against the x-ray detector. The artifact is seen most often in patients who are either supine or semierect. It usually appears as an almost vertical line along the outer third of the upper lung zones. You must be able to recognize this artifact; otherwise, you will put a chest tube in a patient who does not need one. Three ways to recognize this artifact include the following.

1. A skin-fold line often extends above the lung apex into the supraclavicular soft tissues.
2. An increasing density or whiteness may become apparent as you look from the hilum toward the periphery of the lung, just before you reach the line that you think may be a pneumothorax. If there is increasing density (whiteness) as you proceed laterally, followed by sudden decrease in density, this probably represents a skin fold (Fig. 3-74). In the case of a small pneumothorax, both the lung and the pneumothorax are quite dark, and they are separated by a thin white line, which is the visceral pleura.
3. A skin-fold line often is relatively straight, whereas a pleural line follows the curve of the inner aspect of the chest wall.

Because air tends to go to the highest position that it can find in the pleural space, it can be difficult to appreciate a small or even a moderate-sized pneumothorax on a frontal chest x-ray of a supine patient. With a supine AP
angles are quite sharp or acute. The pleural space, however, goes much farther down along the edge of the lateral aspect of the liver and spleen than most people think. If air is in the pleural space, it can easily track down, making the costophrenic angle or sulcus much deeper and the angle much more acute than is normally seen. Thus be careful to look for an extremely sharp or deep costophrenic angle or a costophrenic angle that becomes progressively deeper and sharper on sequential supine chest x-rays. If you see this, a pneumothorax is probably present (Fig. 3-76). Have the patient sit upright, and take another chest x-ray; you will often see an apical pneumothorax, because the air typically will move from the sulcus up to the apex.

chest projection the x-ray beam is vertical, and the pneumothorax is layered horizontally along the anterior portion of the chest, and probably at least 500 mL of air must be in the pleural space for the pneumothorax to be readily apparent. In supine infants and neonates, an anterior pneumothorax is common. Often the only way to see this pneumothorax is to obtain a supine lateral image and look for lucency (or a dark area) in the retrosternal region. As mentioned earlier, in severely traumatized patients it is quite common to find, on a CT scan, a small anterior pneumothorax that was unappreciated on the chest x-ray (Fig. 3-75).

On the supine AP chest x-ray of an adult, one of the most reliable signs of a pneumothorax is what is known as the deep sulcus sign. Normally the lateral costophrenic

FIGURE 3-71 Accentuation of the pneumothorax. In this young male patient with chest pain, on a typical inspiration chest x-ray (A), no pneumothorax is identified. With expiration (B), the lung becomes smaller, but the pneumothorax stays the same size; thus relatively it appears bigger and can sometimes be easier to see.

FIGURE 3-72 Tension pneumothorax. On a posteroanterior chest x-ray (A), the left hemithorax is dark or lucent because the left lung has collapsed completely (white arrows). The tension pneumothorax can be identified because the mediastinal contents, including the heart, are shifted toward the right (black arrows), and the left hemidiaphragm is flattened and depressed. A computed tomography scan done on a different patient with a tension pneumothorax (B) shows a completely collapsed right lung (arrows) and shift of the mediastinal contents to the left.
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A number of issues arise regarding appropriate clinical management of a pneumothorax. Often clinicians want to know how big the pneumothorax is. A few radiologists will give the volume in terms of percentage, although this is inaccurate. I refer to them as small, medium, large, and tension pneumothoraces. Experiments have been done on cadavers indicating that, on an upright image, if 50 mL of air has been placed in the pleural space, the apex of the lung will have dropped approximately to the level between the second and third posterior ribs. One centimeter of space lateral to the lung constitutes about a 10% pneumothorax. One inch of space between the lateral chest wall and the lung margin is about a 30% pneumothorax.

After a chest tube has been placed, note not only the size of residual pneumothorax and the position of the tip but also the side port of the chest tube. This is seen as a discontinuity of the opaque line in the catheter; it should project inside the chest cavity and not be out in the soft tissues (see Fig. 3-27, B). When a chest tube is properly placed, connected to a vacuum, and unobstructed, if there is persistence of the pneumothorax, consider the possibility of a bronchopleural fistula. This usually is a result of blunt trauma with a tear in the region of a major bronchus. Other possibilities are a loculated pneumothorax or an anterior pneumothorax (with a posteriorly placed chest tube and the patient supine).

After a lung has been fully reexpanded and the chest tube remains in place, some slight compressive atelectasis is found in the lung that abuts the chest tube. As a result, for a day or so after the chest tube is withdrawn, you can see a linear track where the chest tube had been. This is normal, and it will resolve spontaneously in a day or so.

**Pneumomediastinum**

Air within the mediastinum often (although not always) is associated with a pneumothorax. With a pneumomediastinum, air collections that are typically vertical are found within the upper portion of the mediastinum and lower neck. On the lateral view, you can sometimes
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| Collection in the chest that does not resolve with placement of a chest tube. It is sometimes difficult to distinguish between a pneumomediastinum and a pneumopericardium. Pneumopericardium in an adult is rare, typically resulting from a stab wound. You should remember that the pericardium envelops the heart and reaches only as high as the level of the hila. It does not extend around the hila or over the ascending aorta. Thus in a pneumopericardium, air should be confined to the margins of the major chambers of the heart and not higher (see discussion in Chapter 5 and Fig. 5-4).

**Subcutaneous Emphysema**

Air in the soft tissues of the chest wall is often caused by blunt trauma, with a pneumothorax and some broken ribs, or by penetration, as with a stab wound or placement of a chest tube. Air in the soft tissues is seen as dark linear or ovoid areas. Subcutaneous emphysema can extend into the supraclavicular and lower cervical regions. When this happens, however, make sure that you are seeing subcutaneous emphysema and not a pneumomediastinum that has extended up into the lower cervical area. When subcutaneous emphysema is extensive, it can dissect into the pectoral muscles, producing a bizarre fan-shaped appearance of the air as it outlines the muscle fibers (Fig. 3-78).

**Pleural Effusions**

The appearance of pleural effusions or other fluid collections depends on their size and location. Pleural effusions usually are at least 100 mL if they are seen on a routine upright chest x-ray. The most typical location of an effusion is in the dependent portions of the pleural space; therefore they are seen best on upright chest x-rays. Blunting of the lateral costophrenic angles will be identified.
on the anterior or posterior chest x-ray, and blunting of the posterior costophrenic angle will be seen on the lateral view. Somewhat larger effusions may extend into the inferior aspect of the major fissure (Fig. 3-79), and very large effusions displace and compress lung tissue.

The appearances of larger effusions vary according to the position of the patient when the x-ray was obtained. On the upright chest x-ray, increasing basilar density (whiteness) and loss of the normal lung/hemidiaphragm interface is noted (Fig. 3-80, A). It can be difficult to figure out whether you are looking at a large or moderate-sized basilar pleural effusion or a basilar alveolar infiltrate. If the patient was supine when the x-ray was obtained, the effusion typically will be layered horizontally in the posterior pleural space. Because the x-ray beam is vertical for a supine chest x-ray, all you may see is a relatively increased density or whiteness of the affected hemithorax as compared with the normal side (Fig. 3-80, B). In cases of doubt or to determine whether a pleural fluid collection is freely moving, you can obtain a decubitus chest x-ray. If you suspect that an effusion is present on the right, order a right lateral decubitus view, that is, with the right side down when the x-ray is taken (Fig. 3-80, C). Pleural effusions are easy to see on chest CT scans and often have some associated air-space disease or atelectasis not easily appreciated on chest x-rays (Fig. 3-81).

Pleural effusions have two other appearances sufficiently common that you should be aware of them. The first is a subpulmonic pleural effusion. In my experience this is more common on the right side. The tip-off to its existence is when it appears that the hemidiaphragm on the right is slightly higher than normal, with the highest portion of the dome more lateral than usual. The highest portion of the dome of the right hemidiaphragm is normally in the midclavicular line or slightly medial to this. If the highest portion is lateral, suspect a subpulmonic effusion (Fig. 3-82).

A loculated pleural effusion located within a fissure may be mistaken for an intrapulmonary lesion (a pseudotumor). On careful examination, loculated effusions in a fissure are typically lenticular or oval (not round) and are located in the expected position of the major or minor fissure (Fig. 3-83).

Chest x-rays cannot be used to differentiate between a transudate and an exudate. The cause of an effusion, however, can sometimes be inferred. Massive effusions are usually malignant in origin. Pancreatitis is associated with

FIGURE 3-78 Subcutaneous emphysema. Air (arrows) is seen along the lateral soft tissues of the right chest outside the rib cage dissecting into the muscles.

FIGURE 3-79 Moderate-sized pleural effusion. On this upright posteroanterior chest x-ray (A), blunting of the right costophrenic angle (arrows) is due to pleural fluid. On the lateral view (B), fluid can be seen tracking up into the major fissure (black arrows), and blunting of the right posterior costophrenic angle is seen (white arrows).
FIGURE 3-80 The appearance of pleural effusions depending on patient position. On an upright posteroanterior chest x-ray (A), a large left pleural effusion obscures the left hemidiaphragm, the left costophrenic angle, and the left cardiac border. On a supine anteroposterior view (B), the fluid runs posteriorly, causing a diffuse opacity over the lower two thirds of the left lung; the left hemidiaphragm remains obscured. This can easily mimic left lower lobe infiltrate or left lower lobe atelectasis. With a left lateral decubitus view (C), the left side of the patient is dependent, and the pleural effusion can be seen to be freely moving and layering (arrows) along the lateral chest wall. These findings are shown diagrammatically as well for a right pleural effusion (D).

FIGURE 3-81 Pleural effusions on computed tomography scan. The scan shows bilateral fluid collections posteriorly on both right and left sides (arrows). The fact that the fluid is lower attenuation (darker) than the soft tissues and the pleura is not thickened implies that these are effusions rather than an empyema. Note that some adjacent lung density is seen from atelectasis. This is a common secondary finding when moderate or large effusions are present.
left-sided effusions, whereas cirrhosis is associated with right-sided effusions. Most cardiogenic effusions are bilateral and are associated with cardiomegaly and other signs of CHF. About 40% of pneumonias are associated with a small effusion. When a moderate or large pleural fluid collection occurs with a pneumonia, an empyema or malignancy should be suspected.

**Empyemas**

An empyema is pus within the pleural space. It is the result of a postinfectious process 60% of the time, being postsurgical (20%) or posttraumatic (20%) the rest of the time. On a chest x-ray an empyema may look much like a pleural effusion or pleural thickening, but it does not move freely and will not layer on a decubitus chest x-ray. The process is often elliptical, with the long axis along the lateral chest wall, and the lung is compressed or displaced. Empyemas often are loculated and have septa. A CT scan is the easiest way to visualize empyemas and locate them for potential drainage (Fig. 3-84). Occasionally an empyema may contain gas or air. The gas is most commonly the result of a bronchopleural fistula and is much less frequently due to gas-forming bacteria or a prior thoracentesis. On a contrasted CT scan an empyema also can be recognized by thickened or enhancing pleura.

**Pleural Calcification and Pleural Masses**

Most pleural calcifications are the result of an old calcified empyema or asbestosis. Calcification from an empyema is almost always unilateral and can be quite dense, whereas after asbestos exposure, calcification is often bilateral and not quite so dense (Fig. 3-85). Asbestosis also can produce an interstitial or reticulonodular pulmonary parenchymal pattern and occasionally a “shaggy-looking” heart. Mesotheliomas occur after asbestos exposure, and a focal pleural mass or thickening should raise your suspicion of this tumor. You should remember, however, that the most common tumor after asbestos exposure is a lung cancer and not a mesothelioma.
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FIGURE 3-84 Empyema. A computed tomography scan shows a posterior left pleural fluid collection (arrow) containing air (dark) and surrounded by thickened pleura. The thickened pleura appears to be split by the lenticular fluid collection.

FIGURE 3-85 Asbestosis. Both the posteroanterior chest x-ray (A) and the lateral view (B) show areas of plaquelike calcification along the pleura and the hemidiaphragms (arrows). Pleural lesions often appear to project within the lung parenchyma.

MEDIASTINAL LESIONS

Masses

A large number of diseases initially occur in the mediastinum and are seen on the anterior chest x-ray as a widening or bulge in the central soft tissues of the chest. The differential diagnosis will change depending on the location of the lesion in the mediastinum. You must determine whether the problem is in the anterior, middle, or posterior mediastinum. The silhouette sign can be helpful in determining the site of a pathologic process. This was described earlier in this chapter.

Probably the next and simplest way to localize the lesion is to look at the lateral chest x-ray. Several classification schemes exist of the portions of the mediastinum and its contents. I use anterior, middle, and posterior, but some authors include a superior portion. If filling-in of the space behind the top of the sternum and the ascending aorta is seen, you are most likely dealing with an anterior mediastinal lesion. Basically four types of lesions tend to occur in the anterior mediastinum: substernal thyroid gland, thymic lesions, germ cell tumors (much more common in male patients) (Fig. 3-86), and lymphoma. Occasionally retrosternal and internal mammary lymph nodes can become enlarged from metastases of breast cancer or from leukemia. Students can remember most of the anterior mediastinal lesions by using the four Ts. This stands for thymoma (Fig. 3-87), thyroid lesions, teratoma (Fig. 3-88), and T-cell lymphomas. A benign normal variant is the pericardial fat pad (Fig. 3-89). This almost always is found at the right cardiophrenic angle.

Lesions in the middle mediastinum include thoracic aortic aneurysms, hematomas, neoplasms, adenopathy (Fig. 3-90), esophageal lesions, diaphragmatic hernias (hiatal or Morgagni type), and duplication cysts. Morgagni hernias tend to be on the right side. Any middle mediastinal lesion associated with the aorta should be considered an aneurysm until proven otherwise.

Posterior mediastinal lesions are seen on the lateral view projecting over the spine and are also paraspinal on the frontal chest x-ray. Most (90%) posterior mediastinal lesions are neurogenic. They may represent neuroblastomas in young children, but in adults are more likely to be neurofibromas, schwannomas, or ganglioneuromas. Other posterior mediastinal lesions include hernias (hiatal or Bochdalek type), neoplasms, hematomas, or extramedullary hematopoiesis. Bochdalek hernias are most often on the left side.

DIAPHRAGM

Diaphragmatic Rupture

Rupture of the diaphragm may occur after blunt trauma. The diaphragm most frequently is ruptured on the left side, perhaps because the liver may dissipate some of the force of an abdominal blow, lessening the likelihood of rupture of the right hemidiaphragm. The most common appearance is loops of bowel protruding into the lower chest cavity without the normal dome-shaped structure of
FIGURE 3-86 Seminoma. On the posteroanterior chest x-ray (A) of a 25-year-old patient with testicular enlargement, a mass can be clearly seen (M). Note the outline of the aortic arch (AO), indicating that this mass must be either in front of or behind the aortic arch, but not next to it. A lateral view (B) shows an anterior mediastinal mass, in this case, metastatic seminoma.

FIGURE 3-87 Thymoma. A chest x-ray (A) reveals an unusual contour over the left hilum (arrows). That the hilum is not obscured (no silhouette sign) indicates that the mass must be either in front of or behind the hilum. A computed tomography scan (B) reveals a soft tissue mass (arrow) just to the left of the aorta. This is the most common location of a thymoma.

FIGURE 3-88 Mediastinal teratoma. A chest x-ray (A) shows a large upper right mediastinal mass (arrows), but no specific internal structure is apparent. A computed tomography scan (B) reveals that the mass (arrow) contains multiple types of tissue elements, including fat (dark), soft tissue (gray), and calcium (white). This is essentially diagnostic of a teratoma.
Figure 3-89 Pericardial fat pad. A, A soft tissue mass (arrows) is seen in the right cardiophrenic angle on the frontal chest x-ray. B, It also is seen in the anterior mediastinum on the lateral view (arrows). On this view, the anterior (A), middle (M), and posterior (P) portions of the mediastinum have been identified.

Figure 3-90 Sarcoid. Marked lymphadenopathy (dotted lines) is seen in the region of both hila in the right paratracheal region (A). The transverse contrast-enhanced computed tomography scan of the upper chest (B) clearly shows the ascending and descending aorta (Ao) as well as the pulmonary artery (PA) and superior vena cava. The right (RB) and left (LB) main stem bronchus area also is seen. Arrows, the extensive lymphadenopathy. (See also Fig. 3-55 for the alveolar form of sarcoid.)

Figure 3-91 Diaphragmatic rupture. Six days after an auto accident, bowel loops can be seen in the left lower chest (arrows). Diaphragmatic rupture is more common on the left than on the right.

the hemidiaphragm (Fig. 3-91). The manifestations of a ruptured diaphragm can be delayed, and sometimes the bowel herniates through the diaphragm only 1 or 2 weeks after the initial accident. The patient may remain asymptomatic for months or years.

Suggested Textbooks on the Topic
Breast imaging generally refers to mammography. Mammography is complementary to physical examination, and each can detect a significant number of tumors not found by the other. The primary purpose of mammography is to detect small breast cancers and, by so doing, to improve survival. In young women the breast is extremely dense. The density of the normal parenchymal tissue is the same as the density of a carcinoma. In young women, not only is the incidence of breast cancer low, but it is also very difficult to tell whether a cancer is present amid the normal dense tissue. As women age, fatty infiltration of the breast and atrophy of the parenchyma occur. Because the fat is lucent (dark) on a mammogram and a cancer is dense (white), tumors are more easily visualized as a woman ages. The density of the breast is partly due to hormonal stimulation. In older women receiving estrogen replacement therapy, the density of the breast tissue increases, making tumors more difficult to see (Fig. 4-1).

Mammograms are usually obtained in what are referred to as the craniocaudal (top to bottom) and axillary oblique views. The latter, a somewhat tilted lateral view, allows better visualization of the tail of the breast tissue as it extends out toward the axilla than is possible on a straight lateral view. On the craniocaudal view it is often not easy to tell which is the medial and which is the lateral aspect. By convention the identifying markers or technologist’s initials are placed along the lateral edge of the breast. Mammograms are often referred to as screening or diagnostic workup. The latter have special views and often use magnified images.

Ultrasound examination is often used as an adjunct to mammography to determine whether a lesion is solid or cystic and to localize a lesion for needle biopsy. Ultrasound can be a useful adjunctive method but should not be relied on as a screening method for breast cancer. Computed tomography scanning is not indicated for examination of the breast. There are nuclear medicine techniques to image breast lesions (breast-specific gamma imaging and positron emission mammography), as well as three-dimensional mammography (tomosynthesis), but their use for evaluation of a suspicious mass or screening for breast cancer remains a matter under investigation. Magnetic resonance imaging (MRI) is occasionally used in selected patients.

Interpretation and Workup

Great variation is often found between women in the appearance of the breast tissue. Fortunately, most women have symmetric tissue when one breast is compared with the other. Any asymmetries in density should be examined carefully, because they may represent a cancer (Fig. 4-2). In addition to asymmetric masses, another sign of breast cancer is tiny grouped calcifications. Often called microcalcifications, these are usually fine (approximately ≤1 mm), sandlike, linear, pleomorphic, or branching in any distribution. Most women, as they age, have benign calcifications within the breast. These are usually rounded calcifications greater than 2 mm in diameter (Fig. 4-3). In women over the age of 60 years, serpiginous calcifications can normally be seen within blood vessel walls. Associated indirect signs of malignancy also may be present. These include focal skin thickening or dimpling due to an underlying tumor, unilateral nipple retraction, and vascular asymmetry (increased vascularity due to the tumor).

Computer-aided-detection programs are built into modern digital mammography equipment. They are commonly used to analyze the digital breast images for suspicious areas and alert the radiologist to findings that may have been missed on initial image inspection. Literature remains divided on whether use of computer-aided detection increases early cancer detection rate; however, use of the system increases the number of breast biopsies and false-positive examinations.

Once a suspicious lesion is identified on both craniocaudal and axillary oblique views, further investigation usually ensues, in the form of a “diagnostic” magnified mammogram and an ultrasound examination (Fig. 4-4) or a biopsy (Fig. 4-5). If a lesion is solid, asymmetric, or stellate, or if grouped microcalcifications are seen, an intensive search should be undertaken for prior mammograms that can be used for comparison. The reason for this is that a surgical biopsy will necessarily result in scar tissue, and scar tissue often leaves an asymmetric radial density that can look like a neoplasm; hence you should obtain biopsies only when necessary. If the solid lesion is new or if old images are not available and the lesion is thought to be suspicious, a biopsy is recommended. If the lesion is palpable, the surgeon may simply proceed with a biopsy.

If the suspicious lesion is not palpable, either stereotactic needle biopsy or needle localization can be performed by the radiologist. In the stereotactic procedure the patient is placed face down on a table with the breast suspended, and images are taken with coordinates. These coordinates are entered into a computer, and a core-biopsy gun is fired, taking a sample of the lesion for pathologic analysis. The needle localization procedure is done for nonpalpable lesions immediately before surgery for excision or lumpectomy. The breast is compressed with a holder that has coordinates on the sides, and a mammogram is taken.
A thin needle can then be inserted at the coordinates of interest until it is shown that the end of the needle is either at or slightly past the lesion. At this point a small amount of blue dye is injected, and a thin, hooked wire is passed through the needle. As the wire exits the point of the needle, it opens and becomes fixed in the tissue. The needle is withdrawn, leaving the wire in place. The surgeon then removes the tissue near the end of the hooked wire (Fig. 4-6). The biopsy specimen is x-rayed to make sure that the lesion of interest has been removed. MRI is sometimes used preoperatively in women diagnosed with breast cancer to assess for tumor size and to exclude additional cancers.

The lymph node drainage of a breast cancer can be variable. As a result, before surgery for a known breast cancer, many surgeons will want the patient to have a nuclear medicine procedure to localize the sentinel node. A small amount of radioactive substance is injected near the lesion...
site, and then the radioactivity migrates to the nearest draining lymph node. This node can be marked or localized at surgery, and in theory it is the node that is most likely to contain metastases.

**SCREENING**

Breast cancer screening methods may include clinical breast examination (performed by a trained health care professional) and mammography. Breast self-examination is not recommended as a screening tool. Much discussion over the last decade has concerned the indications for screening mammography. Concerns about overutilization revolve around financial issues, as well as the potential for radiation-induced breast carcinoma several decades later. Current guidelines are shown in Table 4-1. The radiation cancer studies (such as those done for follow-up of atomic bomb survivors at Hiroshima and Nagasaki) show that the risk for breast cancer after radiation exposure is greatest when exposure occurs at a young age. Little, if any, risk ensues from mammograms performed after age 50 years. Present guidelines vary as to whether to perform a mammogram every 1 to 2 years beginning at age 40 years or to wait and only do screening every 2 years in those ages 50 to 74 years.

Mammograms can be used in the evaluation of a breast prosthesis. Normally the prosthesis can be seen as an oval
area of increased density in the central portion of the breast. Complications that arise include calcification, which can occur around the prosthesis, and this is sometimes visualized on chest x-rays (Fig. 4-7). Leakage of a prosthesis can be identified if the leakage has been enough to cause deflation of the prosthesis (Fig. 4-8). Leaking silicone or saline cannot be visualized directly on a mammogram. Screening mammography for occult breast carcinomas can be quite difficult in patients with prostheses, because the prosthesis can obscure a small cancer.

Ultrasound examination of the breast should not be considered to be a primary screening tool, because it cannot differentiate carcinomas from fibroadenomas or other benign solid lesions. It is useful only to differentiate a solid lesion from a cyst. This is most helpful in the initial workup of a young woman with a palpable lesion. MRI is used for screening in selected women who have significantly high risk (20% to 25% or greater) for breast cancer according to the Breast Cancer Risk Assessment Tool developed by the U.S. National Cancer Institute, those with an inherited gene mutation (BRCA1 or BRCA2), chest radiotherapy under the age of 30 years, or a personal history of lobular or ductal carcinoma in situ.

Suggested Textbook on the Topic
Cardiovascular System

NORMAL ANATOMY AND IMAGING TECHNIQUES

The normal anatomy and configuration of the heart on a chest x-ray and on computed tomography (CT) scanning were discussed in Chapter 3. Imaging of the heart also can be done by using magnetic resonance imaging (MRI). This modality provides good visualization of the cardiac anatomy. The lungs are not well seen on these scans because respiratory motion causes image degradation. The anatomy of the heart at several different levels on an MRI scan is shown in Figure 5-1. Both MR and nuclear medicine images can be gated to the cardiac cycle, allowing images to be produced in systole and diastole, as well as in the phases in between (Fig. 5-2). Transthoracic ultrasound (echocardiography) also can be used to image through those portions of the heart that are in contact with the chest wall. This method is generally considered the practice of cardiologists and is discussed here only when it is the appropriate test to order.

Imaging of the peripheral vascular system has changed dramatically over the last decade. Historically, good spatial resolution was achieved only with invasive techniques that used direct arterial access and injection of contrast material through a catheter. With the advent of faster CT and MRI scanners, both venous and arterial anatomy can be visualized adequately for most diagnostic purposes. Even though CT and MRI scans are typically displayed as “slice anatomy,” the vascular image data are often manipulated to display rotating three-dimensional images of the vascular anatomy. Invasive procedures are normally reserved for therapeutic intervention (such as balloon dilation of a stenosis or stent placement). Appropriate imaging indications for cardiovascular problems are shown in Table 5-1.

EVALUATION OF THE CARDIAC SILHOUETTE

Generalized Cardiomegaly

Examination of the shape of the heart on a chest x-ray can sometimes provide clues to the type of cardiac disease present. If the heart appears large in most dimensions, it is often difficult to tell whether multichamber enlargement, a myocardial infarction, or a pericardial effusion is present. If acute (within several days), marked enlargement of the cardiac silhouette is seen, the most likely diagnosis is a pericardial effusion. Under these circumstances the heart has a pendulous appearance and is much wider at the base. This is often referred to as a “water bag” appearance (Fig. 5-3). Pericardial effusions must be greater than 250 mL to be detectable radiographically. Effusions are sometimes visible on CT scans of the chest, but if you suspect a pericardial effusion, the imaging procedure of choice is echocardiography. After penetrating trauma or surgery, air may be seen within the pericardium (Fig. 5-4).

Constrictive pericarditis is most commonly due to tuberculosis and viral and pyogenic infections. It also may occur with radiation therapy. Ninety percent of patients with constrictive pericarditis will have pericardial calcification (which may be visible only on CT), and 60% will have a pleural effusion. Of those patients with pericardial calcification, 50% also will have constrictive pericarditis.

Cardiomegaly can be due to valvular disease, cardiomyopathy, congenital heart disease, pericardial effusion, and mass lesions. Cardiomyopathies and pericardial effusions both generally lead to symmetric enlargement, whereas valvular disease and congenital heart disease often have specific chamber enlargement. The dilated cardiomyopathies are caused by ineffective contraction during systole and most commonly result from infections and metabolic disorders. They also may be caused by collagen vascular disease and toxic agents such as alcohol and chemotherapeutic drugs. An example of the latter is doxorubicin (Adriamycin), one of the most widely used chemotherapeutic agents (Fig. 5-5).

Use of the cardiothoracic ratio to assess heart size and the effect of cardiac failure on the appearance of the pulmonary vessels and lungs was discussed in Chapter 3. The width of the heart should not exceed half the width of the chest at its widest point. This measurement is reliable only on an upright posteroanterior (PA) chest image; on an anteroposterior (AP) chest x-ray, the heart will often exceed this measurement owing to magnification. On a supine image even more magnification and high position of the hemidiaphragms occur. This high position will push the heart upward and outward, making it appear wide. A note of caution should be inserted here about patients who have chronic obstructive pulmonary disease (COPD). The shape of the heart is determined by external forces and by internal factors. One factor relates to the level of the hemidiaphragms. The measurement of cardiothoracic ratio assumes that the hemidiaphragms are in normal position. With COPD the hemidiaphragms are driven inferiorly (often to the level of the posterior twelfth rib). The heart then sags and elongates. This can make an enlarged heart appear normal in size, especially considering the cardiothoracic ratio. It follows, then, that if the heart appears too wide in a patient who has COPD, it is really very large.
diastole and systole, allowing calculation of an ejection fraction. The normal left ventricular ejection fraction (LVEF) is between 55% and 75%. In older persons the lower limit of LVEF is probably about 50%. With both the nuclear medicine gated SPECT study (Fig. 5-6) and echocardiography, visualization of the myocardium occurs. The ventricular cavity is then measured at various portions of the cardiac cycle, and the ejection fraction is calculated. All of these studies also can detect regional wall-motion abnormalities.

Because assessment of cardiac function by chest x-ray is rather poor, quantitative evaluations of cardiac ejection fraction are usually made by nuclear medicine multiple gated acquisition (MUGA) scanning or gated single-photon emission CT (SPECT) studies or by echocardiography. In the nuclear medicine MUGA procedure, red cells are labeled with radioactive material, and images of the heart are obtained in a gated fashion. Computer analysis enables construction of a time/activity curve showing the amount of activity in the left or right ventricle in both

FIGURE 5-1 Transverse (axial) T1 magnetic resonance images A to D of the thorax in the transverse plane showing normal vascular anatomy.
FIGURE 5-2  Magnetic resonance images of the heart in systole and diastole. Transverse images obtained at the level of the right and left ventricle (LV) show the left ventricle in systole (A) and in diastole (B).

FIGURE 5-3  Pericardial effusion. In a patient with a viral syndrome, a posteroanterior chest x-ray (A) shows mild cardiomegaly with prominence of the left cardiac border. One week later (B), a marked and sudden increase in the transverse diameter of the heart due to a pericardial effusion is apparent. A definitive diagnosis is best made by using cardiac ultrasound. Pericardial effusions also can be seen on computed tomography scans (C) as a fluid density (arrows) surrounding the heart.
### TABLE 5-1 Appropriate Imaging and Other Studies for Cardiovascular Problems

<table>
<thead>
<tr>
<th>CLINICAL PROBLEM</th>
<th>IMAGING STUDY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most cardiac problems</td>
<td>Initial posteroanterior and lateral chest radiography</td>
</tr>
<tr>
<td>Congestive heart failure (new or worse)</td>
<td>Chest radiography and ejection fraction; wall motion evaluation by nuclear medicine or echocardiography</td>
</tr>
<tr>
<td>Congestive heart failure (chronic)</td>
<td>Chest radiography</td>
</tr>
<tr>
<td>Hypertension (suspected essential)</td>
<td>No imaging indicated</td>
</tr>
<tr>
<td>Hypertension (suspected renal artery stenosis)</td>
<td>Nuclear medicine captopril renogram or MR angiogram</td>
</tr>
<tr>
<td>Left ventricular ejection fraction</td>
<td>Nuclear medicine multiple gated acquisition study or echocardiography</td>
</tr>
<tr>
<td>Chest pain or shortness of breath (suspected pulmonary embolism)</td>
<td>Chest x-ray and CT angiogram</td>
</tr>
<tr>
<td>Shortness of breath (suspected cardiac origin)</td>
<td>Chest x-ray and echocardiography</td>
</tr>
<tr>
<td>Blunt chest trauma (suspected aortic injury)</td>
<td>Chest x-ray, CT angiogram</td>
</tr>
<tr>
<td>Acute chest pain</td>
<td>Electrocardiography, chest radiography, and coronary angiography</td>
</tr>
<tr>
<td>Suspected myocardial infarction</td>
<td>Chest x-ray, CT angiogram</td>
</tr>
<tr>
<td>Suspected aortic dissection</td>
<td>Electrocardiography, chest x-ray</td>
</tr>
<tr>
<td>Nonspecific, low probability of coronary disease</td>
<td></td>
</tr>
<tr>
<td>Chronic chest pain</td>
<td>Chest x-ray, echocardiography or nuclear medicine cardiac perfusion scan</td>
</tr>
<tr>
<td>Low probability of coronary disease</td>
<td>Nuclear medicine cardiac perfusion scan or coronary angiogram</td>
</tr>
<tr>
<td>Moderate probability of coronary disease</td>
<td></td>
</tr>
<tr>
<td>High probability of coronary disease</td>
<td>Electrocardiography; if negative, then stress electrocardiogram, nuclear medicine, myocardial perfusion study, or stress echocardiogram; if positive, then coronary angiogram</td>
</tr>
<tr>
<td>Coronary ischemia</td>
<td></td>
</tr>
<tr>
<td>Congenital heart disease</td>
<td>Chest x-ray, echocardiography</td>
</tr>
<tr>
<td>Endocarditis</td>
<td>Echocardiography</td>
</tr>
<tr>
<td>Valvular disease</td>
<td>Echocardiography</td>
</tr>
<tr>
<td>Pericardial effusion</td>
<td>Echocardiography</td>
</tr>
<tr>
<td>Constrictive pericarditis</td>
<td>Echocardiography; if equivocal, then CT</td>
</tr>
<tr>
<td>Aortic trauma</td>
<td>Angiography or CT with contrast</td>
</tr>
<tr>
<td>Thoracic aortic dissection</td>
<td>CT with IV contrast or transesophageal ultrasonography</td>
</tr>
<tr>
<td>Abdominal aortic aneurysm</td>
<td>CT with IV contrast or transesophageal ultrasonography</td>
</tr>
<tr>
<td>Symptomatic</td>
<td>Ultrasonography for screening. Ultrasound or noncontrast CT for follow-up</td>
</tr>
<tr>
<td>Asymptomatic</td>
<td></td>
</tr>
<tr>
<td>Deep venous thrombosis</td>
<td>Duplex ultrasonography</td>
</tr>
<tr>
<td>Sudden painful cold leg</td>
<td>CT angiogram or MR angiogram</td>
</tr>
<tr>
<td>Carotid bruit</td>
<td>Duplex ultrasonography; if high-grade stenosis, then contrast angiography</td>
</tr>
<tr>
<td>Claudication</td>
<td>Doppler ultrasonography of lower extremity</td>
</tr>
</tbody>
</table>

CT, Computed tomography; IV, intravenous; MR, magnetic resonance.

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**Left Atrial Enlargement**

Isolated left atrial enlargement occurs most commonly in mitral stenosis. The earliest sign is displacement of the esophagus posteriorly (Fig. 5-7, A). Enlargement of the left atrial appendage on the PA view is the next sign to appear (Fig. 5-7, B). As the left atrium enlarges further, the esophagus becomes more posteriorly displaced; splaying or widening of the inferior carinal angle is seen; and the enlarged left atrium can be seen on the PA x-ray as a double density behind the heart and below the carina (Fig. 5-7, C). The normal inferior carinal angle should not exceed 75 degrees.

Rheumatic heart disease most often affects the mitral valve and to a lesser extent the aortic valve. The classic appearance of a mitral heart on a PA chest x-ray is easily recognized by four bumps along the left cardiac border. This also is sometimes called the “ski mogul” heart. Going from superior to inferior, the bumps represent the aortic arch, pulmonary artery, left atrial appendage, and left ventricle (see Fig. 5-7, B). Left atrial enlargement also is seen with congenital cardiac lesions
that have intracardiac shunts, as well as in patients who have left ventricular failure.

As rheumatic heart disease progresses, mitral stenosis and mitral insufficiency develop. The heart becomes very large because of dilatation and hypertrophy of the left ventricle. In the combined form of mitral disease, the left atrium becomes even larger than is seen in mitral stenosis alone. Typical findings are a straightening of the left cardiac border due to left atrial enlargement; left ventricular enlargement as evidenced by leftward and downward displacement of the cardiac apex; and, if left ventricular dilatation becomes massive, rightward displacement of the right ventricle. On the lateral view, in addition to the obvious left atrial enlargement, the posterior displacement of the heart continues down inferiorly, indicating left ventricular enlargement as well. In severe mitral disease the mitral valve and the aortic and tricuspid valves are affected. In general, the manifestations of the more proximal valve lesion are the most prominent. With mitral and tricuspid disease, enlargement of the left atrium and left ventricle and also of the right atrium and right ventricle occurs.

Many radiologists say that you cannot differentiate right atrial from right ventricular enlargement on a chest x-ray, and this is probably true. Fortunately, in most adults, when one of the right chambers is enlarged, so is the other. On the frontal chest x-ray, right atrial enlargement is suggested by an increased convexity of the right heart border. Isolated right ventricular enlargement is very difficult to appreciate, because it overlaps the right atrium and left ventricle on the frontal view. On the lateral view, both right ventricular and right atrial enlargement will cause a filling in of the anterior clear space behind the sternum (Fig. 5-8). Normally on the lateral view, the anterior portion of the heart fills in only approximately one third or less of the anterior clear space, unless enlargement of the right atrium or right ventricle is found.

Prosthetic tricuspid and mitral valves are often used in treatment of rheumatic heart disease. You should be able to recognize these valves by their size, location, and orientation (Fig. 5-9). The valve with the largest area is the tricuspid valve; the mitral valve is intermediate sized, and the smallest is the aortic valve. You also should be able to recognize prosthetic mitral and tricuspid valves. As expected, the mitral valve is located posteriorly and to the left in the heart, and the tricuspid valve is anterior and toward the right side.

**Left Ventricular Enlargement**

On a frontal chest x-ray, left ventricular enlargement, as already mentioned, produces a round left cardiac border.
as well as downward displacement of the apex. On the lateral view, the posterior aspect of the heart, where it intersects the hemidiaphragm, is usually posteriorly displaced behind the inferior vena cava. The Hoffman-Rigler sign also can be used. To use this, find the intersection of the inferior vena cava with the hemidiaphragm on the lateral image, and then measure 2 cm up and 2 cm back. If the heart projects posteriorly, left ventricular enlargement probably is present. A note of caution should be inserted here because an enlarged right heart can sometimes push the left ventricle back. To exclude this, look at the space behind the sternum: only the lower one third should be filled by soft tissue.

Left ventricular dilatation can be due to a number of causes, including coronary artery disease, aortic stenosis, and aortic regurgitation. You should take care to consider the possibility of a left ventricular aneurysm before you suggest left ventricular enlargement and quit. Ventricular aneurysms most commonly occur near the apex and anteriorly and have a high rate of mortality. Left ventricular hypertrophy is difficult to detect radiographically. It may be present in patients who have a normal cardiac configuration on chest x-ray. If this is suspected, an echocardiogram (ultrasound) is the test of choice.

**Aortic Stenosis and Insufficiency**

Aortic stenosis is most commonly valvular, although in a smaller number of patients, it may be either subvalvular or supravalvular. Valvular stenosis can be due to rheumatic heart disease, a bicuspid (rather than tricuspid) aortic valve, or degenerative changes (usually in patients older than 70 years). It may be difficult to detect this condition from findings on a plain x-ray of the chest, and sometimes the only finding is a calcified aortic valve. Initially, with aortic stenosis, left ventricular hypertrophy is noted. The heart will be normal in size and may show slight rounding of the cardiac apex. When left ventricular dilatation occurs, the left cardiac border elongates, and the apex of the heart moves downward toward the left hemidiaphragm. The aortic knob will be normal in size, although the ascending aortic arch is enlarged, causing a convexity of the right upper cardiac margin. The enlargement of the ascending aorta is due to poststenotic dilatation.

With aortic insufficiency the left ventricle becomes much larger, and on a PA chest x-ray, the apex of the heart may project below the most superior portion of the left hemidiaphragm. The ascending aorta still shows some enlargement (Fig. 5-10). Prosthetic aortic valves are relatively easy to recognize by their relatively small size and the fact that they are located at the root of the ascending aorta (Fig. 5-11).
FIGURE 5-8 Mitral and tricuspid insufficiency. As a late finding in rheumatic heart disease, mitral and sometimes tricuspid insufficiency develops. On the posteroanterior chest x-ray (A), there is marked enlargement of not only the left atrium (LA) but also the left ventricle (LV; seen as straightening of the left cardiac border), as well as right-sided enlargement, particularly of the right atrium (RA; seen by marked prominence of the right cardiac border). On the lateral view of the chest (B), the left ventricle can be seen overlapping the spine, and the right atrium and right ventricle (RV) have filled in the retrosternal space to more than the usual lower one third.

FIGURE 5-9 Prosthetic mitral and tricuspid valves. Both the mitral (M) and the tricuspid (T) valves were difficult to appreciate on the posteroanterior view of the chest (A) and were therefore drawn in. They are easily seen on the lateral view (B) in the expected regions between the left atrium (LA) and left ventricle (LV) and the right atrium (RA) and right ventricle (RV). Also note that a cardiac pacer comes down the superior vena cava through the right atrium and into the right ventricle. These two valves are normally relatively large because of relatively low pressure gradients across these valves.
FIGURE 5-10 Aortic insufficiency. A prominent left ventricle (LV) is seen both on the posteroanterior view (A) and the lateral view (B). In addition, a convexity appears in the region of the ascending aorta (arrows) because of poststenotic dilatation.

FIGURE 5-11 Prosthetic aortic valve. The prosthetic valve was not easily visible on the posteroanterior view (A) and was therefore drawn in. On the lateral view (B), the valve is easily seen in the expected region between the left ventricle (LV) and the ascending aorta (Ao). Also note its relatively small size. The arrows indicate the direction of blood flow. RV, right ventricle.

Pulmonary Artery Enlargement

Enlargement of the pulmonary artery is fairly easy to recognize on the PA chest x-ray by a bulging along the left cardiac border just below the aortic arch (Fig. 5-12). Pulmonary artery enlargement can be due to a number of causes, but probably the three most common are pulmonic stenosis (with poststenotic dilatation), pulmonary artery hypertension, and abnormalities in which increased flow through the pulmonary artery occurs, such as a patent ductus arteriosus or an atrial septal defect (ASD).

If enlargement of both the left and the right main pulmonary arteries is present, consider the diagnosis of pulmonary arterial hypertension. In this entity, in addition to the very large central pulmonary arteries, rapid “pruning” of the vessels occurs as they proceed peripherally in the lung. Even though the central vessels are extremely large, it is unusual to be able to see vessels at the edge of the lung. Pulmonary hypertension may be due to a number of causes, including ASD and ventricular septal defect (VSD), patent ductus arteriosus, arteriovenous shunt, left ventricular failure, mitral valve disease, pulmonary emboli,
Chapter 5 | Cardiovascular System

Tetralogy of Fallot includes pulmonic stenosis, VSD, an overriding aorta, and right ventricular hypertrophy. On the x-ray, usually decreased pulmonary vascularity and a boot-shaped heart with an uplifted apex and a concavity along the left cardiac border are seen (Fig. 5-13). If cardiomegaly with the right atrium enlarged is noted, the differential diagnosis includes Ebstein’s malformation, tricuspid atresia, and pulmonic atresia. In Ebstein’s anomaly a giant right atrium appears, with a shoulder along the right side of the heart and a very small pulmonary artery. In this entity, downward displacement of the tricuspid valve occurs, with the right ventricle being partially atrialized (Fig. 5-14).

Cyanotic heart disease with increased pulmonary vascularity includes transposition of the great vessels (which is most common), truncus arteriosus, total anomalous pulmonary venous return (TAPVR), tricuspid atresia, and a single ventricle. Radiographic features of transposition of the great vessels include a heart that is said to have an “egg-on-side” shape and a narrow superior mediastinum secondary to a hypoplastic thymus (Fig. 5-15).

Acyanotic congenital heart disease similarly should initially be evaluated by determination of pulmonary vascularity. In those with normal vascularity, aortic stenosis, pulmonic stenosis, coarctation, and interruption of the aortic arch should be considered. Acyanotic heart disease with increased pulmonary vascularity should next be investigated by looking for left atrial enlargement. This is not present in ASD, and an endocardial cushion defect may be considered.

An ASD is the most common congenital cardiac anomaly in adults and rarely is symptomatic in infancy or childhood. The common radiologic findings in an ASD, in addition to enlargement of the pulmonary artery, are an increase in the size of the right atrium and right ventricle. This is often best seen as filling in of the retrosternal clear space on the lateral view (Fig. 5-16). The imaging modality of choice, if an ASD is suspected, is echocardiography.
If acyanotic heart disease with increased pulmonary vascul arity and left atrial enlargement is found, next look at the aorta. If the aorta is enlarged, a patent ductus arteriosus should be suspected, because excess blood flow through the aortic arch is shunted to the pulmonary arteries. If the aorta is not enlarged, consider a VSD.

**PULMONARY EMBOLISM**

Pulmonary embolism (PE) is a potentially fatal entity. Typical symptoms include dyspnea (80%), tachypnea (>16 respirations per minute, 80%) pleuritic chest pain (70%), rales (60%), fever (45%), tachycardia (40%), and hemoptysis (20%) (Table 5-2). Patients who initially have no dyspnea,
TABLE 5-2 Signs and Symptoms Associated With Probability of Predicting Acute Pulmonary Embolism

<table>
<thead>
<tr>
<th>Sign/Symptom</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tachycardia (&gt;100 beats/min)</td>
<td>3</td>
</tr>
<tr>
<td>Sudden-onset dyspnea</td>
<td>3</td>
</tr>
<tr>
<td>Hemoptysis</td>
<td>1.5</td>
</tr>
<tr>
<td>Malignancy</td>
<td>1.0</td>
</tr>
<tr>
<td>Older age</td>
<td>1.0</td>
</tr>
<tr>
<td>Hypocapnia (PaCO₂ &lt;5.1 kPa)</td>
<td>1.5</td>
</tr>
<tr>
<td>Hypoxemia (PaO₂ &lt;11.0 kPa)</td>
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<td>Right ventricular overload</td>
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<tr>
<td>Signs or symptoms of DVT</td>
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<td>PE more likely than alternative diagnosis</td>
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<tr>
<td>Immobiliation or recent surgery</td>
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<tr>
<td>Previous DVT or PE</td>
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<td>Oligemia</td>
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<td>Amputation of hilar artery</td>
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<tr>
<td>Pleural-based consolidation</td>
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<tr>
<td>Hemidiaphragm elevation</td>
<td>1.0</td>
</tr>
<tr>
<td>Linear atelectasis</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Score <4.5: pulmonary embolism unlikely (less than 5% to 10%).
Score ≥4.5: pulmonary embolism likely.


TABLE 5-3 Pretest Probability for Pulmonary Embolism (Wells’s Criteria)

<table>
<thead>
<tr>
<th>Clinical sign or symptom</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinical signs and symptoms of deep venous thrombosis (minimum of leg swelling and pain with palpation of the deep veins)</td>
<td>3</td>
</tr>
<tr>
<td>Pulmonary embolism as or more likely than alternative diagnosis</td>
<td>3</td>
</tr>
<tr>
<td>Heart rate greater than 100 beats/min</td>
<td>1.5</td>
</tr>
<tr>
<td>Immobiliation or surgery within the previous 4 weeks</td>
<td>1.5</td>
</tr>
<tr>
<td>Previous deep venous thrombosis or pulmonary embolism</td>
<td>1.5</td>
</tr>
<tr>
<td>Hemoptysis</td>
<td>1.0</td>
</tr>
<tr>
<td>Malignancy treatment in the last 6 months or palliative therapy</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Historically a nuclear medicine ventilation-perfusion (V/Q) lung scan was the procedure of choice for suspected PE, but now it has largely been replaced by CT scanning. V/Q scans are now usually performed on patients who have an allergy to intravenous iodine contrast or are in renal failure. In the nuclear medicine study, ventilation is assessed by having the patient inhale and then exhale a radioactive gas or an aerosol containing radioactive particles (Fig. 5-18, A). Perfusion is assessed by intravenously injecting a number of biodegradable radioactive particles that are unable to pass through the pulmonary capillary bed. These are trapped in the capillary bed, and because they give off radiation, images of the lungs can be obtained in various projections (Fig. 5-18, B). The V/Q lung scans are then compared. You are looking for a defect on the perfusion scan that is not seen on the ventilation scan (a mismatch). The reason is that a PE generally does not interfere much with ventilation. Abnormalities such as tumors and bullae would cause both a ventilation abnormality and a perfusion abnormality (a matched defect). If a number of segmental defects are seen on the perfusion

Historically a nuclear medicine ventilation-perfusion (V/Q) lung scan was the procedure of choice for suspected PE, but now it has largely been replaced by CT scanning. V/Q scans are now usually performed on patients who have an allergy to intravenous iodine contrast or are in renal failure. In the nuclear medicine study, ventilation is assessed by having the patient inhale and then exhale a radioactive gas or an aerosol containing radioactive particles (Fig. 5-18, A). Perfusion is assessed by intravenously injecting a number of biodegradable radioactive particles that are unable to pass through the pulmonary capillary bed. These are trapped in the capillary bed, and because they give off radiation, images of the lungs can be obtained in various projections (Fig. 5-18, B). The V/Q lung scans are then compared. You are looking for a defect on the perfusion scan that is not seen on the ventilation scan (a mismatch). The reason is that a PE generally does not interfere much with ventilation. Abnormalities such as tumors and bullae would cause both a ventilation abnormality and a perfusion abnormality (a matched defect). If a number of segmental defects are seen on the perfusion
scan and are not identified on the ventilation scan, the images will be interpreted as high probability for PE. Under these circumstances, it is more than 80% likely that the patient has PE.

In most health care institutions, CT pulmonary angiography (CTPA) is the preferred initial imaging study for suspected pulmonary embolus, and some recent clinical algorithms do not even include radionuclide ventilation-perfusion imaging. To some extent this may be the result of the high number of “nondiagnostic” scan interpretations and the generally perceived higher interobserver interpretive variance for nuclear medicine V/Q imaging compared to CT angiography. With current-generation CT scanners, coverage of the entire chest in high resolution can be achieved in one short breath hold lasting a few seconds. CTPA is the test of choice in unstable patients due to the short time required to do the examination. Very high resolution axial images of the pulmonary arteries with three-dimensional reconstruction are possible. CT scanning is often definitive when nondiagnostic V/Q scan results are obtained (Fig. 5-18, C). The specificity for pulmonary embolus detection with multidetector CT is greater than that of V/Q and has greatly contributed to its use. Some difficulties with spiral CT protocols are the need for precise timing of the contrast bolus to produce a diagnostic examination, and the clinical quandary presented by the detection of small peripheral emboli in normal persons or patients with minor symptoms. Incidental emboli are found in 1% to 5% of patients, and many of these patients have malignancies (Fig. 5-19). Incidental emboli are even more common in extremely old patients. Findings from a number of studies suggest that although CT angiography may detect more pulmonary emboli, the detection of clinically relevant disease did not change. Thus the question of overdiagnosis of pulmonary emboli by CT angiography has been raised. If nuclear medicine scans or CT scans are equivocal and if a patient has positive tests for deep venous thrombosis, and clinical suspicion is high, the individual usually is treated.

Septic PEs are common in drug addicts. They are usually seen as ill-defined pulmonary nodules, but they can
cavitate (Fig. 5-20). Differentiation from metastatic disease is made mostly on the basis of patient history, and, in the case of septic emboli, positive blood cultures and presence of fever.

### ISCHEMIC CARDIAC DISEASE

#### Congestive Failure

The pulmonary imaging findings of congestive heart failure are discussed in Chapter 3. The diagnosis of congestive heart failure is made on the basis of the patient’s medical history and physical examination; a chest x-ray is confirmatory. Accurate measurements of LVEF and regional wall motion are made using previously discussed nuclear medicine techniques or echocardiography. If exercise treadmill, nuclear medicine, or echocardiography results are positive or if the LVEF is less than 35%, a coronary angiogram may be indicated.

#### Coronary Artery Disease and Angina

Coronary artery disease can be asymptomatic, associated with stable or unstable angina, or evident as the result of a myocardial ischemic event. Angina is considered stable if it occurs with a predictable level of exertion and has not changed pattern for more than 60 days. It usually lasts 0.5 to 10 minutes and quickly subsides with rest or nitroglycerin. Unstable angina is pain at rest or with minimal exertion, typically lasting 20 to 30 minutes or increasing in frequency, duration, or severity. It is caused by insufficient oxygenation of the myocardium. Laboratory abnormalities (e.g., elevated creatine kinase, myocardial bound [CK-MB] levels) of a myocardial infarction (MI) are not present.

Most patients with coronary artery disease have relatively normal chest x-rays. As coronary artery disease progresses, however, cardiac decompensation may occur, with enlargement of the cardiac silhouette and signs within the pulmonary parenchyma of congestive failure. Although it is quite rare, occasionally calcifications in the coronary arteries can be seen on a plain radiograph (Fig. 5-21). Coronary artery calcification is associated with intimal ath- erosclerosis, it does not indicate a significant coronary artery stenosis. Calcification is seen best on CT scans and is not seen on a chest x-ray unless it is extensive. With conventional CT about 90% of patients who have coronary artery calcification have some stenosis, although not necessarily of significant size (>50% reduction in diameter).

Evaluation of coronary artery disease usually involves a determination of whether the patient simply has angina, a significant stenosis and ischemia, or an MI. The normal initial workup includes tests of cardiac enzymes and an electrocardiogram (ECG). A stress ECG also is frequently performed. Indications for an initial noninvasive cardiac stress test are shown in Table 5-4. The least invasive imaging methods for evaluation of coronary artery disease are echocardiography and nuclear medicine myocardial perfusion studies. Echocardiography is based on stressing the patient and then looking for a regional wall-motion abnormality, caused either by induced ischemia or by a previous infarction. Although this method is

![FIGURE 5-20 Septic emboli. In this patient, who is a drug abuser with a fever, the initial chest x-ray (A) shows ill-defined patchy infiltrates (arrows). A computed tomography scan (B) of the same patient shows these to be predominantly peripheral.](image)

| TABLE 5-4 Indications for an Initial Noninvasive Cardiac Stress Test<sup>†</sup> |
|-------------------------|-------------------------------------------------------------------|
| Patients with a known history of coronary artery disease          |
| A man older than 60 yr or a woman older than 70 yr with          |
| definite angina                                                   |
| Patients experiencing hemodynamic changes or                     |
| electrocardiographic changes during an episode of pain            |
| Patients who describe a change in angina pattern                  |
| Patients with an electrocardiogram that reveals ST-segment       |
| elevation or depression of ≥1 mm                                  |
| Patients with an electrocardiogram that reveals marked           |
| symmetric T-wave inversion in multiple precordial leads           |

<sup>†</sup>In patients with chest pain in whom a myocardial infarction has been excluded.

<sup>†</sup>Exercise stress test, pharmacologic stress test, nuclear medicine myocardial stress test, or echocardiographic stress test.
used in many institutions, it is operator dependent, and therefore nuclear medicine studies are commonly performed.

A nuclear medicine study can use a number of radioactive myocardial perfusion agents (such as thallium and sestamibi) to image the musculature of the left ventricle. Images are typically obtained in “slice” or tomographic cuts. With computer analysis these images may be displayed in the short axis, that is, looking down the barrel of the left ventricle; in the horizontal long axis, essentially slicing the left ventricle horizontally lengthwise; or in the vertical long axis (e.g., slicing the left ventricle from top to bottom in the long axis). Patients are typically imaged with and without the heart having been stressed either by exercise or by chemical agents. If a defect is seen on both exercise and rest images, a high probability of MI exists; if a defect is seen only on stress images, this implies ischemia (Fig. 5-22).
Coronary artery stenosis occurs most commonly in the left anterior descending artery, next most commonly in the right coronary artery, and least commonly in the left circumflex artery. The degree of stenosis is directly related to the amount of blood-flow reduction. A decrease of less than 50% in the diameter of a vessel or less than 75% in the cross-sectional area is not considered significant. A greater than 75% decrease in the diameter of a vessel is equivalent to a greater than 95% decrease in cross-sectional area, and this is regarded as a severe stenosis. As a rule of thumb, a decrease of 50% or more in diameter of a vessel is equivalent to a 75% or greater decrease in cross-sectional area and flow, and this level or more is regarded as significant.

Visualization of the individual coronary arteries is best done with coronary angiography. Because this is an invasive, expensive procedure and the radiation dose is high, it is not used as a screening test. It often is done only after positive results of nuclear medicine study or echocardiogram are found. Obviously, it also must be done if bypass surgery is contemplated. Coronary angiograms are performed and interpreted by cardiologists. Cardiologists can now use coronary angiography to place a catheter either to dilate a particular area of coronary stenosis (angioplasty) or to infuse a clot-lysing agent in an area of recent occlusion. After dilation, a wire mesh stent can be placed in the coronary artery to retard and hopefully to prevent restenosis. These stents can sometimes be seen on chest x-rays (Fig. 5-23).

**Computed Tomography Coronary Artery Screening and Calcium Scoring**

In the last several years, evaluation of older patients for the amount of calcium in the coronary arteries has become popular. This rather quick examination is done with either a multidetector spiral CT (see Fig. 5-21, B) or an electron-beam CT scanner. No intravenous contrast is used. The CT scan is used to detect, count, and measure calcifications in the coronary arteries. Calcification indicates atherosclerosis and may be one of the first signs of coronary artery disease. The presence of calcification alone does not indicate significant coronary artery disease. For example, detectable calcification is found in 30% to 40% of persons in their 40s and in 70% to 80% of persons in their 60s. In general, a multidetector CT calcium score of 0 to 10 indicates very low risk; 11 to 100, moderate risk; 101 to 400, moderately high risk; and more than 400, high risk. The calcium score for an individual is measured against age and gender norms. Usually only those at 75% or greater on age- and sex-specific calcium score go on for additional workup. Remember that a patient can have significant coronary artery disease without calcifications. As many as 50% of persons with an MI (often due to a “soft” plaque) will not have significant calcification.

**Myocardial Infarction**

An acute MI is usually diagnosed by history, ECG changes, and laboratory abnormalities (elevated CK-MB levels). If the patient is within 6 hours of the onset of chest pain, a coronary angiogram is indicated in a facility where balloon angioplasty, stent placement, or thrombolytic therapy is performed. Coronary angiography also is indicated if cardiogenic shock, papillary muscle rupture, LVEF less than 35%, or an ischemic VSD is present, or if the patient has an arrhythmia and is a cardiac arrest survivor. If the patient is initially seen later than 6 hours with evidence of an MI, initial evaluation is done either by a rest or stress ECG, nuclear medicine myocardial perfusion scan (Fig. 5-24), or echocardiogram.

**AORTA**

**Anatomy and Imaging Techniques**

A number of anomalies of the aortic arch are found, the most common of which is a right-sided aortic arch (Fig. 5-25). There are several different types. Some have the arch on the right, with simple mirror-image branching of the innominate, common carotid, and right subclavian arteries. This type also descends along the right side of the spine and can be associated with tetralogy of Fallot or truncus arteriosus. Right aortic arches are associated with congenital heart disease in 5% of cases. Other variants of right-sided aortic arch include anomalous origins of the pulmonary artery off the ascending or descending aorta; however, these are impossible to differentiate on plain chest x-ray.

Calcification of the aortic arch is common in persons older than 60 years. It is fairly unusual between the ages of 40 and 50 years, and calcification suggests a higher-than-average incidence of atherosclerotic disease. Calcification can be seen in the aortic arch and also often in the great vessels (Fig. 5-26).

Injection of contrast directly into the aorta (contrast angiography) yields the most definitive evaluation of
FIGURE 5-24 Myocardial infarction. Here the left ventricle is viewed from the side. Clearly, less perfusion exists in the distal anterior wall and apex (arrows). This did not change at rest, indicating a permanent lack of perfusion (infarct). This is the same patient shown in Figure 5-6, who had abnormal wall motion in the same area.

FIGURE 5-25 Right-sided aortic arch. Although the heart is in its normal left-sided configuration, the ascending, transverse, and descending thoracic aorta (Ao) are on the right side.

normal and anomalous anatomy (Fig. 5-27). The left anterior oblique view is the most useful, because this lays out the anatomy better without much overlap of the great vessels or of the ascending and descending aorta. Imaging also can be done with CT or MR scanning.

Coarctation of the Aorta

Coarctation is a congenital narrowing of the proximal descending thoracic aorta, which usually occurs in the vicinity of the ductus arteriosus. Symptoms are rarely, if ever, present during childhood. The diagnosis is
A hematoma is found on a CT scan done on a traumatized patient (Fig. 5-31).

Thoracic Aortic Aneurysms

Aneurysms may be the result of atherosclerosis, inflammatory, mechanical, traumatic, or congenital causes;
Sudden onset of chest pain in a patient with an aneurysm should suggest rupture or ongoing dissection. Detailed evaluation of an aneurysm can be easily performed by using CT scanning with a bolus of intravenous contrast. This will allow the lumen to be visualized, as well as clot along the inner wall of the aneurysm. In many patients, portions of the clot come loose and lead to distal thromboembolic events (see Fig. 5-32, C). An arteriogram is not the best initial method for evaluation of aneurysms, because usually all that is visualized is the patent lumen.

FIGURE 5-30 Aortic tear. A chest x-ray (A) obtained in an individual who was in a motor vehicle accident shows multiple rib fractures (black arrows), filling in of the normal concavity of the aortopulmonary window (long white arrow), and fluid over the apex of the left lung (small arrows). These latter two findings are suggestive of mediastinal hemorrhage. A digital subtraction contrast aortogram (B) shows a bulge of contrast (arrow) due to a tear in a typical location.

FIGURE 5-31 Mediastinal hematoma. The chest x-ray (A) in a traumatized patient shows a widened upper mediastinum (arrows). A contrast-enhanced computed tomography scan at the level of the thoracic inlet (B) and at the level of the aortic arch (C) shows gray soft tissue density surrounding the vessels, indicating hemorrhage (arrows) and vascular damage.

fibromuscular dysplasia; and cystic medial necrosis. An aneurysm of the ascending aorta historically was most likely due to syphilis. This is rare now, and Marfan’s syndrome is a more likely cause.

With aneurysms of either the thoracic or the abdominal aorta, surgery or endograft placement is often performed, because a marked increase in risk for aortic rupture is found. Aneurysms may be discovered incidentally, or the patient may present with pain, rupture, or thromboembolic complications. Aneurysms of the thoracic aorta are fairly easy to identify on chest x-rays as widening of the ascending aorta or aortic arch (Fig. 5-32). Sudden onset of chest pain in a patient with an aneurysm should suggest rupture or ongoing dissection.

Detailed evaluation of an aneurysm can be easily performed by using CT scanning with a bolus of intravenous contrast. This will allow the lumen to be visualized, as well as clot along the inner wall of the aneurysm. In many patients, portions of the clot come loose and lead to distal thromboembolic events (see Fig. 5-32, C). An arteriogram is not the best initial method for evaluation of aneurysms, because usually all that is visualized is the patent lumen.
Aortic Dissection

Aortic dissection is the result of an intimal tear causing separation of the layers of the wall of the aorta. It is more common in men than in women and usually occurs between the ages of 45 and 70 years. The incidence is higher in patients with Marfan’s syndrome, coarctation of the aorta, and bicuspid aortic valve disease. Aortic dissection also commonly occurs in patients with aortic atherosclerosis, particularly those who are hypertensive. Dissection carries a very high mortality if undiagnosed and untreated. Dissection of the thoracic aorta proximal to the left subclavian artery is a surgical emergency, whereas dissections of the descending thoracic aorta are usually managed by medical treatment of the patient’s hypertension.

The dissection can allow blood to flow between the layers of the aortic wall, causing a false lumen. Sometimes this false lumen will reenter the true lumen farther down the aorta. Generally, aortic dissection begins either in the ascending aorta or in the descending aorta just distal to the left subclavian in the upper back and chest. About one third of patients will have extremity pain, and another one third will have a central nervous system abnormality if the dissection involves the ascending aorta and great vessels.

Aortic dissection should be suspected on a chest x-ray if a double contour of the aortic arch is seen, if progressive serial enlargement is noted, or if displacement of intimal calcification more than 6 mm from the outer aortic margin is found. This last sign must be interpreted with caution, because a minor degree of rotation of the chest may cause anterior arch calcification to project eccentrically over the posterior arch. On chest x-ray, most patients with a dissection will have a dilated aorta with a widened mediastinum and cardiomegaly.

Enlargement of the aortic arch on a single image is not specific for a dissection, inasmuch as the aortic arch can frequently be enlarged in patients with hypertension or atherosclerosis. Lack of enlargement of the aortic arch should not be taken as evidence that a dissection is not present, because the arch is of normal size in 25% of dissection cases (Fig. 5-33).

The diagnosis of dissection can be made with a contrasted CT or an MRI study. CT scanning is somewhat quicker, and it is easier to manage a patient who may suddenly decompensate. Demonstration of an intimal flap on CT is conclusive evidence of a dissection. An intimal flap and the false lumen can be seen in 70% of patients. Transesophageal ultrasound can be used to evaluate dissections or aneurysms of the descending thoracic aorta, because the esophagus is in such close proximity. Generally, however, surgeons want a more complete evaluation, such as that provided by CT, before they will operate on a patient.

PERIPHERAL VESSELS

Head and Neck

A carotid bruit may be identified as part of a stroke or transient ischemic attack workup or as an incidental result of a physical examination done for other reasons. Carotid bruits are not sufficiently predictive of high-grade symptomatic carotid stenosis to identify those that are amenable to surgery. As a result, both asymptomatic and symptomatic patients with a bruit should be evaluated with duplex ultrasonography to determine the degree and extent of stenosis. Interpretation is based on the image of the vessel walls and the flow across the area in question. Patients with a high-grade (>60% to 80%) stenosis may benefit from carotid endarterectomy. The role of surgery in low-grade stenoses or in asymptomatic patients remains debatable. Surgery is considered in those patients with recurring transient ischemic attacks while receiving medical therapy and those with severe carotid ulceration. Carotid ultrasound also is indicated in patients with other vascular
disease and before carotid surgery or aortic aneurysm repair. It also is widely done in patients with other peripheral vascular disease, for example, in those with foot pain at rest, nonhealing foot ulcers, gangrenous changes of the feet, or a resting ankle-brachial index of 0.5 or less.

Evaluation of vessels of the head and neck classically was done by using contrast angiography. This involves percutaneous access to the femoral artery and placement of the catheter up the aorta with selective catheterization of the individual great vessels, including the carotid and vertebral arteries. The typical contrast angiogram shows exquisite detail of the vessels of the neck, face, and brain and can easily demonstrate areas of stenosis or aneurysm that may be dilated and a stent placed (Fig. 5-34).

All contrast angiography of the vessels of the head and neck carries a small risk for stroke, because of injection of air bubbles, or of vascular spasm or clotting, because of the catheter. Recently advances in CT and MRI scanning have allowed MR and CT angiography to be performed as noninvasive procedures.

Abdominal Aorta and Iliac Vessels

In patients with extensive atherosclerosis, striking calcification of the abdominal aorta and iliac arteries may occur (Fig. 5-35, A). Remember that atherosclerosis is a common cause of aneurysm formation, and you should therefore be assessing the diameter of the vessels. Because on the AP x-ray of the abdomen the aorta overlies the spine, it can be difficult to assess calcification in the aortic wall. The lateral view of the abdomen or of the lumbar spine often gives a better appreciation of the calcified abdominal aorta (Fig. 5-35, B). The abdominal aorta should not exceed 2.5 cm in diameter; as with the thoracic aorta, once the diameter exceeds 5 cm, an increased likelihood of rupture exists. The diameter of the aorta should be measured from the anterior wall back to the vertebral bodies and not just to the posterior calcified wall. Sometimes the calcification in an abdominal aneurysm can be somewhat subtle and, on the AP view, may be seen as curvilinear streaks along the lateral aspects of the vertebral bodies (Fig. 5-36).

An easy noninvasive examination of the abdominal aorta can be done using abdominal ultrasound. Not only the aorta but also other vessels can be visualized, such as the superior mesenteric artery and vein (Fig. 5-37). Abdominal ultrasound is the imaging test of choice if follow-up is needed on a patient who has a dilated aorta that has not yet reached 5 cm in diameter. In a symptomatic patient whose condition raises fear of clot within the aorta, dissection, or rupture, a CT scan with an intravenous bolus of contrast material is the test of choice (Fig. 5-38). Some physicians recommend that abdominal ultrasound be used as a screening procedure for abdominal aortic aneurysm in nonsmoking men older than 65 years, in male smokers older than 50 years, and in all persons older than 50 years who had a parent with abdominal aneurysm. Recent treatment of abdominal and iliac aneurysms involves the use of large endoluminal endografts. These are typically placed via catheter access in the femoral artery (Fig. 5-39). Follow-up of these endografts to exclude progression of the aneurysm, leakage, or occlusion is usually done with CT (Fig. 5-40).

Historically evaluation of abdominal and pelvic vessels other than the aorta was done by contrast angiography. Not only can the major vessels, such as hepatic artery and renal arteries, be identified, but also all their branches can be seen in great detail. Even small lumbar arteries can be visualized (Fig. 5-41). Currently arterial anatomy is best visualized using either CT angiography or MR angiography. Atherosclerotic changes and areas of stenosis or blockage are easily identified (Fig. 5-42). After identification of areas of stenosis, it is possible to insert a catheter that has a balloon on the end and to dilate the areas of stenosis. This is called percutaneous transluminal angioplasty. The success rate actually depends on the vessel, and the success of angioplasty is greatest in the larger vessels, such as the iliac arteries. Five-year patency rates are usually quoted as 70% to 90%. Often it also is possible to insert a metallic stent, an expandable wire mesh tube that is placed inside the vessel to keep it from restenosing.

A percutaneous invasive vascular procedure can be used in patients with severe portal hypertension (a transjugular
FIGURE 5-34 Carotid artery stenosis. A lateral projection (A) from a standard contrast arteriogram shows the common carotid (CC), the external carotid (EC), and the internal carotid (IC) arteries. An area of stenosis can be identified at the base of the internal carotid artery (large arrow). A digital subtraction angiogram (B) makes areas of stenosis much easier to see, because the bones have been subtracted off the image. A lateral view of the neck shows a stent that was placed post dilation.

FIGURE 5-35 Calcification of the abdominal aorta. A plain x-ray of the abdomen (A) shows extensive calcification of the abdominal aorta and iliac vessels (arrows). Calcification of the abdominal aorta is usually much easier to see on the lateral view (B). If the distance from the anterior calcified wall back to a vertebral body exceeds 5 cm, an abdominal aortic aneurysm is present.
FIGURE 5-36 Progressive development of an abdominal aortic aneurysm. A plain x-ray of the abdomen of a patient done in 1975 (A) showed a small area of linear calcification overlying the right side of L5 (arrows). This represents calcification within the wall of the aorta. A repeated x-ray 10 years later (B) showed bilateral linear areas of calcification (arrows). The distance between these two linear calcifications represents the width of the aneurysm.

FIGURE 5-37 Ultrasound demonstration of normal vascular anatomy in the upper abdomen. A transverse sonogram (A) shows structures such as the liver and pancreas (Panc) and vertebral body (Vert) and also the superior mesenteric artery (SMA), vein (SMV), and abdominal aorta (Ao). A longitudinal view just to the left of midline (B) shows the liver and abdominal aorta as well as the origin of the celiac axis and superior mesenteric artery.

intrahepatic portosystemic shunt, or TIPS procedure). This method is used on patients with end-stage cirrhosis who are not candidates for surgery. The approach involves puncturing the right jugular vein and passing a catheter down the superior vena cava into the inferior vena cava and then into the hepatic vein. A needle is pushed through the liver into the portal system; the needle tract is dilated with a balloon; and a stent is placed in the dilated tract. This allows blood to flow from the portal vein into the hepatic veins and vena cava without going through the liver. Reducing the portal pressure can reduce complications such as variceal bleeding and ascites.

Renal Artery Stenosis and Hypertension

Only 1% to 2% of hypertension is due to renal artery stenosis. The clinical features that help distinguish this from other forms of hypertension are occurrence at an unusual age (younger than 30 and older than 50 years) or poor response to medical therapy. Physical examination may reveal a bruit in the flank or upper abdomen. Laboratory evaluation may rarely yield evidence of hyperaldosteronism, including hypokalemia and metabolic acidosis. An appropriate initial imaging test is a nuclear medicine captopril renogram. The captopril causes the
Chapter 5 | Cardiovascular System

FIGURE 5-38 Abdominal aortic aneurysm and rupture. A transverse contrast-enhanced computed tomography (CT) scan (A) of the lower portion of the abdomen shows the aorta with a calcified rim and the lumen (L) filled with contrast and mural clot (C). In a different patient who had abdominal pain, a noncontrast CT scan (B) shows the true lumen of the aorta (L), which is visible because of the calcified aortic wall. What looks like soft tissue surrounding the aorta and extending into the left psoas region is hemorrhage (H) due to a leak.

FIGURE 5-39 Aortic aneurysm endograft repair. Here wire mesh stents with a lining have been inserted into the abdominal aorta and proximal iliac arteries. They can be seen projecting over the lumbar spine and sacrum. These endografts are inserted through the femoral arteries, and an open surgical procedure is not required. The calcified rim of the aneurysm is visible on the left (arrows).

FIGURE 5-40 Occluded endograft repair. Evaluation and follow-up of aortic and iliac stents is done with computed tomography (CT) scanning. In the noncontrast CT scan (A), the wire mesh stents in the iliac vessels can be seen. On the contrast-enhanced CT scan (B), only one of the limbs of the repair is patent, and the other (arrow) is occluded and does not fill with contrast.
FIGURE 5-41 Normal vascular anatomy of the abdomen and pelvis. An angiogram in an anteroposterior projection of the upper abdomen (A) shows the abdominal aorta (Abd Ao), the hepatic (Hep A) and splenic arteries (Sp A), the right (RRA) and left renal arteries (LRA), and the superior mesenteric artery (SMA). A subsequent image over the lower abdomen and pelvis (B) taken a few seconds later shows the distal abdominal aorta with small lumbar branches, the common iliac artery (CIA), the internal (Int IA) and external (Ext IA) iliac arteries, and the common femoral artery (CFA).

FIGURE 5-42 Magnetic resonance arteriogram of the abdominal and pelvic vessels. The aorta and both kidneys are clearly visualized. There is a complete obstruction of the left common iliac and right common femoral arteries (arrows) with distal flow through to collateral vessels.

Deep Venous Thrombosis

Evaluation of the veins of the lower extremities is particularly important, because this is a common site for development of thrombi that can lead to potentially fatal pulmonary emboli. Deep venous thrombosis fails to produce clinical signs in half the patients who have it. Thrombosis in calf veins is usually insignificant; however, in the femoral veins and pelvic veins, thrombi are significant. Risk factors include prolonged bed rest, immobilization of an extremity, pregnancy, oral contraceptives, malignancy, and postoperative and traumatic circumstances.

The historical approach for imaging veins was contrast venography. With this approach, contrast material is injected into the veins on the dorsum of the foot, and the contrast is visualized as it proceeds up the veins of the leg and into the pelvis. Contrast venography allows visualization of the deep venous system but not of the superficial venous system. Clots can be seen as intraluminal defects with contrast material surrounding them. Total obstruction with visualization of collateral veins also can be seen with thrombosis. One of the problems with contrast venography is that it involves the use of affected kidney efferent arterioles to dilate and the kidney can be seen to have poor function temporarily. If this occurs, the study is repeated without captopril, and, if this is normal (because the kidney compensates for the renal artery stenosis), an angiogram and possible angioplasty are indicated. Another choice is to perform an MR angiogram (Fig. 5-43) or a CT angiogram.
iodinated and intravenously administered contrast material. Sometimes venous access is difficult in patients who have a grossly swollen leg. It is possible that the contrast itself may cause some inflammation of the vein and may carry a low but real complication rate of thrombophlebitis. As a result, the use of contrast venography has markedly declined.

The initial imaging test of choice for a patient with suspected deep venous thrombosis is ultrasonography. Ultrasound examination has a sensitivity and specificity of approximately 95%. The femoral artery and vein can both easily be visualized by using ultrasound. With pressure, the femoral vein will normally be compressed. If a clot exists within the vein, echoes will be seen within the lumen, and no compression will be identified. Color Doppler ultrasound can be used to classify flow in the vein into no flow or partial flow.

Recurrent deep venous thrombosis or deep venous thrombosis that is not successfully treated with heparin can result in multiple episodes of PEs. Because of the life-threatening nature of this problem, methods have been developed to keep the thrombi from migrating into the lung. Probably the most frequently used method is placement of a filter in the inferior vena cava. Access is gained through the femoral vein, and contrast is injected to make sure that no clot is in the iliac vein or inferior vena cava itself. After this, a catheter is advanced to the level just below the renal veins, and an expandable wire net or basket is pushed out the end of the catheter. The most commonly used device now is a Greenfield filter, and if it is present, it is easily seen on an AP x-ray of the abdomen projecting over the right side of the upper lumbar vertebra (Fig. 5-44).

Workup of Claudication

Claudication is most commonly caused by chronic arterial ischemia from atherosclerosis. The atherosclerosis can involve any site from the aortoiliac region distally. The simplest method to document lower extremity arterial occlusive disease is with ultrasonography. This is most commonly done in a vascular laboratory, and Doppler ultrasonography is used to measure the ankle-brachial index. A normal ankle-brachial index is 1.0 or greater. Before any type of surgical intervention, an arteriogram that includes visualization of the aortoiliac, femoral, popliteal, and tibial arteries is required. Few imaging tests are useful in evaluating extremity pain caused by venous or small vessel insufficiency, or for neurologic or muscular pain.

Suggested Textbooks on the Topic
INTRODUCTION

Imaging Techniques and Anatomy

The most common imaging study of the abdomen is referred to as a KUB, or plain image of the abdomen. The term KUB is historical nonsense. It stands for kidney, ureter, and bladder, none of which is usually seen on a regular x-ray of the abdomen; nevertheless, the term remains widely used. A KUB is usually done with the patient supine (Fig. 6-1). When examining this image, you should look at the bony structures, the lung bases, and then at the soft tissue and gas patterns (Table 6-1). The soft tissue–pattern analysis should include evaluation of the lateral psoas margins. Whether you see them bilaterally, only faintly, or throughout their length depends on the shape of the psoas and the amount of retroperitoneal fat in that individual. It is all right if you do not see the psoas margin on either side. If you see the psoas margin on one side but not on the other, this is most commonly due to normal anatomic variation. In about 25% of cases, however, pathology will be found on the side of the obscured psoas margin.

Even though they are difficult to see, you should look for the outlines of the kidneys. Again, if you cannot see the outlines, you should not be terribly concerned, because they are often obscured by overlying bowel gas and fecal material. The liver is seen as a homogenous soft tissue density in the right upper quadrant. The spleen can sometimes be seen as a smaller homogenous density in the left upper quadrant. Although you will be able to appreciate massive enlargement of either one of these organs, minimal to moderate enlargement is very difficult to ascertain, and you should think twice before you suggest it. Clinical palpation and percussion are at least as accurate as x-rays in this situation.

Evaluation of the gas pattern also is important (Table 6-2). Because people routinely swallow air and drink lots of carbonated beverages, the stomach almost always has some gas within it. When a person is lying on his or her back, the air will go to the most anterior portion of the stomach, which is the body and antrum. This is seen as a curvilinear air collection, just along the left side of the upper lumbar spine (Fig. 6-2). If the person has swallowed a lot of air, you may see gas bubbles within the entire gastrointestinal (GI) tract extending from the stomach to the rectum. The origin of almost all these bubbles is swallowed air and not gas produced by intestinal bacteria. You should be able to identify the air patterns in the stomach, small bowel, colon, sigmoid, and rectum. Gas in the small bowel usually can be identified, because small bowel mucosa has extremely fine lines that cross all the way across the lumen. Most small bowel gas is located in the left midabdomen and the lower central abdomen. The colon often can be traced from the cecum in the right lower quadrant to both the hepatic and the splenic flexures and down to the sigmoid. The cecum and the colon often have a bubbly appearance representing a mixture of gas and fecal material. Colonic air often has a somewhat cloverleaf-shaped appearance caused by the haustra of the colon. Normal small bowel diameter should not exceed 3 cm, and the colon should not exceed 6 cm. The cecum can normally be somewhat larger than the rest of the colon and may be up to 8 cm in diameter.

In addition to a supine abdominal image, a “three-way” view of the abdomen is often obtained. The additional two views are an upright posteroanterior (PA) chest x-ray and a view of the abdomen taken with the patient standing upright. The PA view of the chest is taken to look for chest pathology that may be mimicking or causing abdominal symptoms as well as to look for free air underneath the hemidiaphragms. The reason for the standing view of the abdomen is to look at the air/fluid levels within the bowel to differentiate between an obstruction and ileus.

A common variant is called colonic interposition (also called Chilaiditi syndrome). In this normal variant, the hepatic flexure of the colon can slip up between the superior aspect of the liver and the dome of the right hemidiaphragm (Fig. 6-3). This should not be mistaken for free air. When colonic interposition occurs, you can almost always see the haustral markings of the colon.

Computed tomography (CT) scanning is the most common procedure used to image abdominal pathology. The visualization of the solid organs, peritoneum, and retroperitoneum that is obtained with CT means that CT is being ordered as much as or more than plain abdominal radiographs. CT anatomy is presented in Figure 6-4. With new scanners the entire pelvis and abdomen can be imaged in a few minutes. For evaluation of the solid organs, imaging may be done with or without iodinated intravenous contrast agents. For evaluation of suspected pathology in the stomach, small intestine, colon, or rectum the lumen can be differentiated by using orally administered contrast agents (either dilute barium or just water).

The patients commonly prepare by drinking oral contrast for about 1 to 3 hours before the examination. If pelvic pathology is suspected, rectal contrast is occasionally given at the time of the examination.
TABLE 6-1 Items to Look for on a Plain Abdominal Image (KUB)

<table>
<thead>
<tr>
<th>Gas Patterns</th>
<th>Stomach, small bowel, and rectosigmoid</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Abnormal or ectopic collections</td>
</tr>
<tr>
<td>Organ Shapes and Sizes</td>
<td></td>
</tr>
<tr>
<td>Liver</td>
<td></td>
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<tr>
<td>Spleen</td>
<td></td>
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<tr>
<td>Kidneys</td>
<td></td>
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<tr>
<td>Soft tissue pelvic masses</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
<tr>
<td>Calcification</td>
<td></td>
</tr>
<tr>
<td>Asymmetric psoas margins</td>
<td></td>
</tr>
<tr>
<td>Skeleton</td>
<td></td>
</tr>
<tr>
<td>Basilar lung abnormalities</td>
<td></td>
</tr>
</tbody>
</table>

KUB, Kidney, ureter, bladder.

TABLE 6-2 Evaluation of Gas Patterns on a Plain Image of the Abdomen

| Collections Normally Present                                                                 |
|-----------------------------------------------|------------------------------------------|
| Look for dilatation of structure and assessment of wall or mucosal thickness in stomach, small bowel, colon, and rectosigmoid |

| Collections Not Normally Present |
|----------------------------------|----------------------------------|
| Free air under the diaphragm (upright image) |                       |
| Free air on supine radiograph (double bowel wall sign) |              |
| Right upper quadrant: portal vein (peripheral in liver), biliary system (central in liver) |         |
| Small bubbles in an abscess | Emphysematous cholecystitis, pyelonephritis, or cystitis |

FIGURE 6-1 Normal anatomy seen on a supine x-ray (KUB) of the abdomen.

FIGURE 6-2 Normal bowel gas pattern. Gas is normally swallowed and can be seen in the stomach (St). Small amounts of air normally can be seen in the small bowel (SB), and this is usually in the left midabdomen or central portion of the abdomen. In this patient, gas can be seen throughout the entire colon, including the cecum (Cec). Where the air is mixed with feces, a mottled pattern appears. Cloverleaf-shaped collections of air are seen in the hepatic flexure (HF), transverse colon (TC), splenic flexure (SF), and sigmoid (Sig).

FIGURE 6-3 Colonic interposition. This is a normal variant in which the hepatic flexure can be seen above the liver. This is seen as a gas collection under the right hemidiaphragm (arrow), but it is clearly identified as colon, owing to the transverse haustral markings.
With CT “virtual colonoscopy” a three-dimensional (3-D) reconstruction of the abdomen is generated and the computer is used to create images that track the inside of the colon. The technique requires that the colon be well cleaned so that small bits of fecal material are not mistaken for polyps. True colonoscopy has the advantage that if a lesion is seen, a biopsy can be performed.

Ultrasound examination is used primarily to image the liver, kidneys, gallbladder, common bile duct, and, to a much lesser extent, the pancreas and appendix. Ultrasound is often limited by the inability of the sound to penetrate air and by large loops of bowel that may obscure underlying pathology. Ascites is easily detected and localized for paracentesis.

Nuclear medicine scans provide physiologic information that is often not available using other imaging techniques. It is often used to quantitate gastroesophageal reflux and gastric emptying times, to diagnose acute cholecystitis and bile leaks, to determine the site of GI bleeding, and to stage tumors.

**Pneumoperitoneum**

It is easiest to identify small amounts of free air in the peritoneal cavity by doing an upright chest x-ray. In this manner, as little as 3 or 4 mL of air may be visualized (Fig. 6-5, A). An upright abdominal radiograph is usually not especially useful to look for free air, because the domes of the diaphragms are often off the upper edge of the image. It is extremely difficult to appreciate even relatively large amounts of free air within the peritoneal cavity by looking at a supine (KUB) view of the abdomen. If a lot of free air is present, you may be able to see the bowel wall outlined by air (Fig. 6-5, B). If the patient is too sick to stand, and you suspect a small pneumoperitoneum, order a left lateral decubitus view of the abdomen. In this manner, with the patient lying on the left side (for 10 to 15 minutes), small amounts of air can be seen tracking up over the lateral aspect of the right lobe of the liver. Tiny amounts of free air can be detected on CT scans (Fig. 6-5, C).

**FIGURE 6-4** Normal transverse computed tomography anatomy of the abdomen and pelvis. The patient has been given oral, rectal, and intravenous contrast media.
FIGURE 6-4, cont’d
Chapter 6  Gastrointestinal System

**Intra-abdominal Abscesses and Fever of Unknown Origin**

Air can be seen within some, but by no means all, abscesses. Although an extremely large abscess may be appreciated on a plain radiograph, it is often difficult to tell whether you are looking at air in the bowel or in some other structure. For this reason the imaging test of choice when an abdominal or pelvic abscess is suspected is a CT scan (Fig. 6-6). It is important that under these circumstances you order a CT scan with GI contrast so that the entire bowel can be filled with contrast. If this is not done, it may be difficult, even on a CT scan, to differentiate a collection of bowel that has air and fluid within it from an abscess.

The imaging workup of a patient with a fever of unknown origin usually begins with a chest x-ray. Most infectious processes of the chest are quite obvious. Once intrathoracic pathology has been excluded, the next place to look is the abdomen and pelvis. Assuming that the physical examination of the abdomen and pelvis is negative, a CT scan is usually ordered.

**Feeding Tubes**

As mentioned in Chapter 3, feeding tubes or nasogastric tubes are particularly recalcitrant medical devices. Not only can they inadvertently be passed into the trachea and major bronchus, but also they love to coil within the pharynx and stomach. On the plain radiograph a well-placed enteric (Dobbhoff) feeding tube can be seen coming down the esophagus, passing in an arc through the stomach toward the right of midline, and then progressing downward in a reverse arc through the duodenum, back to the left, across the vertebral column. It is best to have the tip of these feeding tubes near the junction of the duodenum and jejunum (ligament of Treitz) (Fig. 6-7). An unacceptable position of a feeding tube tip is in the esophagus or at the gastroesophageal junction (Fig. 6-8). If you feed patients
FIGURE 6-5 Pneumoperitoneum. A, A few milliliters of free air can be identified (arrows) under the right hemidiaphragm on this upright posteroanterior chest x-ray. B, A supine abdominal radiograph obtained on a different patient with massive pneumoperitoneum shows the bowel wall (arrows) outlined on both sides by air. C, In a different patient a tiny amount of free air (arrow) anterior to the liver can easily be seen on a CT scan.

FIGURE 6-6 Hepatic abscess. This drug abuser initially was seen with right upper quadrant pain and fever. On the upright chest radiograph (A), a collection of air is seen in the right upper quadrant. Notice the thick and irregular margin between the air and the hemidiaphragm, indicating that this is not free air. A transverse computed tomography scan (B) shows an air and pus collection due to a large abscess in the right lobe of the liver.

Abdominal Calcifications

Abdominal calcifications are quite common, and you should be familiar with them so that you know which are important and which to discount (Table 6-3). Fortunately, most of them have some characteristics that make this task relatively easy. Calcifications in the right upper quadrant are usually gallstones or kidney stones. If the calcifications are multiple, are close together, and lie outside the normal expected area of the kidney, you can be reasonably assured that they are gallstones (Fig. 6-9). A single calcification in the right upper quadrant may be due either to a kidney stone or to a gallstone. A simple way to tell the difference is to take a right posterior oblique view. A gallstone will rotate anteriorly and will not move with the outline of the kidney. Another way to tell the difference is to order a right upper quadrant ultrasound study, on which gallstones are easily identified (Fig. 6-10). In addition, if the patient has
FIGURE 6-7 Optimal positioning for an enteric feeding tube. On an anteroposterior radiograph of the upper abdomen, the feeding tube should be seen extending down the esophagus (E) slightly to the left of midline, taking a gentle curve to the right through the stomach (St), and then reversing its curve through the duodenum (D) and going back to the left across the spine to the junction of the fourth portion of the duodenum and the jejunum (ligament of Treitz).

FIGURE 6-8 Unacceptable position of feeding tube. In this case the tip of the feeding tube is in the distal esophagus, with the remainder coiled within the body of the stomach. Feeding with the tube in this position is likely to cause aspiration.

FIGURE 6-9 Multiple gallstones. Any collection of grouped calcifications in the right upper quadrant (arrows) is most likely due to gallstones but does not indicate acute cholecystitis.

TABLE 6-3 Differential Diagnosis of Abdominal Calcifications

<table>
<thead>
<tr>
<th>Quadrant</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Right Upper Quadrant</strong></td>
<td>Gallstones</td>
</tr>
<tr>
<td></td>
<td>Renal calculus, cyst, or tumor</td>
</tr>
<tr>
<td></td>
<td>Adrenal calcification</td>
</tr>
<tr>
<td><strong>Right Midabdomen or Right Lower Quadrant</strong></td>
<td>Ureteral calculi</td>
</tr>
<tr>
<td></td>
<td>Mesenteric lymph node</td>
</tr>
<tr>
<td></td>
<td>Appendicolith</td>
</tr>
<tr>
<td><strong>Left Upper Quadrant</strong></td>
<td>Splenic artery</td>
</tr>
<tr>
<td></td>
<td>Splenic cyst</td>
</tr>
<tr>
<td></td>
<td>Splenic histoplasmosis (multiple and small)</td>
</tr>
<tr>
<td></td>
<td>Renal calculus, cyst, or tumor</td>
</tr>
<tr>
<td></td>
<td>Adrenal calcification</td>
</tr>
<tr>
<td></td>
<td>Tail of pancreas</td>
</tr>
<tr>
<td><strong>Central Abdomen</strong></td>
<td>Aorta or aortic aneurysm</td>
</tr>
<tr>
<td></td>
<td>Pancreas (chronic pancreatitis)</td>
</tr>
<tr>
<td></td>
<td>Calcified metastatic nodes</td>
</tr>
<tr>
<td><strong>Pelvis</strong></td>
<td>Phleboliths (low in pelvis)</td>
</tr>
<tr>
<td></td>
<td>Uterine fibroids (popcorn appearance)</td>
</tr>
<tr>
<td></td>
<td>Dermoid</td>
</tr>
<tr>
<td></td>
<td>Bladder stone</td>
</tr>
<tr>
<td></td>
<td>Calcifications in buttocks from injections</td>
</tr>
<tr>
<td></td>
<td>Prostatic (behind symphysis)</td>
</tr>
<tr>
<td></td>
<td>Vas deferens (diabetic)</td>
</tr>
<tr>
<td></td>
<td>Iliac or femoral vessels</td>
</tr>
</tbody>
</table>
right upper quadrant pain or jaundice, the ultrasound image will allow you to assess whether the common bile duct is dilated and to look at the internal architecture of the liver and pancreas.

Left upper quadrant calcifications are essentially always related to the spleen. Multiple small punctate calcifications are the result of histoplasmosis (Fig. 6-11). Serpiginous or rounded calcifications in the left upper quadrant usually are related to splenic artery calcification or to a splenic artery aneurysm (Fig. 6-12).

With chronic pancreatitis, calcification of the pancreas often is found. This can be seen as spotted or mottled calcification, usually lying in a somewhat horizontal distribution over the vertebral bodies of L1 and L2 and extending to the left. Remember, however, that on a plain abdominal x-ray, most persons with chronic pancreatitis do not have visible calcifications. CT scanning can identify calcifications much more easily than can a standard x-ray (Fig. 6-13, A), but you should rely on clinical and laboratory history, not on a CT scan (Fig. 6-13, B), for the diagnosis of chronic pancreatitis.

Calcification of mesenteric lymph nodes can occur as a result of previous infections. These are usually seen as somewhat rounded or popcorn-shaped calcifications in the right midabdomen. A tip-off is the significant downward movement of these calcifications on the upright views, because the mesentery is very mobile (Fig. 6-14).

In a patient who has right lower quadrant pain, look carefully in this area for calcifications. A stone within the appendix (appendicolith) often projects over the right side of the sacrum (Fig. 6-15) and can be difficult to see unless you look carefully. An appendicolith is present in approximately 10% of patients with appendicitis, and if you see an appendicolith, a high probability of appendicitis exists. Other signs of appendicitis are a bubbly gas collection (appendiceal abscess) in the right lower quadrant or a focal ileus (dilatation) of the nearby small bowel caused by the inflammatory reaction.

In adults it is common to see rounded calcifications in the lower half of the pelvis. These almost always are 1 cm or less in diameter, and they are phleboliths (calcifications within pelvic venous structures). They are easy to identify because they often have a lucent or dark center (Fig. 6-16).
FIGURE 6-12 Splenic vascular calcifications. Serpiginous calcifications in the left upper quadrant (A) are almost always due to splenic artery calcification. This finding is of no clinical significance. Occasionally, splenic artery aneurysms may cause a shell-like, rounded, left upper quadrant calcification (B). NG, Nasogastic.

They can occasionally be confused with stones in the distal ureter, and if a patient has symptoms of renal colic or obstruction, it is often necessary to perform a noncontrast CT or intravenous pyelogram (IVP) to determine which of the calcifications in the lower pelvis may be a phlebolith or a calculus.

Uterine fibroids can often be calcified. This type of calcification is similar to the popcorn type seen in the mesenteric lymph nodes. The difference is that fibroids are located in a suprapubic position and centrally in the pelvis. On occasion these can be quite large and spectacular (Fig. 6-17).

Two special types of calcification can be seen in the male pelvis. The first, prostatic calcifications, are found immediately behind the symphysis pubis. They are quite common and are the result of benign inflammatory disease. They are not associated with prostate cancer (Fig. 6-18). The second, and more rare, type of calcification looks like a little set of antlers in the middle of the pelvis, projecting slightly above the symphysis pubis. This represents calcification of the vas deferens and almost always indicates that the patient has diabetes (Fig. 6-19).

Acute Abdominal Pain

Acute atraumatic abdominal pain requires urgent evaluation. Evaluation of the location, onset, progression, and character of abdominal pain is necessary to begin development of a reasonable differential diagnosis. A thorough medical history and physical examination are necessary because abdominal pain may be associated with GI, genitourinary, cardiovascular, or respiratory disorders.

An electrocardiogram may be necessary to exclude myocardial causes. In addition to physical examination of the chest and abdomen, pelvic and rectal examinations also may yield useful information. Sudden onset of pain is often associated with bowel perforation, ruptured ectopic pregnancy, ovarian cyst, aneurysm, or ischemic bowel. Gradually increasing and localizing pain is more common in appendicitis, cholecystitis, and bowel obstruction.

After the patient has been assessed clinically, a reasonable approach to imaging can be formulated. In most cases of acute abdominal pain, the best initial imaging study is an upright PA chest x-ray and a supine and upright view of the abdomen (the so-called three-way abdomen). CT scanning is used when abscess, aneurysm, or retroperitoneal pathology is suspected. Ultrasound is the best initial examination if gallbladder, obstetric, or gynecologic etiologies are suspected.

Acute Gastroenteritis

A diagnosis of acute gastroenteritis is made on the basis of clinical history and the presence of diarrhea. The patients also may have vomiting, nausea, and abdominal pain. Dehydration is a common complication. The only procedure recommended is flexible sigmoidoscopy if blood is present in the stool.

Abdominal Masses

Abdominal masses can arise from any organ or structure in the peritoneal space, retroperitoneum, aorta, pelvis, or
FIGURE 6-13 Calcification in chronic pancreatitis. Rarely, on a plain radiograph of the abdomen (A), a horizontal band of calcifications can be seen extending across the upper midabdomen (arrows). Calcification within the pancreas is much easier to see on a transverse computed tomography scan of the upper abdomen (B). Calcification is seen as white speckled areas within the pancreas (arrows). The darker areas within the pancreas represent dilated common and pancreatic ducts. GB, Gallbladder; K, kidney; L, liver; Sp, spleen; St, stomach.

FIGURE 6-14 Calcification in the mesenteric lymph nodes. This is a benign finding. The calcifications are typically located in the midabdomen to the right of midline, are somewhat popcorn shaped (arrow), and are relatively easy to see on a supine KUB (A). On an upright view of the abdomen (B), these calcifications drop substantially, owing to the mobility of the mesentery.

FIGURE 6-15 Appendixolith. This calcification within the appendix can be seen almost anywhere in the right lower quadrant but is especially difficult to see when it overlies the sacrum (arrows). A right lower quadrant calcification in a patient with pain in this area should carry an extremely high clinical suspicion of acute appendicitis.
FIGURE 6-16 Phleboliths. These rounded vascular calcifications within the pelvis (arrow) are common and are of no clinical significance. They are usually round and less than 1 cm in diameter. They often have a lucent or dark center. They are typically seen in the lower half of the pelvic brim and can occasionally be difficult to differentiate from a ureteral calculus without a CT scan.

FIGURE 6-17 Calcified fibroids. Central pelvic calcifications, which are somewhat amorphous, most commonly represent fibroids (arrows).

FIGURE 6-18 Prostatic calcification. Calcification situated immediately behind the pubis (arrows) in a male patient usually represents the sequelae of previous prostatitis.

FIGURE 6-19 Calcification of the vas deferens. These bilateral asymmetric calcifications occur in the lower to middle portion of the male pelvis (arrows). When they are seen, they almost always indicate that the patient has diabetes.

abdominal wall. As a general rule, most abdominal masses do not grow down into the pelvis, but pelvic masses (being largely confined) often grow up into the abdomen. The initial imaging study should be a three-way view of the abdomen to look for associated thoracic pathology (such as metastases or effusions), abnormal gas collections, displacement of the bowel, renal outlines, or associated calcification. Although ultrasound imaging can be used to characterize an abdominal mass, CT scanning of the abdomen and pelvis with intravenous and oral contrast is usually obtained.

ESOPHAGUS

Anatomy and Imaging Techniques

The appropriate initial imaging study for a number of suspected clinical problems is shown in Table 6-4. Imaging of the esophagus for many problems is best done by direct visualization (endoscopy). Because this is a major procedure requiring sedation, many physicians begin by ordering an upper GI examination or a contrast esophagogram. In addition to barium, other water-soluble contrast materials can be used. If a tear or perforation of the esophagus is suspected, it is best initially to use water-soluble contrast material rather than barium. If aspiration is suspected, barium is used, because water-soluble contrast can irritate the lung.

The normal esophagus has a rather smooth lining. Two indentations, due to impression by the aortic arch and the left main stem bronchus, can be seen along the left side (Fig. 6-20). Normally a peristaltic wave, initiated by swallowing, propels food down the esophagus. You should not diagnose a stricture on the basis of one image alone, because you may be looking at a normal area of peristaltic contraction. Sometimes in the distal portion of the esophagus, a “Z” line can be seen going across the esophagus. This represents the junction between the mucosa of the esophagus and the stomach (Fig. 6-21).
<table>
<thead>
<tr>
<th>SUSPECTED CLINICAL PROBLEM</th>
<th>IMAGING STUDY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gastroesophageal reflux</td>
<td>Medical therapy</td>
</tr>
<tr>
<td>Mild or transient symptoms</td>
<td>Endoscopy with biopsy</td>
</tr>
<tr>
<td>Severe or persistent symptoms</td>
<td>Barium swallow</td>
</tr>
<tr>
<td>Esophageal tear</td>
<td>Meglumine diatrizoate (Gastrografin) swallow</td>
</tr>
<tr>
<td>Bowel perforation or free air</td>
<td>upright chest and supine abdominal plain radiograph; supine and left lateral decubitus if patient is unable to stand</td>
</tr>
<tr>
<td>Hematemesis</td>
<td>Endoscopy (less preferred, contrast UGI series)</td>
</tr>
<tr>
<td>Gastric or duodenal ulcer</td>
<td>Test for <em>Helicobacter pylori</em>; if medical therapy fails, endoscopy or double-contrast UGI series</td>
</tr>
<tr>
<td>Trauma, blunt or penetrating</td>
<td>Chest x-ray, supine/upright abdomen and CT with IV contrast</td>
</tr>
<tr>
<td>Abdominal aortic aneurysm</td>
<td>Supine and lateral abdomen, then ultrasound or CT with IV contrast</td>
</tr>
<tr>
<td>Pancreatic mass or inflammation</td>
<td>CT or MRI</td>
</tr>
<tr>
<td>Pancreatic pseudocyst follow-up</td>
<td>CT or ultrasound</td>
</tr>
<tr>
<td>Acute abdominal pain with fever (suspect abscess)</td>
<td>CT with IV contrast</td>
</tr>
<tr>
<td>Liver lesion</td>
<td>MRI or CT with and without IV contrast</td>
</tr>
<tr>
<td>Incidental noncystic found on ultrasound</td>
<td>MRI or CT with and without IV contrast</td>
</tr>
<tr>
<td>Suspect metastases</td>
<td>Ultrasound or nuclear medicine hepatobiliary scan</td>
</tr>
<tr>
<td>Acute cholecystitis</td>
<td>Right upper quadrant ultrasound</td>
</tr>
<tr>
<td>Chronic cholelithiasis</td>
<td>Right upper quadrant ultrasound</td>
</tr>
<tr>
<td>Common duct obstruction</td>
<td>CT with IV contrast or CT enterography</td>
</tr>
<tr>
<td>Jaundice</td>
<td>Ultrasound or nuclear medicine hepatobiliary scan</td>
</tr>
<tr>
<td>Painless, suspect biliary obstruction</td>
<td>CT with and without IV contrast</td>
</tr>
<tr>
<td>Painless, suspect liver</td>
<td>Ultrasound</td>
</tr>
<tr>
<td>Suspected bile leak</td>
<td>Nuclear medicine hepatobiliary study</td>
</tr>
<tr>
<td>Small bowel stricture or polyp</td>
<td>CT enterography</td>
</tr>
<tr>
<td>Intestinal obstruction</td>
<td>Supine and upright radiograph of abdomen as an initial study, followed by those listed below</td>
</tr>
<tr>
<td>Esophagus or stomach obstruction</td>
<td>UGI and small bowel series or endoscopy</td>
</tr>
<tr>
<td>Small bowel obstruction</td>
<td>CT with IV contrast</td>
</tr>
<tr>
<td>Distal small bowel or colon obstruction</td>
<td>Barium enema</td>
</tr>
<tr>
<td>Crohn’s disease</td>
<td>CT with IV contrast or CT enterography</td>
</tr>
<tr>
<td>Right upper quadrant pain (+ Murphy’s sign, fever)</td>
<td>Ultrasound or nuclear medicine hepatobiliary scan</td>
</tr>
<tr>
<td>Right lower quadrant pain</td>
<td>Ultrasound, if female &lt;45 yr; CT, if suspect inflammatory process</td>
</tr>
<tr>
<td>Appendicitis</td>
<td>CT</td>
</tr>
<tr>
<td>Adults</td>
<td>Ultrasound</td>
</tr>
<tr>
<td>Children</td>
<td>Ultrasound</td>
</tr>
<tr>
<td>Suspected pelvic abscess</td>
<td>CT with IV contrast or ultrasound</td>
</tr>
<tr>
<td>Ulcerative colitis</td>
<td>Colonoscopy (see text for screening); if incomplete or unavailable, barium enema</td>
</tr>
<tr>
<td>Ischemic colitis</td>
<td>CT with IV contrast</td>
</tr>
<tr>
<td>Suspected renal or ureteral stone</td>
<td>Noncontrast CT</td>
</tr>
<tr>
<td>Pelvic pain (female)</td>
<td>Ultrasound</td>
</tr>
<tr>
<td>Bladder pathology</td>
<td>Cystoscopy; if not available, CT cystogram</td>
</tr>
<tr>
<td>Uterine or ovarian pathology</td>
<td>Ultrasound</td>
</tr>
</tbody>
</table>
Dysphagia and Odynophagia

Initially it is important to differentiate dysphagia (difficulty swallowing or sticking of food) from odynophagia (pain with swallowing). The most common cause of dysphagia is hiatal hernia with gastroesophageal reflux disease (GERD). Patients with mild dysphagia do not need imaging or endoscopy, but they should have a trial of GEDR medical therapy. Patients with severe symptoms should be investigated with endoscopy or barium swallow.

Many patients in the age range from 60 to 80 years have dysmotility and do not pass food properly. They generally have vague symptoms. A barium swallow is indicated to exclude other pathology. Patients who complain of food getting stuck often have a benign or malignant stricture. These usually require endoscopy with biopsy.

Difficulty swallowing also can be the result of central nervous system pathology. Pharyngeal paresis with ineffective constriction of muscles may be due to abnormalities involving cranial nerves IX and X, stroke, or degenerative changes. In these patients, failure to close the glottis often results in aspiration.

Odynophagia is usually due to an infection or a medication that produces esophagitis. In these patients a barium swallow can visualize ulcerations or other characteristic
mucosal patterns (such as herpes). Endoscopy also can be used, with the advantage of biopsy of visualized abnormalities.

**Esophageal Diverticula**

In the lower cervical region, sometimes a pharyngeal diverticulum (Zenker’s diverticulum) projects posteriorly. Food can be caught in this, causing dysphagia (Fig. 6-22). In the middle of the esophagus (near the carina), a traction diverticulum may be caused by scarring from mediastinal granulomatous disease. Just above the stomach, a pulsion diverticulum can sometimes be found. The two latter types are rarely symptomatic.

**Presbyesophagus**

As a function of aging, tertiary deep contractions may develop within the esophagus. These are usually disordered and can interfere with the normal peristaltic process and swallowing. These tertiary contractions are easily visualized as multiple transverse or ringlike contractions of the esophagus (Fig. 6-23). No specific therapy is indicated for this condition, and it is common in persons older than 60 years.

**Hiatal Hernia and Gastroesophageal Reflux Disease**

A large number of people suffer from “heartburn” or dysphagia as a result of reflux of gastric contents into the esophagus. This may occur because of esophageal motility problems, incompetence of the lower esophageal sphincter, hiatal hernia, delayed gastric emptying, or increased intragastric or intra-abdominal pressure. In adults the most common cause appears to be transient relaxation of the lower esophageal sphincter with reflux esophagitis.

With mild or transient symptoms, a trial of medical therapy is usually instituted without any imaging procedures being performed. If the symptoms are persistent or severe, endoscopy with biopsy is usually performed. In patients with swallowing difficulties, a barium swallow can demonstrate a mass or a stricture, which then requires endoscopic biopsy. A biopsy also is indicated in immunocompromised patients and those with known Barrett’s esophagus. GERD can be documented by use of an intra-esophageal pH probe or less sensitive imaging or nuclear medicine reflux studies.

The most common type of hiatal hernia is the sliding type, in which the gastroesophageal junction and a portion of the fundus of the stomach slide upward into the thorax. Small hiatal hernias can be identified by noting an indentation at the distal esophagus (Schatzki’s ring), as well as longitudinal gastric mucosa folds distal to the ring (Fig. 6-24). Large hiatal hernias can be identified by seeing the fundus of the stomach projecting up into the retrocardiac space (Fig. 6-25). Another type of hiatal hernia occurs more rarely. This is the paraesophageal type, in which the fundus of the stomach slips past the gastroesophageal junction, which remains in the normal location. Large hiatal hernias can be seen on the chest x-ray, even without the use of barium. The typical finding is an air/fluid level or soft tissue mass located behind the heart but in front of the spine (Fig. 6-26).
FIGURE 6-24 Small sliding-type hiatal hernia. When a small portion of the fundus of the stomach slips up through the hemidiaphragm, a small hiatal hernia (HH) can be identified. The two keys to identification are (1) a very sharp ringlike construction (called Schatzki’s ring, which is seen between the two white arrows); and (2) the normal longitudinal lines of gastric mucosa (black arrow), which can be seen projecting up above the hemidiaphragm.

FIGURE 6-25 Large sliding-type hiatal hernia (HH). A large portion of the fundus of the stomach (St) has slipped up through the hemidiaphragm into the retrocardiac region (arrows) and can easily be identified on an upper gastrointestinal examination.

FIGURE 6-26 Large hiatal hernia. Hiatal hernias can sometimes be seen on a plain chest x-ray. On an upright posteroanterior chest x-ray (A), a mass with an air/fluid level (small black arrows) within it can be seen behind the heart (large arrows). This also can be easily seen on the lateral chest x-ray (B).
Esophageal reflux can sometimes be seen on an upper GI examination, but if it is not seen, the patient may still be refluxing at other times and under other conditions. A more sensitive imaging method uses nuclear medicine. A small amount of radioactive material is mixed with orange juice, which the patient drinks. A computer region of interest is set up over the chest, abdominal compression is applied, and the patient is monitored for about 1 hour. If the study is positive, reflux occurs, but if it is negative, the same caveat applies. A more invasive but more accurate method used by gastroenterologists is to put a pH probe on the end of a tube and station this for some time above the gastroesophageal junction.

**Foreign Bodies in the Esophagus**

The foreign bodies lodged in the esophagus of children are most commonly coins. They often stick just above the level of the aortic arch (Fig. 6-27). A number of other foreign bodies lodge at the gastroesophageal junction (Fig. 6-28). In adults the most common object is a piece of unchewed meat. Meat will not be visualized on a plain x-ray but can easily be seen during a contrast esophagogram.

**Strictures and Dilatation**

Strictures in the esophagus are a common cause of food lodging at a specific level. High esophageal strictures can occur as a result of scarring after suicide attempts in which the individual swallowed lye or corrosive alkaline material (Fig. 6-29). Middle and distal esophageal strictures may develop from scarring due to gastroesophageal reflux or may result from a tumor. Most benign strictures have a smooth appearance. The diameter of a stricture can be assessed during a barium swallow by giving the patient a radiopaque pill of known diameter. These pills will quickly dissolve (Fig. 6-30). Strictures due to carcinomas most commonly are irregular and have overhanging edges (Fig. 6-31). Biopsies are usually performed, even of benign-appearing strictures, to exclude malignancy.

Two entities can cause marked dilatation of the esophagus: achalasia and scleroderma. The esophagus may be so dilated that it can be visualized on chest x-ray as a tortuous structure in the posttracheal and retrocardiac regions, and often a horizontal air/fluid level can be seen in the upper esophagus. Air/fluid levels within the esophagus are definitely abnormal.

In achalasia (Fig. 6-32) the gastroesophageal sphincter fails to relax. The esophagus becomes massively dilated and tapers distally to a beaklike shape. Usually no evidence of gastroesophageal reflux is found. A massively dilated esophagus that looks like achalasia can also be seen in Chagas’s disease, which is caused by an infection with *Trypanosoma cruzi*. This parasite releases a neurotoxin that destroys ganglion cells in the myenteric plexus.

Scleroderma is a collagen vascular disease involving the smooth muscle. The esophagus is usually only mildly dilated and has no primary contractions. Gastroesophageal reflux can occur with this condition, causing stricture and ultimately proximal dilatation.
FIGURE 6-28 Steak knife lodged at the esophagogastric junction. This mentally ill patient claimed to have swallowed his steak knife at dinner-time. The chest x-ray shows the metallic blade (arrow) at the gastroesophageal junction. The wooden handle of the knife, which is down in the stomach, is not seen because wood typically is not visible on a x-ray. Metallic surgical clips are seen to the left of the stomach gas bubble. These are from a previous surgery to remove other swallowed objects.

FIGURE 6-29 Benign esophageal stricture. This upper esophageal stricture (arrows) was due to attempted suicide by lye ingestion. Notice that the stricture does not have any overhanging edges and is relatively smooth and tapered. Essentially all patients with esophageal strictures should have esophagoscopy and biopsy to rule out malignancy.

FIGURE 6-30 Measurement of an esophageal stricture. During a barium swallow a radiopaque pill of known diameter (arrow) can be given. This will lodge above a stricture, but it will quickly dissolve. Knowing the size of the pill allows measurement of a stricture. E, Esophagus.

FIGURE 6-31 Esophageal carcinoma. On this barium swallow a spot image at the gastroesophageal junction clearly shows a dilated distal esophagus (E), as well as the fundus of the stomach (St). A thin, irregular column of barium is seen joining the two, and overhanging beaklike edges (dark curved arrow) suggest a malignancy. The normal contour of the esophagus is outlined (white arrows), and the dark straight arrows indicate a mass protruding into the fundus of the stomach.
Tears of the esophagus occur in Boerhaave’s syndrome as well as in Mallory-Weiss syndrome. In Boerhaave’s syndrome, spontaneous perforation of the esophagus occurs because of a sudden increase in intraluminal esophageal pressure, and clinically the patient has severe epigastric pain. Overall mortality in this syndrome is approximately 25%, but it approaches 100% if diagnosis is delayed 24 hours. Severe epigastric pain and dyspnea are common. An erect chest image is useful, because it may demonstrate a left pleural fluid collection, left pneumothorax, or mediastinal air.

A Mallory-Weiss tear is usually a longitudinal nontransmural tear in the lesser curvature of the stomach, often extending across the gastroesophageal junction. These tears are produced by prolonged vomiting in alcoholics, are usually self-limited, and are not painful. There should be no evidence of a pneumomediastinum, although hematemesis is present.

Varices

Long, tortuous, longitudinal or vertical wormlike filling defects in the distal esophagus can be the result of varices. The large vascular channels in the esophageal wall are large enough to displace barium (Fig. 6-34, A). The best way to appreciate varices is by endoscopy or CT scanning (Fig. 6-34, B and C), because only when the varices are large and extensive can they be seen on a barium swallow.

Esophagitis and Tears

Ulceration and irregularity of the esophageal mucosa can be the result of reflux esophagitis, and in these circumstances, the irregularities are extremely fine. In patients who are immunocompromised, Candida albicans (Monilia) infection of the esophagus may create a very coarse irregular pattern (Fig. 6-33).
Tumors

Malignant tumors of the esophagus are squamous cell carcinoma 95% of the time and adenocarcinoma about 5% of the time. Adenocarcinomas usually arise in the region of the gastroesophageal junction or have grown out of the stomach to involve the lower esophagus (see Fig. 6-31). Adenocarcinomas also occur somewhat higher in the esophagus in patients with chronic gastroesophageal reflux, in whom islands of columnar mucosa develop (Barrett’s esophagus).

STOMACH AND DUODENUM

Anatomy and Imaging Techniques

Lesions of the stomach and duodenum are most appropriately visualized with an upper GI examination or endoscopy. If a perforated viscus is suspected, meglumine diatrizoate (Gastrografin) or another water-soluble material should be used as a contrast agent rather than barium. CT scanning is usually not an appropriate initial imaging modality for most stomach or intestinal pathology.

The appearance of the stomach on an upper GI study can be variable depending on whether the patient is prone or supine. With the patient supine, barium collects in the most dependent position, which is the fundus of the stomach, and the normal mucosal patterns of the body and antrum are easily visualized (Fig. 6-35). In the prone position the body and antrum of the stomach are the most dependent, and barium will collect there. The duodenal bulb projects upward to the right and posteriorly relative to the gastric antrum. It is important to obtain images with the bulb distended. Radiologists will almost always take several pictures of the bulb in different stages of peristalsis.

The duodenum has a C-loop configuration and extends to the ligament of Treitz near the body of the stomach. The jejunum is usually located in the left midabdomen, and the ileum, in the lower central and right abdomen. A normal variant is malrotation of the small bowel, with a number of variations. The stomach and duodenal bulb may be in a normal position, but the third and fourth portions of the duodenum may be on the right side of the spine rather than swinging across the spine and behind the stomach in the region of the ligament of Treitz. Sometimes the duodenum is positioned normally, but all of the small bowel is on the right side, and the cecum and colon are on the left side. Another much less common variant is situs inversus, in which the liver, stomach, and all abdominal organs are reversed between right and left, and the heart is on the right.

Gastritis and Gastric Ulcer Disease

*Helicobacter pylori* is a bacterium responsible for about 80% of gastritis and gastric or duodenal ulcers. The presence of *H. pylori* is detected noninvasively with immunoglobulin G antibody serology or a urea breath test. Appropriate antibiotic therapy (such as bismuth, metronidazole, and...
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tetracycline) usually cures 95% of patients. Symptomatic patients should also be treated and discouraged from using alcohol, aspirin, or nonsteroidal antiinflammatory drugs and asked to refrain from smoking. If symptoms persist or a fecal occult blood test (FOBT) is positive, an endoscopy or a barium upper GI series is indicated. Large gastric folds may be the result of simple gastritis, although they also are seen with lymphoma, Ménétrier’s disease (giant hypertrophic gastritis), and Zollinger-Ellison syndrome. Simple gastritis may be present without ulceration, and the only finding on an upper GI examination may be enlarged gastric folds (Fig. 6-36). Ulcers are unusual in Ménétrier’s disease but are quite common in Zollinger-Ellison syndrome.

The detection rate of gastric ulcers with upper GI examination is only approximately 70%. The nondetectable ulcers are often too superficial or too small to be seen. Occasionally the ulcers are so large that the crater is overlooked. Ulcers identified on upper GI examination should be characterized as benign, indeterminate, or malignant. In general, benign ulcers decrease to half their original size with several weeks of therapy and should show almost complete healing within 6 weeks. Unless an ulcer has all benign features, endoscopy with biopsy is usually recommended. There are four radiographic signs of a benign ulcer: (1) If the mucosal folds are thin and regular and extend up to the margin of the ulcer crater, the lesion is probably benign; (2) benign ulcers typically extend beyond the projected margin of the stomach (Fig. 6-37); (3) a 1- to 2-mm lucent line may be seen around the mouth of the ulcer on a tangential view of a benign ulcer; and (4) normal peristalsis in the region and invagination of the wall opposite the ulcer are helpful signs to indicate benignity.

Of all ulcers, 95% are benign, and 5% are malignant. Of the malignant ulcers, 90% are due to carcinoma and, to a lesser extent, to lymphoma and other rare malignancies or metastases. With a cancer, usually a thickened and markedly irregular wall is noted. Peristalsis is limited or decreased. The stomach may have decreased distensibility, and the mass or ulcer tends to lie within the projected outline of the stomach, rather than projecting beyond it (Fig. 6-38). If the tumor becomes large enough to involve most of the stomach, the stomach becomes rigid and nondistensible, and this is termed linitis plastica (leather bottle stomach) (Fig. 6-39).

Duodenal Ulcers

Ulcers that arise within the first portion of the duodenum are benign at least 90% of the time. These may have an infectious origin, and the spiral organism H. pylori has been
FIGURE 6-37 **Benign gastric ulcer.** A, A large ulcer (arrow) is seen along the lesser curvature of the stomach. Notice that the ulcer projects out beyond the normal expected lesser curvature (dotted line); this is one sign that the lesion is benign.

FIGURE 6-38 **Malignant gastric ulceration.** A large series of ulcers is seen along the greater curvature of the stomach. Notice that, in addition, a mass projects into the lumen from the expected normal greater curvature (dotted line). This is a sign of malignancy.

FIGURE 6-39 **Linitis plastica.** On this upper gastrointestinal examination, the stomach (St) is small, deformed, and narrowed. It never changed appearance on later additional images. This so-called leather bottle stomach, or linitis plastica, is due to advanced infiltrative gastric cancer.

Gastric Emptying

Patients with abnormal gastric motility may have either accelerated emptying of gastric contents (dumping) or delayed gastric emptying. The latter is quite common in diabetics. Because barium is not physiologic, nuclear medicine studies that tag food or liquid with a small amount of radioactive material are used to quantitate gastric emptying. Computer regions of interest are drawn over the stomach, and the emptying rate is calculated. For solid foods, half the material should leave the stomach in less than 90 minutes, and less than 10 percent should remain in the stomach at 4 hours.
Gastric Dilatation or Outlet Obstruction

Gastric distention can be due to a number of causes that can be divided into physiologic and metabolic or obstructive. An enlarged stomach may be seen on a plain abdominal x-ray in a patient with vomiting or loss of appetite. If causes of gastric dilatation and poor motility, such as diabetes, narcotic drugs, and others are not evident, obstructive causes such as neoplasms must be excluded. Either a barium upper GI series or endoscopy is indicated. If an abdominal mass other than the stomach can be palpated, a CT scan is indicated.

LIVER

Today the most common method of imaging the liver and spleen is with a CT scan. In many institutions, CT scans are done with and without the use of intravenous contrast. For most situations, however, a single CT scan with intravenous contrast is often adequate and less expensive. The liver or spleen also can be imaged by using ultrasound or nuclear medicine, but there is less anatomic resolution and less complete imaging of other nearby structures.

Cirrhosis and Alcoholic Liver Disease

Probably the most common imaging manifestation of alcoholic liver disease is fatty infiltration. This can be imaged on either ultrasound or CT. On ultrasound images the liver parenchyma should have the same echogenicity as the renal cortex, but with fatty infiltration the liver becomes more echogenic (Fig. 6-41). On a noncontrasted CT scan the liver and spleen should be of the same density. If the liver is darker than the spleen or muscle, you can suspect fatty infiltration. Often the fatty infiltration is focal and not uniform, especially because portal venous flow delivers more alcohol to the right lobe of the liver than to the left lobe (Fig. 6-42).

Obesity is the most common cause of a fatty liver. The low density in the area can usually be differentiated from low density due to malignancy or other abnormality, because fatty infiltration is usually geographic or has straight borders in its distribution. Lack of a mass effect also may be noted, with normal vessels and architecture being preserved in the areas of the fat. Finally, the periportal region or medial segment of the left lobe is often spared. Even without the use of intravenous contrast, the hepatic and portal veins in the area of fatty infiltration will appear prominent (whiter) because of the surrounding low density.

Ascites is another common manifestation of alcoholic liver disease. If ascites is massive, gas in the small bowel will be seen floating centrally or concentrated in the middle and anterior abdomen on a supine plain radiograph of the abdomen. You also may see a generalized gray haziness overlying the whole abdomen (Fig. 6-43). Small amounts of ascites can easily be visualized on a CT scan along the edge of the liver and in the pericolic gutters. If your only interest is in determining whether the patient has ascites or in locating a suitable area to tap the ascites, ultrasound is an efficient and less expensive modality (Fig. 6-44).
Trauma

In penetrating abdominal injuries the liver is the most commonly injured intra-abdominal organ, and it is the second most commonly injured organ in blunt abdominal trauma. Blunt abdominal trauma can cause hepatic lacerations, subcapsular hematomas, and intraparenchymal hemorrhage. Usually in cases of blunt abdominal trauma a CT scan is ordered to assess not only the liver but also the spleen, kidneys, and other organs. Hepatic laceration and hemorrhage usually manifest as an area of low density compared with the liver, although very acute hemorrhage can be denser (whiter) than the liver (Fig. 6-45). Hepatic lacerations are often treated conservatively if possible, because removal of a large portion of liver carries a high risk for mortality. Intraparenchymal liver hemorrhages may ultimately be resorbed.

Hepatic Tumors

The most common benign hepatic tumor is a hemangioma. This is often discovered incidentally on ultrasound examination, where it appears as an area of increased or bright echo within the liver (Fig. 6-46, A). Hemangiomas also are discovered incidentally on noncontrasted CT scans of the abdomen. On this type of scan the lesion appears as a rounded area of low density within the liver. A hemangioma can look like a malignant primary tumor or even a metastatic lesion. One way to differentiate a benign hemangioma from other lesions is to do serial CT scans over a period of minutes as intravenous contrast is administered. Usually, over a period of 10 to 15 minutes, the hemangioma will fill in with contrast and look like normal liver, whereas most malignancies will not do this (Fig. 6-46, B and C).
The most common primary malignant hepatic tumor is a hepatoma. On a noncontrasted CT scan this appears as an irregular dark area within the liver, but these tumors can show pronounced vascularity on an arterial phase CT (Fig. 6-47). Remember that hepatomas can be multifocal. Five percent of patients with cirrhosis and 10% of patients with chronic hepatitis B will develop hepatocellular carcinoma. Hepatocellular carcinomas are solitary 25% of the time, multiple 25% of the time, and diffuse 50% of the time.

Metastatic lesions of the liver are common. Forty percent of hepatic metastases are from cancer of the colon. Other common cancers that metastasize to the liver are lung, breast, pancreas, and stomach. Lesions may be small or large and single or multiple. Be aware that the visibility of hepatic metastases on a CT scan varies greatly, depending on the technical factors used when the review of images is done from the computerized data. If a CT scan is done with extremely wide windows (wide-contrast scale) and without using intravenous contrast, it may be difficult to see the lesions. The best detectability is achieved by using intravenous contrast and narrow window settings (Fig. 6-48). Technologists will often produce both types of images. The less useful images for this purpose are more pleasing to the eye. You should be sure that you are looking at those with narrow window settings. Normally these images are coarser or have more grain than those done with wide windows.

**Hepatic Cysts**

Hepatic cysts are quite common and are usually incidental findings on CT scans. They are lower density than the
Hepatic Hemangioma

A transverse ultrasound image of the liver shows a hepatic hemangioma as a bright echogenic lesion relative to the normal hepatic parenchyma. In a different patient, an initial image of the contrast-enhanced computed tomography scan of the upper abdomen shows a hemangioma (H) as a low-density area with irregular margins in the posterior aspect of the liver (L). This was an unexpected and incidental finding in this young woman. A scan through exactly the same level obtained 20 minutes later shows that the lesion has almost completely disappeared. In this patient, no further workup is indicated. Sp, Spleen; St, stomach.

Small and Large Hepatic Lacerations

A computed tomography (CT) scan was obtained through the upper abdomen in this patient after a motor vehicle accident. A small area of low density (arrow) is seen in the lateral portion of the right lobe, and blood surrounds the liver. A CT scan in another patient, who was drunk and in a motor vehicle accident, shows a much larger area of lacerated liver in the posterior aspect of the right lobe. A central area of increased density (white) (arrow) indicates acute hemorrhaging at the time of the scan.

Hepatitis

Usually no need exists to image the liver in a patient with known infectious hepatitis. The diagnosis is best made by serum antibody evaluation. If hepatomegaly is seen on physical examination, the antibody tests are negative, and no history of hepatotoxins is known (e.g., alcohol, niacin, sulfa, rifampin, tetracycline, estrogens, acetaminophen), an ultrasound study is indicated to exclude biliary obstruction by occult masses. Occasionally CT or magnetic resonance imaging (MRI) scans are done to evaluate the patient for suspected secondary hepatoma.
Hepatic Abscess

Most hepatic abscesses are visualized with CT scanning. They are low density, or darker than the liver. Unless they have gas within them; their differentiation from neoplasm can be difficult (Fig. 6-50). Usually the clinical presentation of a very sick, febrile patient is enough to suggest the correct diagnosis. If not, CT scanning can be used to help in the diagnosis and also to direct a needle aspiration and place a drainage catheter. Abscesses suspected anywhere in the abdomen are best imaged by CT with both intravenous and oral contrast.

GALLBLADDER AND BILIARY SYSTEM

Anatomy and Imaging Techniques

Several ways exist of visualizing the gallbladder and biliary system, depending on the clinical presentation. Ultrasound is the least expensive and easiest method for looking for
gallstones or biliary dilatation. Unfortunately, the distal common duct is difficult to see. Nuclear medicine hepatobiliary scans are more functional and generally provide physiologic information and information about bile leaks. The fine architecture of both the biliary and the pancreatic ducts can be visualized by use of endoscopic retrograde cholangiopancreatography (ERCP). To do this, a large tube is passed down the esophagus and through the stomach to the duodenum. The ampulla of Vater is then cannulated. Contrast is injected into the pancreatic and common bile ducts (Fig. 6-51). ERCP is a useful way to assess the diameter of a stricture as well as its length (Fig. 6-52, A). During ERCP it also is possible to do a papillotomy and remove stones from the common duct. Recently it has become possible to visualize the ductal system with MRI (Fig. 6-52, B), but this is usually reserved for cases in which ERCP is impractical or impossible.

**Acute Cholecystitis**

If acute cholecystitis is suspected, the examination of choice is a nuclear medicine hepatobiliary scan. In a normal hepatobiliary scan the liver will clear the radioactive tracer, and it should appear in the gallbladder, common bile duct, and proximal small bowel within 1 hour (Fig. 6-53). Failure to visualize the gallbladder when imaging is carried out to 4 hours has a high specificity for acute cholecystitis, because in acute cholecystitis, usually blockage of the cystic duct occurs, and the radioactive tracer cannot get into the gallbladder (Fig. 6-54). In chronic cholecystitis, the gallbladder fills with activity, but this occurs later than normal. Some authors advocate the use of ultrasound for acute cholecystitis and look for gallbladder wall thickening and pain when the ultrasound transducer is pressed on the right upper quadrant. You should have noted the...
latter finding when you examined the patient before you ordered the test. Moreover, gallbladder wall thickening is nonspecific and can occur with other entities, such as hypoprothrombinemia.

**Chronic Cholecystitis and Cholelithiasis**

If you suspect gallstones (cholelithiasis) or biliary duct obstruction, the quickest, cheapest, and most efficient imaging test is an ultrasound examination of the right upper quadrant (see Fig. 6-10, B). On a nuclear medicine hepatobiliary scan, chronic cholecystitis is apparent as delayed gallbladder filling (1 to 4 hours). Cholelithiasis is often incidentally seen on a CT scan (Fig. 6-55), although this is not the initial imaging test of choice for suspected uncomplicated cholelithiasis.

**Biliary Obstruction and Jaundice**

When jaundice is present and a question arises about whether it is due to parenchymal liver disease, such as hepatitis, or to an obstructive lesion of the common bile duct, the initial imaging examination often is ultrasound.

When complete ductal obstruction has been present for more than 24 hours, dilatation of the common and intrahepatic ducts is relatively easy to see with ultrasound. The upper portion of the common duct (normally measured at ultrasound) is usually less than 4 mm in diameter. It becomes slightly dilated with age and can be up to 7 mm in some patients younger than 60 years. In normal persons who are older than 60 years, the common duct diameter should be less than 10 mm. The common duct diameter also can be larger than 4 mm (up to 6 to 7 mm) if the patient has had a cholecystectomy. Because a CT scan provides information on ductal dilatation as well as other useful information (Fig. 6-56), many clinicians will order a CT scan instead of an ultrasound examination.

Intrahepatic obstruction of the common duct is usually due to cholangitis, Caroli's disease, or an intrahepatic neoplasm (hepatoma compressing the ducts or a rare biliary neoplasm). Extrahepatic biliary obstruction usually occurs distally in the intrapancreatic portion of the duct. Common causes are gallstone, pancreatic cancer, and pancreatitis.

Sometimes, after a cholecystectomy and removal of stones from the common duct, a T tube is left in place. This is done to allow bile drainage through the abdominal wall while edema related to surgery and prior stones resolves. Before the tube is pulled, contrast is injected into the T tube to look for possible retained stones.

Occasionally, as a result of surgery, air from the GI tract will reflux into the biliary system. This may be visualized on a KUB (plain radiograph of the abdomen). Air in the biliary tract is usually centrally located in the region of the porta hepatis, and the air is prevented from going very distally into the smaller bile ducts by flow of bile toward the porta hepatis. You must be able to differentiate this relatively benign finding from that of air in the portal venous system. Air in the portal venous system is usually seen as branching air collections near the periphery of the liver (within 2 mm). The air goes peripherally because that is the direction of the flow of blood in the portal veins. Visualization of branching luencies in the outermost 2 cm of the liver is considered presumptive evidence of portal
FIGURE 6-56 Biliary ductal dilatation. A, A longitudinal Doppler ultrasound image through the liver shows a tubular structure without significant flow, which is a slightly dilated common bile duct. A computed tomography (CT) scan of the same patient (B) also demonstrates the intrahepatic dilated biliary system. As a screening test, ultrasound is cheaper and just as effective. CT scanning is more useful to localize the cause of obstruction, such as a pancreatic carcinoma. CBD, Common bile duct.

FIGURE 6-57 Air within the liver. A branching or serpiginous collection of air is seen within the right upper quadrant (arrows) on a kidney, ureter, and bladder (KUB) examination (A). This air is in the region of the porta hepatis and represents air within the biliary system. This is a common finding after gallbladder surgery and has little clinical significance. In contrast, branching collections of air seen peripherally in the liver (arrows) in a different patient (B) represent air within the portal venous system, and this has a high associated mortality. Portal venous air extending to the liver periphery (arrows) is easily seen on a computed tomography scan (C).

venous air. This is seen in diabetic patients and is associated with a high mortality (Fig. 6-57).

PANCREAS

Pancreatitis and Complications

Imaging of the pancreas is typically done using CT scanning and less commonly ultrasound or MRI (Fig. 6-58). Seventy percent of cases of pancreatitis are caused either by alcoholic pancreatitis or by obstruction due to a gallstone in the distal common duct. The diagnosis is usually made by clinical findings of epigastric or lower abdominal pain and hyperamylasemia. Unfortunately, about 30% of patients with pancreatitis have a normal serum amylase level, and about 35% of persons with hyperamylasemia have a disease other than pancreatitis. The most useful imaging method for a patient with pancreatitis is CT scanning. In rare patients who have sudden-onset pancreatitis, the pancreas may be of normal size, but the serum amylase value may be elevated. Most patients with acute pancreatitis have an enlarged pancreas with peripancreatic inflammation, thickening of the
perirenal fascia, and peripancreatic fluid collections (Fig. 6-59). Occasionally one or several dilated loops of small bowel over the central abdomen may be caused by a focal ileus from the underlying inflammation in the pancreas.

Late complications of acute pancreatitis are pancreatic duct obstruction, pseudocyst formation, and abscess (Fig. 6-60). A pseudocyst usually takes approximately 6 weeks to mature fully. At this time a CT scan shows a well-defined cystic area (see Fig. 6-60, B), and CT can be used to perform percutaneous drainage. Be aware that pseudocysts are not necessarily in the pancreas itself. They can be focal fluid collections anywhere in the abdomen and occasionally even in the pelvis or thorax.

With fulminant pancreatitis, formation of an abscess may be noted. This is seen on CT scan as a large soft tissue mass that contains air bubbles, in the region of the pancreas. This condition has a very high mortality rate, and usually a percutaneous drain will be placed to try to drain the abscess. Another complication is progressive pancreatic necrosis due to digestion of tissue (a phlegmon). This is seen on CT as multiple areas of lucency within the pancreas. This condition also has a high mortality rate.

**Tumor**

Adenocarcinoma accounts for 95% of all pancreatic cancer. It has a poor prognosis, with a 1-year survival rate of 10% or less. Clinically the patients initially are seen with jaundice, weight loss, and occasionally with a dilated, nontender gallbladder. CT scanning is the imaging modality of choice to assess not only the tumor size and location but also the possibility of hepatic and nodal metastases.

**Spleen**

**Splenomegaly**

Imaging of the spleen is sometimes done to assess splenic size, although this really should be done clinically by palpation and percussion. The spleen is usually about 10 cm in length, and up to 13 cm may be normal. Causes of splenomegaly are leukemia (especially chronic lymphocytic leukemia), lymphoma, infection (mononucleosis), storage diseases (amyloid and Gaucher’s disease), portal hypertension, and hematologic abnormalities (anemias, thalassemia, myelofibrosis).
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Trauma

After blunt trauma the spleen is the most commonly injured intra-abdominal organ, and a splenic fracture or hematomas may be found. Although surgeons usually try to manage these injuries conservatively, splenic rupture may be noted even a week to 10 days after the initial injury. If you suspect splenic trauma, a CT scan is the test of choice. Hemorrhage and hematoma usually appear as areas of lower density than the spleen (Fig. 6-61). Round or irregular dark areas represent intrasplenic hematomas or lacerations, and abnormal crescentic areas at the edge of the spleen represent subcapsular hematomas. Occasionally, with conservative management, an abscess may subsequently form and can be identified as such on a CT scan because it contains gas.

In addition to being identifiable as trauma, focal splenic lesions can easily be seen on a CT scan. These can be due to splenic abscesses, infarcts, tumors, and occasionally cysts. The sensitivity of CT for detection of these is high, but the specificity is poor, and often the clinical history is necessary to narrow the differential diagnosis.

SMALL BOWEL

You should be able to recognize some small bowel abnormalities by examining the gas pattern on plain radiograph of the abdomen. Small bowel can be identified by its central location and by its rather thin mucosal markings that extend across the entire lumen. One of the most common remarks that you hear when a physician is examining a small bowel image is that air/fluid levels are present. The implication is that this is abnormal, but it is in fact quite normal, because small bowel contents are mostly fluid, and any air or carbon dioxide that is swallowed and passes through the stomach will cause an air/fluid level in the small bowel. Visualization of small bowel pathology is difficult without using oral contrast. This can be barium for a typical radiographic small bowel series or CT.
enterography using large volumes of very dilute barium or water.

**Obstruction Versus Ileus**

A standard question in reference to a patient with abdominal pain is whether he or she has either a small bowel obstruction or paralytic ileus. This question can be resolved with a stethoscope rather than an x-ray, because if bowel sounds are present and relatively frequent, a paralytic ileus is unlikely. On a plain radiograph of the abdomen, the diameter of the small bowel should not exceed 3 cm; if it does, try to determine whether an obstruction or an ileus is present.

If the small bowel dilatation is greater than 4 cm, you are almost certainly looking at an obstruction, because in a paralytic ileus, only mild dilatation is found. The upright image is used to look at the nature of the air/fluid levels. As mentioned earlier, air/fluid levels can be normal, but if you find them in bowel and the small bowel is dilated, look on an upright image for a single loop of small bowel to see whether the air/fluid levels at either end of the loop are at the same level or at different levels. If they are at different levels in a given loop of small bowel, an obstruction is present. This is because muscle tone within the small bowel causes the different levels, and this would not be present with a paralytic ileus (Fig. 6-62). Remember that a long-standing bowel obstruction can ultimately result in a paralytic ileus. The common causes of a paralytic ileus are a postoperative state, vascular ischemia, nearby inflammatory processes (such as pancreatitis and appendicitis), electrolyte imbalance, and drugs (morphine and its derivatives). Small bowel obstructions are mostly due to adhesions, tumors, hernias, and inflammatory strictures.

With an extremely dilated diameter of the small bowel (i.e., obstruction), look to see how far bowel gas extends. If dilated small bowel extends to the lower portion of the abdomen, you are looking at an obstruction that is at least in the distal small bowel or perhaps in the proximal colon. If you see air distally in the colon or in the rectum, you may be looking at either a partial small bowel obstruction or a very acute complete small bowel obstruction (the distal air not yet having been expelled). Sometimes, as the lumen of obstructed small bowel fills with fluid, small bubbles of air are trapped in the most superior part of the lumen between the valvulae conniventes. This leads to the appearance of a “string of pearls” (see Fig. 6-62, C).

The cause of a small bowel obstruction is often difficult to identify on a plain x-ray. Look carefully for gas in the inguinal region to exclude a strangulated hernia (Fig. 6-63). Dilatation of the small bowel in a child older than a few years should raise the suspicion of appendicitis (Fig. 6-64). When you see this, look carefully over the region of the sacrum and right ileum to see if an appendicolith may be present.

**Benign Diseases**

A wide variety of diseases can affect the small bowel and can be visualized on a barium study of the small bowel. The finer points of radiologic differential diagnosis of small bowel disease are beyond the scope of this text, but in general you are looking for mucosal thickening, nodules, dilatation, and areas of stricturing. Fold thickening is assessed by looking at the mucosal pattern. The valvulae conniventes should not measure more than 2 to 3 mm in thickness. The mnemonic for the differential diagnosis of small bowel fold thickening is WAG CLEM, which refers to Whipple’s disease, amyloid, giardiasis, cryptosporidiosis, lymphoma, eosinophilic gastroenteritis, and *Mycobacterium avium-intracellulare* complex. The mnemonic for dilatation without fold thickening is SOSO, which stands for sprue, obstruction (or ileus), scleroderma, and other (medicines and vagotomy). I find it easier to remember the diseases...
about half the patients also have involvement of the colon. Patients have weight loss, recurrent abdominal pain, and diarrhea. Extraintestinal manifestations include skin, eye, joint, and liver abnormalities. Characteristic features are areas of relatively fixed narrowing in the terminal ileum (the string sign) (Fig. 6-65), sinus tracts, and fistulas. In the colon there may be areas of stricture and ulceration with skip areas that have normal mucosa in between. Occasionally collections of air or gas in subserosal portions of the small bowel are found (pneumatosis intestinale) (Fig. 6-66). In adults this is often a benign finding.

than to figure out what these mnemonics stand for, but perhaps they will be useful to you.

Some diseases and conditions result in areas of strictureing. The most common are prior surgery, tumor, and Crohn’s disease (regional enteritis). Lesions of regional enteritis are most common in the terminal ileum, and about half the patients also have involvement of the colon. Patients have weight loss, recurrent abdominal pain, and diarrhea. Extraintestinal manifestations include skin, eye, joint, and liver abnormalities. Characteristic features are areas of relatively fixed narrowing in the terminal ileum (the string sign) (Fig. 6-65), sinus tracts, and fistulas. In the colon there may be areas of stricture and ulceration with skip areas that have normal mucosa in between.
whereas in children it may be associated with necrotizing enterocolitis or ischemia. Associated portal venous air is an ominous finding. In adults the benign form can occur in patients with chronic obstructive pulmonary disease who have air dissecting down from the chest into the abdomen and along the mesentery of the bowel. This also may be associated with asymptomatic pneumatosis. GI bleeding can occur as a result of a Meckel’s diverticulum in the small bowel. Because this is most common in children, it is discussed in Chapter 9.

Ischemic enteritis is due to mesenteric arterial or venous narrowing or occlusion. Most of the cases are due to arterial occlusion. The patients present with a clinical triad of sudden-onset abdominal pain, diarrhea, and vomiting. On plain x-ray there may be multiple air/fluid levels (ileus pattern) and bowel wall thickening. Pneumatosis may also be present. CT angiography is the examination of choice and may show narrowing of the superior mesenteric artery, lack of bowel wall enhancement, or clot in the artery or vein (Fig. 6-67).

Tumors

Tumors of any sort in the small bowel are rare. Tumor incidence in the colon is about 40 times higher. The most common benign growths of the small bowel are leiomyomas, lipomas, adenomas, and polyps. Malignant tumors tend to be adenocarcinomas and to a lesser extent carcinoid, melanoma, and lymphoma. Symptoms of any tumor in the small bowel are obstruction and bleeding.

COLON

All of the colon can be directly visualized with an endoscope. This procedure allows biopsy of lesions, but it requires sedation and is expensive. Radiographic examination of the colon is begun by examining the plain radiograph, but it is better performed by barium or water-soluble contrast enema. It is imperative that the colon be cleansed before the examination; otherwise, residual fecal material can be mistaken for polyps or malignant lesions. The diagnostic enema can be done either by filling the colon completely with barium (single-contrast examination) or by putting in a small amount of barium and then using air (double-contrast examination). The double-contrast examination has a higher sensitivity than the single-contrast examination. On a barium enema a number of different views and projections are obtained. This is essential, because otherwise one loop of bowel would overlie another, and lesions would be obscured. The ascending, transverse, and descending colon, as well as portions of the sigmoid, can be appreciated on the anteroposterior or PA views of the abdomen (Fig. 6-68).

It is important to be sure that patients are well hydrated after a barium enema. If the barium remains in the colon for several days, water will be reabsorbed, and the patient will have difficulty in excreting the barium. Occasionally barium gets into the appendix during a barium enema. This is a normal finding. It may, however, stay there for months after the remainder of the barium is excreted. This can present a somewhat unusual and confusing appearance on a plain radiograph of the abdomen (Fig. 6-69).

The colon can also be examined by CT “virtual” colonography. This almost always done in the context of screening for colorectal cancer. Before the procedure the patient must go through a cleansing routine similar to that for endoscopic colonoscopy. The colon is then inflated with gas (usually carbon dioxide), and then a CT scan is
Colonic Obstruction Versus Paralytic Ileus

The key to the differentiation of colonic obstruction and paralytic ileus on a plain abdominal radiograph is whether dilatation of the cecum is present. The cecum, compared with the rest of the colon, is most dilated in colonic obstruction. Colonic obstruction is most frequently due to a cancer (65%), but it also can be due to diverticulitis (20%) or a volvulus (5%). If the transverse colon is more dilated than the cecum, consider a diagnosis of ileus. The term for an abnormally distended transverse colon is a megacolon, and this refers to dilatation greater than 6 cm in diameter. A toxic megacolon can result from ulcerative colitis, Crohn’s disease, or infectious causes.

When an acute colonic distention (cecum >9 cm) is found, a risk for perforation exists, and the likely causes are tumor obstruction, volvulus, and paralytic ileus. A number of patients have a chronically distended colon, and they have only a small risk for perforation. In such cases, chronic distention may be a result of chronic laxative abuse, neuromuscular disorders (including diabetes), psychogenic problems, or metabolic problems (electrolyte imbalance, hypothyroidism, use of morphine derivatives).

Appendicitis

Acute appendicitis is usually diagnosed clinically. Because the differential diagnosis can include acute gastroenteritis, cholecystitis, intestinal obstruction and perforation, urinary tract infection, female pelvic pathology, and other conditions, some confusion may be apparent as to which imaging tests are indicated. Appendicitis should be suspected if there is a combination of abdominal pain; symptoms including nausea, vomiting, constipation, and diarrhea; the physical findings of guarding, rebound, rectal
FIGURE 6-70 Normal appendix. The appendix can be seen on these computed tomography (CT) scan slices where it joins the cecum (A) (arrow) and at a lower level (B) (arrow). In many normal people the appendix cannot be seen on CT.

FIGURE 6-71 Appendicitis. In a patient with mild appendicitis the computed tomography (CT) scan (A) shows stranding due to edema (arrows) in the tissues surrounding the cecum. In the right clinical setting this is highly suggestive of appendicitis. In a different patient the CT scan (B) demonstrates more-advanced findings with an inflammatory mass around the cecum and a central calcification (an appendicolith).

tenderness, and fever; or an elevated white blood cell count with a left shift.

The initial imaging test is usually of a PA chest and supine and upright abdomen. This is useful to look for free air, dilated bowel, abnormal gas collections in an abscess, and possibly an appendicolith. Dilated central bowel in a child should suggest appendicitis. Some authors have recommended appendiceal ultrasound, but it is a difficult procedure to perform. A positive ultrasound finding is a total outer wall to outer wall appendiceal thickness of greater than 6 mm. Unfortunately, much of the time an overlying ileus with bowel gas makes it difficult or impossible to diagnose appendicitis by using ultrasound.

Both CT and ultrasonography can exclude other causes of pain, as well as implicate the appendix. CT gives a much more comprehensive view of the abdominal structures. The normal appendix may be difficult to identify on CT (Fig. 6-70). Conversely, if it is not visible and no surrounding edema is noted, appendicitis is unlikely. In appendicitis, inflammatory changes or abscesses around the cecum or appendix can easily be seen (Fig. 6-71). Ultrasonography is less commonly used because the images are harder to interpret, and if the ultrasound images are nondiagnostic, a CT scan is usually needed.

### Diverticulosis and Diverticulitis

Prolonged lack of fiber in the diet causes herniation of mucosa outward through the bowel wall (diverticula). Fifty percent of individuals older than 50 years have acquired diverticula. Of this group, 15% to 30% will present with rectal bleeding and pain. Ninety-five percent of diverticula are located in the region of the sigmoid and descending colon. Diverticulosis simply refers to the presence of multiple diverticula. Diverticulosis is often seen in CT scans of older persons (Fig. 6-72).

Diverticulitis is an inflammatory process often caused by extravasation of bowel contents from the tip of the diverticulum. It is confined to the sigmoid colon in 90% of patients, and usually significant resultant bowel wall thickening or formation of intramural abscesses is found. Patients present with left lower quadrant pain 70% of the time, and they also may have diarrhea or constipation, fever, and leukocytosis. Diverticulitis can sometimes be seen on a contrast enema as a small longitudinal track of barium within the wall of the colon. If the diagnosis of diverticulitis is suspected, however, it is better to order a CT scan (Fig. 6-73), because it is possible to have diverticulitis without diverticula being identified on the barium enema.

### Ulcerative Colitis

Ulcerative colitis is associated with arthritis and arthralgia, and the patients have diarrhea and rectal bleeding. The
Ischemic Colitis

Ischemic colitis can result from thrombosis of the superior or inferior mesenteric artery, hypercoagulable states, small-vessel disease, or obstruction of the colon. Initial symptoms are usually vague and nonspecific. This is followed by abdominal pain that seems out of proportion to clinical findings, and often by rectal bleeding. The goal is to make the diagnosis without causing perforation or other complications. A plain abdominal radiograph may reveal free air or “thumbprinting” from mucosal edema or intramural hemorrhage. A patient without signs of peritonitis and in whom the plain radiograph findings are nonspecific may have endoscopy or a single-contrast barium enema. In either case the distention of the colon should be kept to a minimum during the procedure.

Infectious Colitis

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Crohn’s Disease

Crohn’s disease can affect the colon as well as the small bowel. In contrast to ulcerative colitis, it is transmural and rarely involves the rectum. On a barium enema, visualization of aphthous erosions, ulcers, cobblestone fissures, fistula, and strictures may occur. Characteristically, the disease is noncontiguous and skips areas of the colon, so diseased areas of the colon have segments of normal colon in between.
radiographic features, including ulceration, which can be either localized or pancolonic.

Ulcerative colitis and, less commonly, other colitides, can result in a toxic megacolon. A barium enema should not be ordered on a patient in whom a toxic megacolon is suspected, and proctoscopy should be performed. The radiographic feature of toxic megacolon is a dilated colon with a deformed bowel wall, most evident in the transverse portion of the colon. The wall may be nodular, irregular, or haustral or even show what looks like thumbprints of soft tissue extending into the colonic lumen. This thickened-fold appearance also can be due to ischemia of the colon, but it is usually limited to the appropriate vascular distribution, that is, proximal to the splenic flexure for the superior mesenteric artery and distal to the splenic flexure for the inferior mesenteric artery distribution.

**Pneumatosis**

As mentioned earlier, air collections can be seen in the bowel wall on CT or on a plain x-ray. The etiology includes a wide range of causes from benign to life threatening. About 15% of pneumatosis (primary form) occurs in the colon and is often idiopathic and benign. This is particularly true if the air bubbles are large and round. Linear air collections in bowel wall are more associated with ischemia (Fig. 6-75).

**Polyps**

About 90% of polyps are hyperplastic and nonneoplastic. Of those that are neoplastic, adenomas are the most common. Of the adenomatous polyps, 50% are multiple, and although many are asymptomatic, they can cause diarrhea, pain, and bleeding. Seventy percent of polyps occur in the rectum and sigmoid, and 10% each in the ascending, transverse, and descending colon.

The larger the polyp, the more likely it is to be malignant. Of polyps smaller than 1 cm, only 1% are malignant; between 1 and 2 cm, 25% are malignant; and over 2 cm, 40% are malignant. A benign polyp is usually less than 2 cm in diameter, has a thin stalk and a smooth contour, is single, and has a smooth underlying colonic wall. Malignant polyps usually are larger than 2 cm, have no definite stalk, can be multiple, and are often irregular or lobulated (Fig. 6-76, A).

A number of syndromes include multiple polyps, such as familial polyposis, Gardner’s syndrome, Peutz-Jeghers syndrome, and juvenile polyposis. Most of the polyposis syndromes have adenomas as the underlying histology, but the familial type and Gardner’s and Turcot’s syndromes have an extremely high rate of malignancy. In familial
polyposis the rate of malignancy is so high that screening of family members begins at puberty (Fig. 6-76, B), and treatment often involves a prophylactic total proctocolectomy.

Colon Carcinoma

Colon cancer is the second most common cancer in men and women. The most common cancer in men is lung, and in women, it is breast cancer. Fifty percent of colon cancers occur in the rectum or sigmoid, and about 10% each in the cecum, ascending colon, transverse colon, and descending colon. The clinical presentation is most commonly colonic obstruction or rectal bleeding. A debate is ongoing as to whether colonoscopy, barium enema, or CT virtual colonoscopy is the appropriate method of workup or screening. Barium enema is relatively inexpensive compared with colonoscopy, and it has about the same accuracy rate. The advantage of colonoscopy is that if a lesion is identified, a biopsy can be performed immediately. Screening for polyps and colon cancer is commonly done by a fecal guaiac occult blood test (gFOBT) and sigmoidoscopy. A gFOBT has a high incidence of false-positive results from a diet high in red meat or peroxide-containing vegetables (e.g., broccoli, turnips, cauliflower). A new type of fecal occult blood test called a fecal immunochemical test (FIT or iFOBT) is superior to the guaiac test. Sigmoidoscopy provides only limited visualization of the colon. After a positive gFOBT or iFOBT, colonoscopy is usually performed. If colonoscopy is not available or if there is inadequate visualization of the entire colon, a double-contrast barium enema may be performed.

The recommendations for colorectal cancer screening vary among organizations. For persons older than 50 years who are at average risk, the American College of Physicians (ACP) recommends optical colonoscopy or flexible sigmoidoscopy. High-risk patients should be screened beginning at age 40 or 10 years younger than the age at which the youngest affected relative was diagnosed with colorectal cancer. High-risk patients are recommended to have only optical colonoscopy. Screening is not recommended for most patients over 75 years old or who have a life expectancy of less than 10 years. For persons with positive screening test results of any type, optical colonoscopy should be used. The recommended interval for screening average-risk patients is generally 10 years for optical colonoscopy; 5 years for double-contrast barium enema, CT colonoscopy, and flexible sigmoidoscopy; and annually for gFOBT or iFOBT. Although the American Cancer Society and the American College of Radiology recommend use of CT colonoscopy for screening, the ACP guidelines do not recommend CT colonoscopy, and the U.S. Preventative Services Task Force found that there was insufficient evidence to assess the benefits and harms of this procedure.

Some asymptomatic individuals are at a higher than average risk for colorectal cancer. These include persons with ulcerative colitis; Crohn’s disease; familial polyposis syndromes; a personal history of colorectal, breast, ovarian, or endometrial cancer; hereditary nonpolyposis colorectal cancer.
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| FIGURE 6-77 Colon carcinoma. A single-contrast view of the colon (A) demonstrates a filling defect in the cecum (arrows). A compression ring was applied, and a spot view (B) was taken of the cecum. This shows that the tumor (T) has encircled the lumen, producing a typical “apple-core” lesion with overhanging edges. This is characteristic of a cancer.

Gastrointestinal Bleeding

Bleeding is a common presentation of GI pathology. Although bright red blood from the rectum implies a rectal or colonic lesion (98% of the time), this is not necessarily the case; distal small bowel lesions are rarely seen this way. When the source of GI bleeding cannot be found by colonoscopy, it is often valuable to perform a nuclear medicine GI bleeding study. This is done by labeling the red blood cells with radioactive material and then doing sequential imaging over the abdomen to look for abnormal pooling (Fig. 6-79). This examination should be ordered before an angiogram or barium enema. A nuclear medicine study should be ordered only when the patient is having active bleeding, and it is capable of localizing the bleeding site with bleeding rates as low as 0.5 mL/min. In contrast, an angiogram needs approximately 4 mL/min for the bleeding site to be identified. A nuclear medicine scan also is helpful to direct the radiologist as to which vessels to catheterize if an angiogram is needed. Occasionally bleeding and other symptoms may be due to a foreign body (Fig. 6-80). Most patients with these have extremely imaginative stories.

Volvulus

Twisting of the colon can cause either a sigmoid or a cecal volvulus. This obstruction causes severe colicky pain, nausea, abdominal distention, and vomiting. A sigmoid volvulus is about three times more common than a cecal volvulus. A sigmoid volvulus is seen on the KUB radiograph as a massively dilated loop of colon that looks like an inverted “U” projecting up out of the pelvis toward the right upper quadrant. This is also called the “omega loop” sign (Fig. 6-81). Air usually is seen in the proximal colon. With a cecal volvulus, a dilated loop of colon points toward the left upper quadrant, and usually there is associated small bowel dilatation. The diagnostic study of choice for both these entities is a barium enema.
FIGURE 6-78 Colon carcinoma on positron emission tomography/computed tomography (PET/CT) scan. A, The anterior whole body image from a nuclear medicine fluorodeoxyglucose PET scan shows intense metabolic activity in the right lower quadrant. Normal bladder activity is also seen. B, An axial CT scan shows a mass in ascending colon. Axial (C), sagittal (D), and coronal (E) fused PET/CT images clearly localize the cancer. This scan was done to look for distant metastases before hemicolectomy. None were found.

FIGURE 6-79 Colonic bleeding from a diverticulum. A nuclear medicine gastrointestinal bleeding study done by tagging red cells with a small amount of radioactive material has images of the abdomen obtained at 5, 10, and 20 minutes. The aorta (Ao), inferior vena cava (IVC), and a transplanted kidney (K) are visible. In the left lower quadrant, increasing activity (black arrow) appears on the sequential images as a result of bleeding into the colon from a diverticulum.

FIGURE 6-80 Vibrator in the rectum. This plain radiograph shows the vibrator in this patient who “accidentally fell on it while gardening in the nude.”
FIGURE 6-81 Sigmoid volvulus. A plain radiograph of the abdomen shows the massively dilated "inverted U" of colon pointing toward the right upper quadrant.

Suggested Textbooks on the Topic
The urinary system may be imaged in a number of ways. Historically the most common radiographic method was by intravenous injection of an iodine-based contrast agent followed by a series of radiographs (intravenous pyelogram [IVP]). The IVP has been replaced by computed tomography (CT) scanning without or with intravenous contrast (CT urogram). The normal anatomy is shown in Figure 7-1. The other common initial imaging modality is ultrasound.

Often a plain x-ray image of the abdomen (sometimes referred to as a KUB) is available. You should examine this carefully, looking for abnormalities in the skeleton; soft tissue margins of the liver, spleen, and psoas regions; and the gas pattern in the bowel; as well as for calcifications. Of particular interest are those calcifications that project over or overlie the region where you expect to find kidneys, ureters, and bladder.

The kidneys should be examined for size, shape, position, and axis. The length of kidneys on a radiographic study is typically about 11 to 13 cm. On an ultrasound examination they are smaller, only about 10 to 11 cm in length. Intravenous contrast being excreted during a CT examination causes the kidneys to enlarge 1 to 2 cm in length. Normally the left kidney is somewhat higher than the right; the long axis of the kidneys should be tilted slightly inward, with the superior pole of the kidney being more medial than the lower pole. Look for uniform thickness of the cortex relative to the calyces of the collecting system. The shape of the kidneys should be relatively smooth in outline, although occasionally a slight lump is seen on the lateral margin of the kidneys. The lateral lump is sometimes referred to as a dromedary hump, or column of Bertin. Although this is a common variant, you cannot exclude a cyst or neoplasm if a major difference is found between the thickness of the cortex between the calyces and the outer margin of the kidney or if one portion of the cortex is focally thicker than another. Often a renal ultrasound is the most cost-efficient and innocuous way of resolving this problem.

On the CT scan a dark area normally surrounds the hilum of the kidney. Look carefully at the calyces to collect sound is the most cost-efficient and innocuous way of making sure that they are sharp and pointed, not blunted, at their outer corners, and examine the renal pelvis and ureters for any intrinsic or extrinsic defects. The ureters should course inferiorly and medially from the kidneys and anterior to the psoas muscles at the L3 to L5 level. On the anteroposterior projection, the ureters typically are most medial and project over the lateral aspect of the transverse processes at L3, L4, and L5. As the ureters pass over the sacrum, they deviate laterally and then enter the bladder from the posterolateral aspect.

Renal ultrasound is a simple, noninvasive examination (Fig. 7-2). Remember that all ultrasound images are “slices” and that the easiest view of the kidney to understand is the longitudinal view. The right kidney is easily visualized by transmitting sound through the right lobe of the liver. Because bowel and stomach gas prevents ultrasound transmission, the left kidney is usually visualized from the patient’s back. The kidney is bean shaped and has bright central echoes because of the fat surrounding the collecting system. Ultrasound is typically ordered to exclude hydronephrosis or to evaluate renal size or suspected renal cysts.

CT is often used as the initial imaging test for suspected renal cell carcinoma, complicated renal or ureteral stones, or trauma. Magnetic resonance imaging (MRI) or CT may be used in cases of renal cell carcinoma to exclude renal vein or inferior vena cava thrombus. Nuclear medicine techniques are used when function or other parameters must be quantitated. Common indications for radiotopography techniques include evaluation of renal transplants, to determine whether a dilated collecting system is obstructive or nonobstructive, and to detect renovascular hypertension.

Intravenous contrast medium is heavier than urine and layers posteriorly in the bladder when the patient is supine. The anterior and lateral bladder walls are usually not well seen. Consequently, if you wish to see the entire internal surface of the bladder, a Foley catheter can be placed directly into the bladder, the urine drained, and the bladder refilled with contrast material. This procedure is called a cystogram. On a cystogram, images of the bladder are obtained in several different projections. A cystogram can also be performed with CT. When the catheter is removed, the patient may be asked to void and fluoroscopic images taken. In male patients this gives a good demonstration of the urethra (Fig. 7-3). The male urethra also can be studied in a retrograde fashion by inserting a small tube in the tip of the penis and injecting the contrast material. This is usually done only in cases of suspected urethral trauma or stricture.

KIDNEYS

Congenital Abnormalities

Congenital abnormalities of the urinary tract occur quite frequently, and you should be aware of the most common

ANATOMY AND IMAGING TECHNIQUES

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Congenital abnormalities of the urinary tract occur quite frequently, and you should be aware of the most common
TABLE 7-1 Initial Imaging Studies for Common Clinical Genitourinary Problems

<table>
<thead>
<tr>
<th>CLINICAL PROBLEM</th>
<th>IMAGING STUDY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute onset flank pain. Suspected ureteral calculus</td>
<td>Noncontrasted CT</td>
</tr>
<tr>
<td>Recurrent nephrolithiasis</td>
<td>US with plain x-ray or low-dose CT</td>
</tr>
<tr>
<td>Hematuria (painless)</td>
<td>CT urogram</td>
</tr>
<tr>
<td>Acute pyelonephritis in a complicated patient</td>
<td>CT with and without IV contrast</td>
</tr>
<tr>
<td>Recurrent urinary tract infection</td>
<td>Cystoscopy, CT if nonresponding or high-risk patient</td>
</tr>
<tr>
<td>Cystitis (uncomplicated in a female)</td>
<td>No imaging</td>
</tr>
<tr>
<td>Abscess</td>
<td>CT with and without IV contrast</td>
</tr>
<tr>
<td>Renal trauma with suspicion of multisystem injury</td>
<td>CT with IV contrast</td>
</tr>
<tr>
<td>Suspected renal mass</td>
<td>CT with and without IV contrast or MRI</td>
</tr>
<tr>
<td>Renal failure</td>
<td>US</td>
</tr>
<tr>
<td>Hydronephrosis</td>
<td>US</td>
</tr>
<tr>
<td>Obstructive voiding symptoms</td>
<td>US kidneys and bladder</td>
</tr>
<tr>
<td>Bladder rupture</td>
<td>Cystogram or CT cystogram</td>
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<tr>
<td>Urethral obstruction or tear</td>
<td>Retrograde urethrogram</td>
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<tr>
<td>Bladder cancer</td>
<td>Cystoscopy, CT with IV contrast for regional and distant disease</td>
</tr>
<tr>
<td>Suspected renovascular hypertension</td>
<td>CT angiogram or MR angiogram</td>
</tr>
<tr>
<td>Acute-onset scrotal pain. Suspected testicular torsion</td>
<td>Doppler US</td>
</tr>
<tr>
<td>Testicular or scrotal mass or trauma</td>
<td>Doppler US</td>
</tr>
<tr>
<td>Testicular malignancy</td>
<td>US (CT for metastases)</td>
</tr>
<tr>
<td>Pelvic mass (female)</td>
<td>US</td>
</tr>
<tr>
<td>Pelvic pain (female)</td>
<td>US</td>
</tr>
<tr>
<td>Cervical cancer</td>
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<tr>
<td>Screening or &lt;2 cm</td>
<td>MRI with and without contrast</td>
</tr>
<tr>
<td>2 cm or greater</td>
<td></td>
</tr>
<tr>
<td>Ovarian cancer (screening)</td>
<td>Not recommended for general population.</td>
</tr>
<tr>
<td>Ovarian cancer (high risk or symptoms)</td>
<td>US</td>
</tr>
<tr>
<td>Endometrial cancer</td>
<td>No imaging</td>
</tr>
<tr>
<td>(Low grade)</td>
<td>MRI or CT</td>
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<tr>
<td>(High grade)</td>
<td></td>
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<tr>
<td>Uterine fibroids (initial, enlarging, painful, or bleeding)</td>
<td>Pelvic US</td>
</tr>
<tr>
<td>Prostate cancer</td>
<td>PSA measurement and biopsy (not imaging), nuclear medicine bone scan (to exclude osseous metastases)</td>
</tr>
<tr>
<td>Infertility (female)</td>
<td>Physical examination, hormone levels, US</td>
</tr>
<tr>
<td>Suspected multiple gestations</td>
<td>US</td>
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<tr>
<td>Acute pelvic pain (female reproductive age-group)</td>
<td>US</td>
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<tr>
<td>Vaginal bleeding</td>
<td></td>
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<tr>
<td>Anytime during pregnancy</td>
<td>US</td>
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<tr>
<td>Physical examination normal</td>
<td>US</td>
</tr>
<tr>
<td>Postmenopausal, not taking hormone currently or taking it for &gt;6 mo</td>
<td>US</td>
</tr>
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CT, Computed tomography; IV, intravenous; PSA, prostate-specific antigen; MRI, magnetic resonance imaging; US, ultrasound.

variants. Embryologically the ureter buds and grows superiorly from the bladder to meet and connect with the renal parenchyma. The ureter can divide as it ascends, causing a person to have two, partially duplicated or completely separate, collecting systems for one kidney. If complete ureteral duplication is found, the ureter that supplies the upper half of the kidney often becomes obstructed (Fig. 7-4). If the upper pole of the kidney is completely obstructed, all that is visualized is the normally draining lower pole collecting system, and it looks like a drooping lily. You should also be aware that the duplicated ureter that supplies the upper pole may often have an ectopic insertion into the bladder, urethra, or vagina.

A number of other anomalies occur in the course of the normal embryologic ascent of the kidneys out of the bony pelvis. These anomalies include one kidney rising normally and the other kidney remaining in the pelvis. Remember that it is rare to have a unilateral kidney, and thus if you...

FIGURE 7-2  Normal renal ultrasound. A, A longitudinal view of the right kidney was obtained by passing the sound beam through the right lobe of the liver. The kidney is seen behind this, outlined by the markers. The central bright echoes (arrow) in the kidney are due to fat around the collecting system. B, Normal variant column of Bertin (arrows), which is the prominence of the renal cortex near the midpole of the kidney.
see only one kidney in normal position, you should look elsewhere for an ectopic kidney (Fig. 7-5). Another common variant is fusion of the inferior aspect of both kidneys (a “horseshoe” kidney). This is relatively easy to identify, because the axis of the kidneys is abnormal, with the superior aspect of the kidneys tilted outward instead of inward (Fig. 7-6).

Renal Cysts

Renal cysts are quite common, and their incidence increases with age. Most persons older than 60 years have one or more simple renal cysts. These are often found incidentally on ultrasound or CT scans ordered for other reasons. Ultrasound is a good, inexpensive initial test to characterize a renal cyst. The margins of a benign simple cyst should be well defined, and increased echoes should be seen on the posterior aspect of the cyst because of good transmission of sound through the fluid in the cyst (Fig. 7-7, A). If a cyst has septa or internal echoes on ultrasound, a short-term follow-up ultrasound or CT scan is usually ordered to exclude a cystic neoplasm.

On CT scan, renal cysts are typically hypodense relative to the renal parenchyma; however, occasionally they can be hyperdense due to blood or protein content (Fig. 7-7, B). Hyperdense renal cysts should not enhance more than
Polycystic renal disease presents a difficult imaging problem. In the adult form of this heritable disorder, often progressive renal failure occurs. A CT scan will demonstrate very lumpy kidneys, but the cysts may not be well defined, because hemorrhage often is found within the cyst. Cysts also are usually identified in the liver and sometimes in the pancreas (Fig. 7-8).

**Hematuria**

Hematuria can be traumatic or nontraumatic and visible or microscopic. In cases of trauma and visible hematuria, a CT scan is indicated. In cases in which trauma, microscopic hematuria (<50 red blood cells [RBCs] per high-power field [HPF]), and little suspicion of injury to other organs are found, many physicians do not do any imaging but rather wait 48 hours to see if the hematuria clears.

Of patients with nontraumatic visible hematuria, about 25% have cancer, 25% have infection, and 15% have calculi. About 5% of patients with nontraumatic microscopic hematuria (5 RBCs/HPF) have a urologic cancer. Obviously the presence of unilateral flank pain suggests
At least 80% (and ≤90%) of renal calculi are radiopaque and appear dense (or white) on a routine x-ray (Fig. 7-10, A). Occasionally renal stones become very large and essentially fill the collecting system of the kidney. These are referred to as staghorn calculi (Fig. 7-10, B). If calculi are radiopaque and are overlying the kidneys or are within the course of a ureter, they are usually fairly easy to see. Sometimes it can be difficult to visualize a small stone in the region where the ureter passes anterior to the sacrum. Remember that a large number of vascular calcifications occur low within the bony pelvis and to the sides of the bladder. These phleboliths typically can be recognized because they are round, have a lucent (dark) center, and are more lateral and lower in the pelvis than the normal course of the ureter.

The most common clinical presentation of stone disease is intense flank pain with hematuria. If the patient is having a first presentation of renal stone disease, a spiral noncontrast CT scan is indicated, even if no calculus is seen on the plain x-ray of the abdomen. CT scanning is exquisitely sensitive for detection of even tiny calcifications and provides additional detail about other potential causes of pain. Ultrasound can visualize large renal stones and hydronephrosis but is poor for detection of small renal or any size ureteral stones (Fig. 7-11).

Renal Stone Disease

Calcification can occur within the substance of the kidney or within the collecting system. Calcification within the substance of the kidney (nephrocalcinosis) may be cortical (near the periphery of the kidney) or medullary (near the ends of the calyces). Cortical calcification can be due to chronic glomerulonephritis, cortical necrosis, or acquired immunodeficiency syndrome (AIDS)-related nephropathy. Medullary calcification may be idiopathic or caused by papillary necrosis, medullary sponge kidney, or other hypercalcemic states (including hyperparathyroidism and osteoporosis) (Fig. 7-9).
soft tissues (Fig. 7-12, A). Age-related perinephric stranding is usually bilateral and occurs mostly in persons older than 55 years. If a stone is lodged in the distal ureter, a dilated proximal ureter can often be seen (Fig. 7-12, B).

Sometimes it is difficult to differentiate ureteral calculi from atherosclerotic vascular calcification or from vascular phleboliths. One way is to look for a soft tissue rim around the calculus (Fig. 7-12, C). Phleboliths are most common in the lower pelvis below the middle portion of the femoral heads, whereas the ureters have almost always entered the bladder at a more cephalad level.

Occasionally the back pressure caused by an obstructing ureteral stone can rupture a renal calyx or renal pelvis. When this occurs, extravasation of urine and contrast outside the kidney into the perirenal space is seen. When an obstructing lesion of the ureter is present, the urologist may perform cystoscopy and then put a little tube into the distal ureter and inject contrast (a retrograde pyelogram). The ureter, renal pelvis, and calyces are usually visualized. Because pressure is being exerted during the injection, minimal blunting of the calyces is normal under these circumstances. A retrograde pyelogram is useful for looking at small lesions within the collecting system, such as a transitional cell carcinoma. Occasionally air bubbles will be inadvertently injected along with the contrast, and this

On a CT urogram the obstruction of the ureter by a stone may cause delayed visualization of the affected kidney and ureter. When it does visualize, the ureter is usually dilated, and the renal calyces are blunted. On delayed images, whereas the normal kidney is completely clear of contrast, the affected kidney and ureter will be seen retaining contrast. Delayed images are often necessary to determine the exact level of the ureteral obstruction.

Usually a kidney with an acute problem with renal calculi will have associated perirenal edema in the adjacent

FIGURE 7-10 Renal calculi. On a plain radiograph of the abdomen (A), a single calcification is seen in the right upper quadrant (arrow). This is a right renal calculus. Renal calculi should be suspected any time a calcification is seen within the renal outline or along the expected course of the ureter (dotted lines). In a different patient, a plain radiograph of the abdomen (B) shows a calcification conforming perfectly to the collecting system of the left kidney. This is referred to as a staghorn calculus.

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may give the appearance of filling defects. The key to differentiation of these entities is that tumors will not move around on different views; many calculi also have sharp or geometric borders (Fig. 7-13). Air bubbles move and are completely round.

**Renal Failure**

Imaging is indicated in patients with unexplained oliguria or new onset of renal insufficiency or failure (serum creatinine level >2 mg/dL). Most imaging studies of the kidneys rely on normal function. The most common clinical question is whether renal failure is due to obstruction or to medical renal disease. Because the intravenous contrast material used for a CT or MRI scan can reduce renal function, the imaging examination of choice in these circumstances is ultrasonography. Normally the cortex of the kidney has the same ultrasound echo density as the liver or has fewer echoes than the substance of the liver. In cases of medical renal disease, more echoes are found within the renal cortex than within the liver. This is probably the result of fibrosis and scarring (Fig. 7-14). For use of intravenous contrast with a CT or MRI scan, an estimated...
generated by the bacteria within the parenchyma of the kidney. Usually the kidney is nonfunctional, and a dark radiating striated gas pattern is seen where you would normally expect to find a kidney (Fig. 7-15). Occasionally, inflammatory abnormalities can cause enlargement of both kidneys, particularly in acute glomerulonephritis. The differential diagnosis for bilaterally enlarged kidneys includes bilateral obstruction, leukemia, glycogen storage diseases, lymphoma, and polycystic disease, as well as a number of other entities (Fig. 7-16). Infections of the kidney can progress to the stage at which the kidney is essentially nonfunctional. In an entity known as xanthogranulomatous pyelonephritis, a nonfunctional kidney is seen, with some calcification visible within the parenchyma of the right kidney (Fig. 7-17). The kidney is removed surgically. On the basis of any imaging study, it is difficult to differentiate xanthogranulomatous pyelonephritis from a renal tumor. Renal tuberculosis can affect the kidneys, ureter, and bladder; the infection typically begins in the kidneys, and you should look there first. In the early stages, narrowing or amputation of the infundibulum is seen between a renal calyx and the renal pelvis. In late stages, a nonfunctional shrunken kidney with clumps of calcification is found. A number of fungal infections can affect the kidney in diabetic and immunosuppressed patients. Fungal infections often cause large fungal clumps or balls within the collecting system that can obstruct the kidney (Fig. 7-18).

Renal Trauma
Blunt trauma, particularly during motor vehicle accidents, can cause a number of renal abnormalities. Significant
kidney trauma should be suspected when a fracture of the twelfth rib or fractures of the transverse processes of the lumbar vertebrae are found. Another useful sign on the plain x-ray is nonvisualization of the psoas margin on one side. In a renal contusion the kidney is intact, but interstitial edema may lead to reduced blood flow. Lacerations and intrarenal hematomas can be incomplete (not extending into the calyceal system), whereas complete lacerations are usually accompanied by a significant hemorrhage and urine extravasation (Fig. 7-19). Minor renal injuries are usually treated conservatively, and even kidneys that have large lacerations may ultimately heal. Surgical intervention may not be required unless there is major blood loss.

Occasionally avulsion of the renal vascular pedicle occurs with disruption of the blood supply (Fig. 7-20).

The advantage of CT scanning in cases of renal trauma is that you can assess other organs, such as the liver and spleen, for concomitant injuries and the peritoneal and retroperitoneal areas for hematomas. Although it is not generally appreciated, lithotripsy (ultrasound used to fragment renal stones) can cause significant renal trauma. Postlithotripsy hemorrhage generally resolves without intervention, and imaging studies are not usually ordered.
gross or microscopic hematuria raises the suspicion of a urinary malignancy. Large mass lesions within the kidney will displace the collecting system and produce an irregular contour of the kidney on a CT urogram, but very small tumors or pedunculated neoplasms can be difficult to appreciate. Although renal cancer can be visualized with ultrasound, CT scanning with and without intravenous contrast (with thin cuts through the kidneys) is now the imaging procedure of choice in an older patient with persistent painless hematuria and normal cystoscopy (Fig. 7-22). MRI also can be used to evaluate renal masses (Fig. 7-23).

Renal Tumors

Among the occasional benign tumors of the kidneys is an angiomyolipoma. It is easily identified on CT scanning by the presence of fat within the mass (Fig. 7-21). Other tumors include fibromas, oncocytomas, and hamartomas.

Renal cell carcinoma constitutes about 85% of all primary renal malignancies. It usually occurs in the sixth decade, and male patients are affected twice as often as female patients. The classic clinical triad consists of gross hematuria, flank pain, and a flank mass, although this triad is seen in only approximately 10% of patients. Typically,
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Renal Artery Stenosis

Fewer than 5% of patients with hypertension have renal artery stenosis as the cause. Imaging is usually reserved for those patients whose hypertension is uncontrolled by two medications or uncontrolled by medication and have increasing levels of serum blood urea nitrogen or creatinine. Imaging studies for suspected renal artery stenosis are discussed in Chapter 5.

Obstruction of the Renal Collecting System

Obstruction of the ureter of the kidney can be visualized by ultrasound or CT. Although it is difficult or impossible to visualize the full length of the ureter by ultrasound, it is easy to determine whether dilatation of the collecting system exists within the kidney itself (Fig. 7-24). This is seen as an area with relatively few echoes splaying the high-intensity echoes (caused by fat) around the renal collecting system. If you are monitoring a patient with known hydronephrosis, ultrasound is the test to order. Ultrasound also is the test of choice to differentiate hydronephrosis from medical renal disease in a patient who has renal failure. CT scans have the advantage of assessing pathology in other organs, as well as being able to clearly visualize external causes of urinary tract obstruction.
Occasionally dilatation of the renal pelvis is not caused by obstruction. This may have a congenital basis or may be the result of a flaccid collecting system. A simple way of differentiating the two is to order a nuclear medicine furosemide (Lasix) renogram (Fig. 7-27). The patient is injected with a radioactive material that is rapidly cleared by glomerular filtration. This will give a picture of both kidneys that looks like a poor man’s urogram. The advantage of this study, however, is that you can inject the patient with furosemide approximately 15 minutes into the study. If rapid clearance of activity from the kidney and renal pelvis is found, you know that you are dealing with a flaccid system rather than an obstructed one.

**THE URETER**

You should be able to recognize frequent and characteristic lesions that occur in the ureter. Duplication of the ureter...
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...will be a filling defect that can look like a nonopaque stone. Remember that most renal calculi (80%) are radiopaque. A clot should be suspected after trauma and in patients who are taking anticoagulants.

Transitional cell carcinomas can occur either in the renal collecting system or in the bladder. In the renal collecting system they can form a mass that spreads the renal sinus fat and can cause obstruction (Fig. 7-29). In the ureter a renal cell carcinoma may look like a lesion in the wall of the ureter, or it may cause an “apple core” deformity with encirclement of the lumen. Occasionally on a contrast urogram an intraluminal transitional cell carcinoma causes an appearance that looks like an upside-down goblet...

FIGURE 7-27 Differentiation of causes of a dilated collecting system. A nuclear medicine renogram is performed by administering a small amount of radioactivity that is cleared by the kidney. Two-minute sequential images are obtained in a posterior projection. At 14 minutes, activity is seen in both the right and the left dilated collecting systems, and furosemide (Lasix) is given intravenously. The right kidney excretes its activity into the bladder (B), but the left kidney (K) remains essentially unchanged, indicating a flaccid dilated collecting system on the right but an obstructed left collecting system.

FIGURE 7-28 Bilateral ureteroceles. This pyelogram demonstrates a congenital variant with dilatation of the distal ureter as it enters through the bladder wall. This produces a typical “cobra head” deformity (arrows), which is usually of little clinical significance.

FIGURE 7-29 Transitional cell carcinoma. An axial computed tomography image demonstrates a dilated right renal pelvis containing a nodular mass density (arrow), which was proven to be a transitional cell carcinoma. When these tumors are small or in the ureter they are best visualized by cystoscopy and retrograde pyelogram.

and collecting system has already been discussed. Sometimes the ureter has an abnormal entrance into the bladder, with dilatation of the ureter as it passes through the bladder wall (ureterocele) causing a “cobra head” deformity (Fig. 7-28). Ureteroceles are not of much clinical importance and generally do not require treatment.

The ureter normally has peristaltic waves, and therefore on any single image, usually visualization will occur of some portions of the ureter and not others. Do not be fooled into diagnosing a stricture unless you see contrast above, below, and at the level of the lesion and are able to confirm it on several different images. Because a CT scan is done with the patient supine and contrast is heavier than urine, the most anterior portions of the ureters (as they pass over the sacroiliac joints into the pelvis) can be difficult to see.

Dilatation of a ureter is diagnosed only when the ureter is seen to be greater than 8 mm in diameter and contrast is backed up in the ureter without peristaltic waves. When an acute obstruction is present, there is almost always calyceal blunting as well. Dilatation of a ureter usually elicits a reflex response from students, who immediately say “hydronephrosis” and then “obstruction.” Dilatation can be due to a number of other causes, including ureterovesicular reflux, infection, and congenital megaureter.

Common intraluminal abnormalities of the ureter are renal calculi (see earlier), blood clots, transitional cell carcinomas, and, occasionally, fungal lesions. A clot within the ureter is not visible on a plain x-ray. On a CT urogram it will be a filling defect that can look like a nonopaque stone. Remember that most renal calculi (80%) are radiopaque. A clot should be suspected after trauma and in patients who are taking anticoagulants.

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superiorly and laterally. An enlarged bladder can be striking (Fig. 7-32), and without having contrast material in the bladder, it is often difficult to tell whether you are looking at an enlarged fluid-filled bladder or some other soft tissue mass arising from the pelvis or an abdominal mass. One of (Bergman’s sign). Temporary ureteral stents can be placed to relieve ureteral obstruction (Fig. 7-30).

In some patients, indentations seen across the upper one third of the collecting system are caused by vascular impressions of blood vessels as they cross over the ureter. Collateral vessels may cause ureteral notching (Fig. 7-31). In patients who have an infection, small fluid-filled cysts in the ureteral wall may project into the lumen (pyelitis cystica). Occasionally even metastases can indent the ureter at multiple locations. This most often is the result of metastatic melanoma. If a suspected ureteral lesion is seen on a CT urogram, this is almost always confirmed by the urologist, who will perform a retrograde ureterogram before surgery.

Deviation of the ureter can signal nearby pathology. In the region between the lower pole of the kidney and the sacrum, the normal course of the ureters on an anteroposterior or a posteroanterior image is over the transverse processes of the spine. Lateral deviation of a ureter can be the result of retroperitoneal adenopathy, retroperitoneal tumors, abdominal aortic aneurysms, and occasionally, large psoas muscles (in young men or horse riders). Medial deviation can be due to traction caused by fibrosis from chronic leakage of an aneurysm, by methysergide use, or, if only on the right side, by a congenital retrocaval ureter.

**BLADDER**

**Anatomy and Imaging Techniques**

As the bladder fills with urine, it has a water or soft tissue density. The bladder can often be seen on a plain x-ray, because it is frequently outlined by perivesical fat. As the bladder enlarges with urine, it pushes the small bowel

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**FIGURE 7-30** Temporary bilateral ureteral stents. These were placed cystoscopically to relieve bilateral ureteral obstruction. They extend from the renal pelvis to the bladder.

**FIGURE 7-31** Ureteral notching. On this pyelogram, notching along the medial aspect of the proximal left ureter is easily seen (arrows). This can be due to a number of abnormalities, but in this case, it was due to impression on the lumen of the ureter by collateral vessels.

**FIGURE 7-32** Distended bladder. On this plain x-ray image of the abdomen, a large soft tissue mass is seen arising from the pelvis (arrows). It has pushed the small bowel out of the way. The differential diagnosis includes a pelvic tumor, distended bladder, or cystic abnormality arising from the pelvis.
the rules I use is that it is unusual for abdominal masses or tumors to grow down into the pelvis, but it is common for pelvic masses to grow up out of the pelvis into the lower abdomen. Thus if you see a soft tissue mass that involves both the lower abdomen and the pelvis, the mass probably arose in the pelvis. The differential diagnosis of a pelvic mass includes uterine enlargement, ovarian cysts, and tumor or pelvic sarcomas. In the female patient if the bladder is displaced to one side, you should expect an ovarian cause. Usually the bladder is visualized by using water-soluble contrast from a CT or cystogram.

Trauma

Fractures of the pelvis are accompanied by hematomas. These may displace the bladder to one side if they are unilateral, but more often pelvic hematomas are bilateral, and they will compress and elevate the inferior portion of the bladder (Fig. 7-33) so that it looks like an upside-down teardrop. This shape of the bladder also can be caused by pelvic adenopathy, pelvic lipomatosis (mostly in black males with hypertension), and by prominent iliopsoas muscles.

With pelvic fractures or as a result of direct compression of a fluid-filled distended bladder, bladder rupture can occur. This is almost always accompanied by hematuria. About 10% of patients who have a pelvic fracture will have bladder rupture. The bladder can rupture either extraperitoneally (80%) or intraperitoneally (20%). Intraperitoneal rupture of the bladder is recognized on a CT urogram or a cystogram because contrast extravasation into the peritoneal cavity outlines loops of bowel, and the contrast also will layer in the paracolic gutters.

The vast majority of patients with an extraperitoneal bladder rupture will have associated pelvic fractures. With extraperitoneal rupture the extravasated contrast material will be in a streaky or sunburst pattern (Fig. 7-34). About 10% of patients with ruptured bladders will have both an intraperitoneal and an extraperitoneal component.

Pelvic trauma also can result in injury to the urethra. Because the female urethra is so short, it is rarely, if ever, injured in an accident. In the male patient, urethral injuries are more common than bladder injuries. Because the urethra is fixed at the prostatomembranous junction, tears in this area are secondary to shearing. In a patient with pelvic trauma who has blood at the urethral meatus and who is unable to void or can void only with difficulty, a posterior urethral tear should be suspected. In these cases a retrograde urethrogram should be done before any attempt is made to catheterize the bladder, because a small initial tear may be significantly enlarged by any attempt at catheterization (Fig. 7-35). Injuries to the anterior portion
of the urethra are much less common. Injuries to the bulbous portion of the urethra are most commonly due to a straddle injury, in which the patient falls astride a solid object, such as a beam.

**Incontinence**

Incontinence in some form affects about 10 million persons in the United States. Inability to hold urine results from a wide number of causes. The mechanism of urination involves the bladder wall, sphincters, and pelvic musculature, as well as neurologic control in the bladder, spinal cord, and brain. The workup is best begun with a thorough medical history, physical examination, urinalysis, and evaluation of postvoid residual volume. The four forms of incontinence are urge, stress, overflow, and mixed.

Urge incontinence can be due to lesions (infection, stones, or neoplasm) of the bladder near the trigone, causing uncontrolled contractions. Stress incontinence occurs with increased intra-abdominal pressure (e.g., coughing, sneezing) and is most common in parous postmenopausal women; this is a result of estrogen deprivation and relaxation of the pelvic musculature with loss of the normal ureterovesicular angle. Imaging is not usually indicated, and most women are treated conservatively with exercise of the pelvic muscles. In men, stress incontinence is usually secondary to prostatic surgery. Other causes that should be considered include multiple sclerosis or other neurologic abnormalities. Overflow incontinence is due to large volumes in an atonic bladder secondary to spinal cord injury, diabetes, hypothyroidism, chronic alcoholism, or collagen vascular disease. In patients with incontinence and suspected urologic abnormality, urodynamic studies should be conducted before imaging procedures.

**Neurologic Abnormalities**

If trauma compromises the spinal cord, the bladder may become either flaccid or spastic. On a contrasted study, a spastic bladder has the shape of a Christmas tree, with little outpouchings along the lateral margins (Fig. 7-36). These areas of outpouching of contrast or urine are pseudodiverticula caused by hypertrophy of the bladder musculature. A hyperreflexive bladder usually occurs when the spinal cord lesion is at the level of T5 or higher. These patients are prime candidates for urinary infection, calculi, and bilateral collecting system dilatation. Hyporeflexive bladders are usually the result of a herniated disk, multiple sclerosis, diabetic neuropathy, or lower spinal cord tumor. Although these patients may demonstrate a large bladder, the upper urinary collecting systems are usually within normal limits, and vesicoureteral reflux is rare.

**Infections**

There is little reason to do imaging studies in female patients with uncomplicated cystitis. If repeated bouts of infection have occurred, a CT may be indicated to exclude anatomic abnormalities. Because cystitis is rare in male patients, imaging may be indicated after an initial infection. With severe cystitis, mucosal thickening may be noted; however, this should not be evaluated on a study that has a nondistended bladder. Once the bladder is fully distended, it may be possible to image thickened mucosa, although this finding rarely changes treatment. Chronic infection or bladder outlet obstruction can result in formation of bladder stones. These can sometimes be seen on a plain x-ray, but CT scanning is the most sensitive test for detection of bladder stones (Fig. 7-37).

In a number of unusual bladder infections, imaging findings are fairly characteristic. In diabetic patients, emphysematous cystitis may develop, in which gas is present in either the wall or the lumen of the bladder (Fig. 7-38, A). In contrast to emphysematous pyelonephritis, morbidity is not increased with emphysematous cystitis. This condition usually responds well to antibiotic therapy. Air within the bladder itself is more likely due to instrumentation or a bladder/bowel fistula.

Tuberculosis can affect the bladder, but this is extremely rare without strictures and stenosis of the ureters and stenosis of the calyces of the renal collecting system. Schistosomiasis, although rare, can produce characteristic bladder wall calcification (Fig. 7-38, B). A number of inflammatory conditions can cause a small bladder,
including interstitial cystitis, cyclophosphamide cystitis, and radiation therapy. These also can cause calcification within the bladder wall. With the exception of the small capacity, little is characteristic or disease specific about the imaging findings.

**Tumors**

Ninety-five percent of bladder tumors are transitional cell carcinomas. Transitional cell carcinoma is four times more common in men than in women, and a significantly increased incidence has been associated with cigarette smoking. Patients frequently are initially seen with hematuria and occasionally with urinary frequency and dysuria. Pelvic lymph node extension is relatively common. Hematogenous metastases tend to go to liver and lungs and, to a much lesser extent, to bone. When bone lesions are seen, they are typically lytic. Transitional cell carcinoma of the bladder is associated with upper tract transitional cell tumors, and close follow-up of these patients is essential.

Tumors of the bladder rarely calcify, and the diagnosis of tumors is not obvious on plain x-ray images. A CT urogram may show a filling defect within the lumen of the bladder (Fig. 7-39). Be cautious about saying that no cancer is present on the basis of a CT scan. As pointed out earlier, intravenously administered contrast is heavier than urine and layers dependently in the bladder. A tumor will not be visualized unless it is located in the dependent portion of the bladder. CT scanning is useful only to evaluate invasion of adjacent organs and pelvic lymphadenopathy. If a bladder carcinoma is suspected, the initial study of choice should be direct visualization using cystoscopy.

**FIGURE 7-38 Unusual forms of cystitis.** A view of the pelvis obtained during a pyelogram (**A**) in a diabetic patient shows air within the wall of the bladder as well as within the bladder (arrows). This is called emphysematous cystitis. In a different patient, calcification of the bladder wall is seen on a plain x-ray image of the pelvis (**B**). This is due to schistosomiasis.

**FIGURE 7-39 Bladder carcinoma.** A pyelogram (**A**) in a patient with hematuria clearly shows a large, irregular filling defect within the bladder caused by a tumor (**T**). A computed tomography (CT) scan (**B**) in a different patient shows a small bladder carcinoma (arrows). This is visible only because the tumor happens to be in the dependent portion of the bladder with the contrast. Had this lesion been on the anterior surface of the bladder, it probably would not have been visualized on a CT scan.
Anatomy and Imaging Techniques

Enlargement of the prostate causes elevation of the base of the bladder (Fig. 7-40). Prostate enlargement is most often the result of benign prostatic hypertrophy rather than prostatic carcinoma. If the prostate is big enough, outlet obstruction of the bladder may occur. Prostate cancer is common. Much interest has been expressed in the transrectal ultrasound examination of the prostate as a screening test for prostate cancer. This is not a useful test by itself, and no screening modality has been shown to reduce mortality. The U.S. Preventive Services Task Force (USPSTF) does not recommend the prostate-specific antigen (PSA) for screening. The initial investigation for suspected prostate carcinoma should be by digital rectal examination and evaluation of the serum level of PSA. Unfortunately, PSA is neither sensitive nor specific for prostate cancer. If the serum PSA value is elevated, ultrasonography may be helpful in locating a suspicious area in which a transrectal biopsy may be performed. A number of other indices besides total PSA levels are being used, including age-specific PSA and PSA velocity. In general the level of PSA in men between the ages of 40 years and 50 years should not exceed 2.5 ng/mL, and in men older than 50 years it should not exceed 3.5 to 4.0 ng/mL. Note that patients taking finasteride have a PSA level about 50% lower than the true value. Ultrasonography, CT, and MRI are not very accurate in determining local extension of a tumor. CT or MRI can show metastatic lesions in the rest of the abdomen; however, in a patient with a known prostate carcinoma and an increasing PSA level, radionuclide bone scan is the initial test of choice. Prostate cancer is usually treated by surgery or radiation therapy. A common nonsurgical radiotherapy treatment involves placement of multiple radioactive seeds into the prostate. The radioactivity decays in a few weeks, but the metallic capsules remain in place permanently and can easily be seen on plain x-ray or CT scan (Fig. 7-41).

Testicular Pain and Masses

The most common lesions of the scrotum that may require imaging are epididymitis, testicular torsion, and hydrocele, in addition to evaluation for testicular tumors. Doppler ultrasound is the test of choice for a testicular lesion. Epididymitis will be seen as a lesion with hyperemia on the affected side. In acute torsion an area of decreased blood flow will appear on the side in which pain occurs. In a torsion that has been present for a day or more (missed torsion), a lesion without much blood flow centrally, but with a hypervascular rim, may be seen. In general, any mass within the testicle itself should be considered malignant, whereas those lesions outside the testicle but within...
the scrotum are usually benign (Fig. 7-42). Ninety-five percent of solid testicular masses are germ cell tumors (seminoma, embryonal carcinoma, choriocarcinoma, and teratoma). Both hydrocele and varicoceles are easily diagnosed with Doppler ultrasound (Figs. 7-43 and 7-44).

**FEMALE PELVIS**

**Anatomy and Imaging Techniques**

The most common and fruitful imaging methods are pelvic ultrasound and CT. Ultrasound is undoubtedly the most widely used method, because it can easily image the uterus and adnexal regions. Because it does not use ionizing radiation, it can even be used during pregnancy. Imaging of the female pelvis with a plain x-ray is usually of low yield, because most significant pathology associated with female pelvic organs is not calcified. Sometimes a large soft tissue mass can be seen displacing bowel.

Female pelvic ultrasound is done either transabdominally (by having the transducer on the lower anterior abdominal wall and using the bladder as a window) or transvaginally. Transvaginal ultrasound has a much smaller field of view, and it is often very difficult to orient yourself with respect to the images unless you were actually there when they were taken. With transabdominal ultrasound, orientation is much easier. Remember that ultrasound imaging gives you a “slice” picture. The slices are typically either longitudinal or transverse. In the longitudinal plane, you can easily see the vagina, cervix, uterus, and bladder (Fig. 7-45). Areas of high-intensity echoes can be seen in the vagina and sometimes in the center of the uterus as a result of mucus production, hemorrhage, or decidual reaction. Fluid in the bladder, uterus, or cul-de-sac appears as an area without echoes. A small amount of fluid within the cul-de-sac can be a normal finding in the middle of the menstrual period, but in patients in whom an ectopic pregnancy is suspected, this may represent hemorrhage (Fig. 7-46).

Localizing an intrauterine contraceptive device is sometimes challenging. Although it can easily be seen on
a plain x-ray (Fig. 7-47), the fact that it is somewhere in the pelvis does not necessarily mean that it is in the uterus. The most accurate method of localization is with ultrasound.

Evaluation of the uterus by ultrasound does not allow determination of patency of the fallopian tubes. A hysterosalpingogram is typically done to assess tubal patency. This is done by putting a cannula in the cervical os and injecting a water-based contrast material. After the uterus is filled, the contrast goes out the fallopian tubes and spills into the peritoneal cavity. In cases in which obstruction of the fallopian tubes (hydrosalpinx) is present, the contrast proceeds to the point of obstruction and then collects in a dilated portion of the fallopian tube without free spill into the pelvis (Fig. 7-48).

**Infertility**

Infertility is the inability to become pregnant in 12 months if younger than 30 years or in 6 months if older than 30...
years. It may be due to abnormalities of the man or woman. In the woman, it can be due to absent ovulation from any cause and anatomic factors such as tubal scarring, fibroids, congenital uterine abnormalities, or adenomyomatosis. Initial evaluation includes a complete physical examination, a pelvic examination, and a measurement of serum hormone levels. An ultrasound image can be used to assess follicle development. If ovulation is confirmed and physical examination, complete blood cell count, basal body temperature, thyroid function, and pituitary function are normal, and if the male partner is normal, a hysterosalpingogram to assess tubal patency is indicated. It also is indicated to assess tubal patency after surgery or in cases of repeated spontaneous abortion.

Vaginal Bleeding

Dysfunctional uterine bleeding is due to a number of causes, including hormonal imbalance and tumors. Imaging procedures are not in the initial workup. An ultrasound examination is indicated in a premenopausal woman who has a normal cervix and vagina by physical examination and who has bleeding continuing after three cycles of hormone therapy. Ultrasonography also is indicated in postmenopausal women with bleeding who are not taking hormonal replacement therapy or who have been taking daily or cyclical hormonal therapy for more than 6 months.

Ectopic and Intrauterine Pregnancy

Ultrasound is the imaging method of choice to evaluate the status of a pregnancy. Indications for use of ultrasound during pregnancy are shown in Table 7-2. In very early pregnancy, transvaginal, rather than transabdominal, ultrasound is the most sensitive. By measuring the fetal crown-rump length and a number of other parameters, the gestational age of the fetus can be determined (Tables 7-3 and 7-4). The age that is usually quoted refers to menstrual age rather than to the conceptual age. Thus a report that indicates a 5-week pregnancy (gestational age) really corresponds to a 3-week pregnancy (conception dates).

The first ultrasound sign of pregnancy is the appearance of the gestational sac at 28 to 30 days. A yolk sac can be seen at 5 to 6 weeks, and this is the first reliable sign of an intrauterine pregnancy. A heartbeat also is typically seen of the gestational sac at 28 to 30 days. A yolk sac can be seen at 5 weeks (gestational age) (Fig. 7-49). As in intrauterine pregnancy. A heartbeat also is typically seen

**TABLE 7-2 Common Indications for Use of Ultrasound During Pregnancy**

<table>
<thead>
<tr>
<th>Size/dates discrepancy ≥ 2 wk</th>
<th>Multiple gestation</th>
</tr>
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<tr>
<td>Uterine growth less than expected between prenatal visits</td>
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<td></td>
</tr>
<tr>
<td>Assistance in obtaining amniotic fluid</td>
<td></td>
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<tr>
<td>Obstetric history of congenital anomaly, microsomia (&lt;10th percentile body weight), macrosomia (&gt;90th percentile body weight), or placental structural abnormality</td>
<td></td>
</tr>
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<td>Maternal disease, including hypertension, congenital heart disease, diabetes mellitus, renal disease, connective tissue disease, parovirus, cytomegalovirus, rubella, toxoplasmosis, preeclampsia, eclampsia, or human immunodeficiency virus</td>
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<td>Follow-up of prior identified abnormalities, including oligohydramnios or polyhydramnios, intrauterine growth retardation, placenta previa</td>
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</tbody>
</table>

*Routine ultrasound or ultrasound for the sole purpose of identifying sex of the fetus is not necessary.*

**TABLE 7-3 Measurements Versus Gestational Age in Early Pregnancy**

<table>
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<tr>
<th>SAC SIZE (mm)</th>
<th>CROWN-RUMP LENGTH (mm)</th>
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<tbody>
<tr>
<td>10</td>
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<tr>
<td>13</td>
<td>2.0</td>
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<tr>
<td>17</td>
<td>3.7</td>
<td>6.0</td>
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<td>24</td>
<td>7.4</td>
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<tr>
<td>27</td>
<td>11.3</td>
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<td>31</td>
<td>14.7</td>
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<tr>
<td>34</td>
<td>18.2</td>
<td>8.5</td>
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<tr>
<td>—</td>
<td>21.9</td>
<td>9.0</td>
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<tr>
<td>—</td>
<td>30.5</td>
<td>10.0</td>
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<tr>
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*If sac is not round, use the average diameter.*

Patients with an ectopic pregnancy almost always have pain and bleeding, but only 40% will have a palpable adnexal mass. On ultrasound a normal-looking uterus and normal adnexal areas do not exclude an ectopic pregnancy. In the woman it can be due to absent ovulation from any cause and anatomic factors such as tubal scarring, fibroids, congenital uterine abnormalities, or adenomyomatosis. Initial evaluation includes a complete physical examination, a pelvic examination, and a measurement of serum hormone levels. An ultrasound image can be used to assess follicle development. If ovulation is confirmed and physical examination, complete blood cell count, basal body temperature, thyroid function, and pituitary function are normal, and if the male partner is normal, a hysterosalpingogram to assess tubal patency is indicated. It also is indicated to assess tubal patency after surgery or in cases of repeated spontaneous abortion.

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<td>21.9</td>
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<td>30.5</td>
<td>10.0</td>
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<td>—</td>
<td>40.4</td>
<td>11.0</td>
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<td>51.7</td>
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</table>

*If sac is not round, use the average diameter.*

Patients with an ectopic pregnancy almost always have pain and bleeding, but only 40% will have a palpable adnexal mass. On ultrasound a normal-looking uterus and normal adnexal areas do not exclude an ectopic pregnancy. Under these circumstances a repeated examination in 7 to 10 days may be necessary. If the uterus appears normal and a complex adnexal mass is present, the likelihood of an ectopic pregnancy should be considered high. Sometimes a gestational sac and fetal heart motion can be seen outside the uterus. In these circumstances the diagnosis of an ectopic pregnancy is certain (Fig. 7-50).

If an empty gestational sac is seen within the uterus, it may represent a very early intrauterine pregnancy, particularly if the diameter of the sac is 10 to 20 mm. It also may represent a blighted ovum or a pseudogestational sac in a
A pseudogestational sac is seen in approximately 20% of patients with ectopic pregnancies.

In the second and third trimesters of pregnancy, quite complete ultrasonic evaluation of the fetus is possible. The most common reason for an ultrasound at this stage is to determine placental location, fetal growth, and gestational age. The earlier in pregnancy that gestational age is determined, the more accurate it will be. Dating is done by measuring the biparietal diameter of the head (Fig. 7-51) as well as the length of the femur and other structures. At the same time an evaluation should be made of the intracranial structures, the heart (to see that it has four chambers), and the abdominal organs to look for abnormalities such as duodenal atresia, obstructed kidneys, and defects in the spine and anterior abdominal wall. Sometimes in the second and third trimesters three-dimensional fetal ultrasound is performed (Fig. 7-52).

### Radiation During Pregnancy

X-ray examinations may be done during pregnancy but only after careful consideration. Little, if any, reason exists to use x-ray images in the management of labor. Occasionally x-rays may be needed during pregnancy; for example, they may be taken to assess potential injuries of the spine, pelvis, or hips after an automobile accident. Under these circumstances it must be ensured that the same information is used as would if the patient were not pregnant.

### TABLE 7-4 Fetal Measurements Versus Gestational Age

<table>
<thead>
<tr>
<th>GESTATIONAL AGE (wk)</th>
<th>BIPARIETAL DIAMETER (mm)</th>
<th>ABDOMINAL CIRCUMFERENCE (mm) (5th and 95th percentiles)</th>
<th>FEMUR LENGTH (mm) (50th percentile)</th>
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</thead>
<tbody>
<tr>
<td>12</td>
<td>19</td>
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<td>13.3</td>
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<td>14</td>
<td>26</td>
<td>—</td>
<td>14</td>
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<tr>
<td>16</td>
<td>33</td>
<td>105 (85, 126)</td>
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<tr>
<td>18</td>
<td>40</td>
<td>129 (108, 150)</td>
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<td>20</td>
<td>47</td>
<td>152 (132, 173)</td>
<td>32</td>
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<tr>
<td>22</td>
<td>52</td>
<td>175 (154, 196)</td>
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<td>58</td>
<td>197 (176, 218)</td>
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<td>219 (198, 239)</td>
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<td>280 (259, 300)</td>
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<td>299 (279, 320)</td>
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<tr>
<td>36</td>
<td>88</td>
<td>318 (297, 339)</td>
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<td>38</td>
<td>92</td>
<td>336 (316, 357)</td>
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<tr>
<td>40</td>
<td>96</td>
<td>354 (333, 374)</td>
<td>80</td>
</tr>
</tbody>
</table>
Pelvic Inflammatory Disease

Pelvic inflammatory disease is an inflammatory syndrome of the upper genital tract in women and is most commonly associated with *Neisseria gonorrhoeae* and *Chlamydia trachomatis*. The diagnosis is made clinically with the combination of lower abdominal tenderness, bilateral adnexal tenderness, and cervical motion tenderness. Associated inflammatory bowel symptoms may be present. Imaging plays a small role in simple pelvic inflammatory disease, but about 15% of patients with acute pelvic inflammatory disease have a tubo-ovarian abscess. This is best detected with ultrasonography, although CT and laparoscopy also can be used.

Pelvic Pain and Masses

Pelvic pain should be classified as acute or chronic. In most cases, patient age, medical history, physical examination, complete blood cell count, pregnancy test, and urinalysis help assign priorities for the differential diagnosis. An ultrasound examination with Doppler is the imaging test of choice for suspected ectopic pregnancy, tubo-ovarian abscess, and ovarian torsion. It identifies any free fluid in the cul-de-sac. No good imaging test exists for endometriosis; therefore that diagnosis is usually made laparoscopically.

An ovarian lesion is the most common pelvic mass in women, but other causes such as uterine, bladder, and intestinal lesions also must be considered. Most masses are found during routine pelvic examination, and the size, shape, and location are determined. Associated symptoms such as fever, pain, or menstrual abnormalities can provide valuable clues. Laboratory tests such as a complete blood cell count, a urinalysis, and a CA-125 assay also are potentially helpful. In terms of imaging, although a CT scan or barium enema can provide some information, the initial imaging test should be a pelvic ultrasound. It provides information about the internal structure and vascularity of the mass. Although no imaging test is quite accurate in differentiating benign from malignant pelvic masses, if septations, irregular solid portions, or ascites is present, malignancy should be considered, and surgery or laparoscopy may be performed. For reasons that are not clear, ovaries are quite difficult to visualize with CT. In difficult situations pelvic MRI usually provides more information than does CT (Fig. 7-53).

Tumors

The most common benign uterine tumor is a fibroid. These are often calcified and are seen on x-rays in the central portion of the pelvis. The calcification is typically somewhat popcorn shaped (see Fig. 6-17). This finding is usually incidental, because x-rays should not be ordered to look for uterine fibroids. The most common method used to image uterine fibroids and other pelvic masses, as mentioned earlier, is ultrasound. Fibroids will enlarge the uterus in a lumpy fashion and make the internal echo pattern inhomogeneous (Fig. 7-54). Although it is difficult
possible involvement of pelvic side walls, and ureteral obstruction, as well as to look for metastatic disease. The finding of a pelvic mass on CT or ultrasound is usually somewhat nonspecific, although if the mass can be traced down into the pelvis and into the adnexa, it is most likely of ovarian origin. Ovarian carcinoma may involve the bowel, particularly the serosa (Fig. 7-56). There is no evidence that ultrasound, used as a screening modality, can reduce mortality from ovarian cancer.

Carcinoma of the cervix is usually found during annual examination and with a Papanicolaou (Pap) smear. Once a cervical carcinoma has been found, CT or MR scanning can assess the overall size of the tumor and the potential presence of metastases. Often this cancer will obstruct the cervical canal and cause buildup of fluid within the uterus. Cervical carcinomas tend to obstruct the distal ureters, and renal obstruction is the most frequent cause of death from this tumor. Evaluation can initially be done by using a CT scan; however, in follow-up of these patients, it is probably cheaper and safer to look for potentially obstructed kidneys by means of ultrasound. In contrast to ovarian carcinoma, cervical carcinomas often spread locally and involve lymph nodes (Fig. 7-57). Even though CT can detect metastases if the lymph nodes are enlarged, its accuracy for detection of metastases from cervical carcinoma is only 65%, because the nodes may have small metastatic deposits and not be enlarged.
Chapter 7 | Genitourinary System and Retroperitoneum

ADRENAL GLANDS AND RETROPERITONEUM

Adrenal Glands

The adrenal glands are not normally visualized on a plain x-ray image of the abdomen. They can be seen if prior hemorrhage or infection has produced calcification or if a tumor or mass large enough to displace the kidney is present in the adrenal gland. Most anatomy texts would have you believe that the adrenal gland sits on top of the kidney like a little cap. This is not true. The right adrenal gland is located above and slightly anterior to the right kidney, and it is between the right lobe of the liver and the crus of the diaphragm. Often it can be seen on a CT scan as just a small line or less commonly as an upside-down “V” shape. The left adrenal gland likewise does not sit on top of the left kidney but actually sits just anterior and slightly medial to the upper pole of the left kidney. The left adrenal gland typically has an upside-down “Y” shape. If you suspect adrenal pathology, the imaging study of choice is a CT scan (Fig. 7-58).

The width of the adrenal gland should be less than 1 cm, and the limbs of the “Y” should be 3 to 6 mm thick. Masses in the adrenal glands are the result of adenomas (50%) (Fig. 7-59), metastases (35%), pheochromocytoma (10%), lymphoma, and neuroblastoma (in children younger than 2 years). An adrenal adenoma usually is low density (dark) on CT and occurs in about 3% of persons. It is most often found as an incidental finding on CT. After trauma,
enlargement of an adrenal gland is usually due to a hematoma.

An adrenal lesion in excess of 2 to 3 cm in diameter that is not low density on CT should be considered a malignancy. Bilateral adrenal masses are usually the result of metastases, bilateral pheochromocytoma, lymphoma, and granulomatous diseases. At autopsy about 25% of individuals who died of cancer have adrenal metastases. Lung, breast, stomach, colon, and kidney are the most common primary lesions to metastasize to the adrenal gland. In a patient with cancer and an adrenal mass, a high probability exists that the latter is metastatic (Fig. 7-60).

Adrenal hyperplasia may be nodular, as in Cushing’s syndrome, or smooth, as in 25% of patients with Conn’s syndrome. Both these diseases are related to hormone overproduction (adrenocorticotropic hormone [ACTH], cortisol, or aldosterone), which may be caused by an adenoma, tumor, or hyperplasia. The primary diagnosis for most of these lesions is made by evaluation of serum or urine hormone levels. Tumors and clinically significant functional adenomas can usually be localized by CT, but hyperplasia can be difficult to differentiate from normal glands. Most pheochromocytomas (90%) occur in the adrenal medulla, and 10% are bilateral. Occasionally they occur elsewhere in the abdomen. Localization should be done by using a nuclear medicine scan with a substance called meta-iodobenzylguanidine (MIBG) or by MRI.

Retroperitoneal Adenopathy and Neoplasms

CT scanning is the only convenient and practical way to assess patients for retroperitoneal adenopathy. As mentioned earlier in this chapter, patients can have normal-sized lymph nodes that have microscopic metastases. Therefore you should not automatically assume that if adenopathy is absent, no spread of tumor exists. When nodal enlargement occurs in a patient with a known neoplasm, the chances of malignant involvement are high,
FIGURE 7-62 Retroperitoneal fibrosis. A computed tomography scan at the lower level of the kidneys (A) shows dilatation of the left renal pelvis (arrow) and, incidentally, a slightly dilated aorta. A scan obtained just below the iliac crest in the same patient (B) again shows the aortic wall outlined by calcium. The right and left ureters (U) are pulled medially and encased by a soft tissue mass caused by retroperitoneal fibrosis. The white densities in the ureters are from stents or tubes placed in the ureters to relieve obstruction. The psoas muscles (P) also are easily seen. Ao, Aorta.

although not certain, because some patients have hyperplastic lymph nodes without actual tumor involvement.

CT scanning not only can identify adenopathy but also can be used on a serial basis to assess the results of therapy. Unless intravenous contrast is given, it can be difficult to differentiate a large mass of lymphadenopathy about the aorta from an abdominal aortic aneurysm. Another major advantage of CT is that you can look at the abdominal organs and mesenteric regions for metastatic disease while you are searching for adenopathy.

Lymphoma can involve multiple portions of the body, but adenopathy is common in the mediastinum, mesentery, and retroperitoneal areas. CT scans can identify enlarged nodes but cannot tell whether the disease is active. In the past, staging for lymphoma was often done by using whole-body nuclear medicine scans with gallium-67 citrate. These have been replaced with nuclear medicine positron emission tomography (PET) fluorodeoxyglucose scans, which give a good indication not only of location of disease but also of metabolic activity (Fig. 7-61).

Retroperitoneal fibrosis can be confused with an aneurysm or retroperitoneal adenopathy. The distinction is not always easy to make on CT. One differentiating factor is that with retroperitoneal fibrosis, usually medial deviation of the ureters appears because of traction by the fibrotic process (Fig. 7-62). With adenopathy and aneurysms there is usually lateral deviation of the ureters by a soft tissue mass.

General Textbooks on the Topic
INTRODUCTION

Fractures and other abnormalities involving the skull and face were covered in Chapter 2. Initial imaging studies for a number of clinical problems are presented in Table 8-1. A few general comments should be made about the structure of bone. Most bones consist of a densely calcified cortex, or shell, that surrounds the medullary space. The medullary space contains either active (red) marrow or fatty replaced (yellow) marrow. In the adult, red marrow is found in the skull, ribs, spine, pelvis, and proximal portions of the femurs and humeri. Because this red marrow acts as a filter, most bone metastases begin in these locations and chew outward until they involve the cortex.

The midportion of the long bones is referred to as the diaphysis. Toward the ends of long bones is the metaphysis, which extends up to the epiphyseal plate. Beyond the epiphyseal plate is the epiphysis. An epiphysis by definition involves a joint space. Occasionally growth centers are found on portions of long bones where the joint space is not involved (for example, along the greater trochanter of the femur). These centers are referred to as apophyses.

Growth of long bones occurs primarily at the epiphyseal plate, when new bone is added to the lengthening metaphysis, and the epiphyseal plate moves farther along. Some growth occurs along the lateral periosteum as well, to allow the bones to become thicker with age. Some epiphyses are present at birth, and most are closed by age 20 years. The different parts of long bones are important, because some lesions will preferentially affect only certain parts of the bone. For example, it is common for a Ewing’s sarcoma to affect the diaphysis of a long bone, but it will rarely, if ever, affect the epiphysis.

The cortex of bone has fine white lines, which are the trabeculae. These are located predominantly along the lines of stress in the bone, and they provide little pillars of support. Occasional cross-linking trabeculae occur. With disuse, old age, or states of increased blood flow, calcium is carried away from bone. This does not occur in a random fashion but preferentially removes the cross-linking trabeculae first. As the process becomes more advanced, the trabeculae along the lines of stress are removed, and the bone becomes weakened and may be subject to compression fractures. This process is seen in older women. Often in a woman with osteoporosis, on the lateral chest x-ray you will see only the outline of the thoracic vertebral bodies (because the trabeculae have been resorbed), and many midthoracic and upper thoracic wedge-compression fractures are found. As is shown later, with disuse of an extremity or in hyperemic states, initial resorption of calcium occurs in a periarticular distribution because more blood flow is found here than along the shaft of bones.

A final word of caution before we begin: Most bone lesions will be relatively obvious to you as a result of the clinical history. More than 95% of bone radiographs are obtained for evaluation of trauma, arthritis, degenerative conditions, or metastases. A number of classic fractures must be recognized; a few, if missed, can have dire consequences (especially cervical spine fractures). It is crucial that you spend time on these. Although some details of the various arthritic conditions are presented, these are relatively nonspecific and certainly not emergencies or life threatening. Primary bone tumors are very rare, and you should not expect to develop competence regarding these. In clinical practice (other than orthopedics or oncology), you probably will see a primary bone tumor once every 5 or 10 years. Most radiologists see fewer than three or four bone tumors per year. The main point is to be able to discern the lesions and refer them to a radiologist for a reasonable differential diagnosis.

CERVICAL SPINE

Normal Anatomy

The lateral view of the cervical spine is the initial view obtained, particularly in trauma cases. Table 8-2 provides a summary of how to evaluate a cervical spine examination done for trauma. Initial inspection should be directed toward the various contour lines of the cervical spine, which are shown in Figure 8-1. These include the anterior soft tissues, the anterior and posterior spinal line, the spinal laminal line, and the posterior spinous process line. On the lateral view the cervical spine should be bowed forward and have a relatively smooth curve. No sharp angulation should be found at any level. If the patient was lying on a stretcher when the lateral view was taken, the neck is often somewhat flexed, and the cervical spine is straight rather than curved. When you see this, you cannot be sure whether the straightening is due simply to the supine positioning of the patient or to muscular spasm. If the trauma was relatively minor, an upright lateral x-ray of the cervical spine usually will solve the problem. If major trauma is suspected, a computed tomography (CT) or magnetic resonance imaging (MRI) scan may be needed.

Examination of the anterior soft tissues and spaces should be done at several vertebral levels. Evaluation of soft tissue width is typically not a problem unless the patient has an endotracheal tube in place, in which case
### TABLE 8-1 Initial Imaging Studies of Choice for Various Musculoskeletal Problems

<table>
<thead>
<tr>
<th>CLINICAL PROBLEM</th>
<th>IMAGING STUDY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fracture (acute or follow-up)</td>
<td>Plain x-ray</td>
</tr>
<tr>
<td>Cervical spine trauma</td>
<td>CT (however, if low risk by NEXUS or CCR criteria [see text] imaging usually not appropriate)</td>
</tr>
<tr>
<td>Thoracic/lumbar spine trauma</td>
<td>Plain x-ray or CT (spinal fracture at one level indicates risk for spinal fractures elsewhere)</td>
</tr>
<tr>
<td>Stress fracture</td>
<td>Plain x-ray (if negative, consider nuclear medicine bone scan)</td>
</tr>
<tr>
<td>Metastases</td>
<td>Nuclear medicine bone scan, plain x-ray in area of pain</td>
</tr>
<tr>
<td>Osteomyelitis</td>
<td>Plain x-ray; if negative, then MRI or nuclear medicine three-phase bone scan</td>
</tr>
<tr>
<td>Neck pain (chronic)</td>
<td>Plain x-ray (if negative and neurologic signs/symptoms, then MRI)</td>
</tr>
<tr>
<td>Low back pain</td>
<td>Bed rest (for several weeks)</td>
</tr>
<tr>
<td>Without radiculopathy</td>
<td>Imaging not indicated</td>
</tr>
<tr>
<td>With radiculopathy</td>
<td>Noncontrast CT or MRI</td>
</tr>
<tr>
<td>Prior lumbar surgery</td>
<td>MRI without contrast</td>
</tr>
<tr>
<td>Surgical or intervention candidate</td>
<td>MRI without contrast</td>
</tr>
<tr>
<td>Suspicion of cancer, infection</td>
<td>MRI or bone scan</td>
</tr>
<tr>
<td>Immunosuppression</td>
<td>MRI without contrast</td>
</tr>
<tr>
<td>Cauda equina syndrome</td>
<td>MRI</td>
</tr>
<tr>
<td>Arthritis (nonseptic)</td>
<td>Plain x-ray</td>
</tr>
<tr>
<td>Suspected septic arthritis</td>
<td>Joint aspiration, plain x-ray</td>
</tr>
<tr>
<td>Monoarticular joint pain</td>
<td>Plain x-ray; if conservative therapy fails, then MRI</td>
</tr>
<tr>
<td>Shoulder acute pain</td>
<td>Plain x-ray (if negative and suspect tenosynovitis or bursitis, then US)</td>
</tr>
<tr>
<td>Shoulder acute pain (post surgical repair)</td>
<td>MRI</td>
</tr>
<tr>
<td>Shoulder persistent pain (negative x-ray)</td>
<td>MRI</td>
</tr>
<tr>
<td>Elbow chronic pain</td>
<td>Plain x-ray (if negative and suspect osteochondral, tendon, ligament injury, then MRI)</td>
</tr>
<tr>
<td>Hip (suspected avascular necrosis)</td>
<td>Plain x-ray (if negative or equivocal, then MRI)</td>
</tr>
<tr>
<td>Knee pain (non-traumatic)</td>
<td>Plain x-ray (if negative or effusion then MRI)</td>
</tr>
<tr>
<td>Knee acute trauma (local tenderness or effusion or inability to bear weight)</td>
<td>Plain x-ray (if fracture, do CT; if negative, then MRI)</td>
</tr>
<tr>
<td>Knee replacement (routine follow-up)</td>
<td>Plain x-ray</td>
</tr>
<tr>
<td>Pain after knee replacement</td>
<td>Plain x-ray and aspiration (if negative, then nuclear medicine infection scan)</td>
</tr>
<tr>
<td>Knee replacement (suspected loosening)</td>
<td>Plain x-ray (if negative for infection, then CT)</td>
</tr>
<tr>
<td>Chronic ankle pain</td>
<td>Plain x-ray (if negative and suspect tendon or osteochondral injury, then MRI)</td>
</tr>
<tr>
<td>Chronic foot pain</td>
<td>Plain x-ray (if suspected ligamentous, tendon issues, or neuroma, then MRI)</td>
</tr>
<tr>
<td>Reflex sympathetic dystrophy</td>
<td>Plain x-ray (if negative, then a three-phase nuclear medicine bone scan)</td>
</tr>
</tbody>
</table>

CCR, Canadian C-Spine Rule; CT, computed tomography; MRI, magnetic resonance imaging; NEXUS, National Emergency X-Radiography Utilization Study; US, ultrasound.

**FIGURE 8-1** Normal anatomy of the cervical spine in the lateral projection (A) and diagrammatically (B).
one of the patient’s arms is raised next to the head and the other arm placed down alongside the waist. This essentially raises one shoulder and lowers the other, allowing the x-ray beam to penetrate the area of the cervicothoracic junction more easily (Fig. 8-2).

Typically two anterior views are done after the lateral cervical spine view has been examined by a physician and found to be free of fracture or subluxation. First is the anterior view of the lower cervical spine with the mouth closed; this view is used to examine alignment and to exclude oblique fractures. In addition, an open-mouth view of the odontoid is obtained (Fig. 8-3). This view shows the relation of the inferior aspect and lateral margins of C1 to the superior aspect and lateral margins of C2, and it also shows the odontoid very well. It is important to have the mouth open wide enough that the front teeth do not overlie the odontoid. If this happens, you can see the air gap between the two front teeth and mistakenly call this a fracture (Fig. 8-4).

Two relatively common normal variants appear on the lateral view. The first of these looks like a calcified spike or nail and represents calcification of the stylohyoid ligament. It is actually quite lateral, but on the lateral cervical spine view it projects posterior to the mandible and anterior to C1 and C2 (Fig. 8-5). Another common variant is embryologic fusion of two or more vertebral bodies to create a “block” vertebra; this may be a complete or an incomplete fusion. Often a block vertebral body will cause abnormal motion, with associated early degenerative changes.

Oblique views of the cervical spine are obtained only when you are quite sure that no major trauma, fracture, or dislocation is present. The value of the oblique views is mostly to see whether impingement and narrowing of the neural foramina by bony degenerative spurs are present. On a good oblique view you should be able to see the neural foramina very well from C2 down through T1 (Fig.

---

**TABLE 8-2** Items to Look for on a Trauma Anteroposterior and Lateral Cervical Spine Examination

<table>
<thead>
<tr>
<th>Lateral View</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count vertebral bodies to ensure that all seven are seen (if not, consider swimmer’s view or shallow oblique view)</td>
</tr>
<tr>
<td>Alignment</td>
</tr>
<tr>
<td>Anterior vertebral body margins</td>
</tr>
<tr>
<td>Posterior vertebral body margins</td>
</tr>
<tr>
<td>Posterior spinal canal</td>
</tr>
<tr>
<td>Cervical curvature, straightening, or sudden angulation</td>
</tr>
<tr>
<td>Prevertebral soft tissue thickness (see text)</td>
</tr>
<tr>
<td>Widening of vertical distance between posterior processes</td>
</tr>
<tr>
<td>Common fractures</td>
</tr>
<tr>
<td>C1 arch</td>
</tr>
<tr>
<td>C2 odontoid</td>
</tr>
<tr>
<td>Arch (hangman’s)</td>
</tr>
<tr>
<td>Widening between anterior arch of C1 and odontoid</td>
</tr>
<tr>
<td>C3-C7 anterior avulsion</td>
</tr>
<tr>
<td>Wedge compression</td>
</tr>
<tr>
<td>C6-C7 posterior process (clay-shoveler’s)</td>
</tr>
<tr>
<td>Facets (to exclude unilateral locked facet)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Anterior View</th>
</tr>
</thead>
<tbody>
<tr>
<td>Odontoid view</td>
</tr>
<tr>
<td>Widening of the lateral portion of C1 relative to C2 (Jefferson’s fracture)</td>
</tr>
<tr>
<td>General alignment of lateral margins and spinous processes</td>
</tr>
<tr>
<td>Lucent fracture lines</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Oblique View (If No Major Trauma Is Suspected)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neural foraminal narrowing</td>
</tr>
<tr>
<td>Alignment of facet joints</td>
</tr>
</tbody>
</table>

---

FIGURE 8-2 Normal anatomy of the cervical spine on the lateral swimmer’s view.
FIGURE 8-3 Normal anatomy of the cervical spine on the anteroposterior (AP) odontoid view (A) and the standard AP cervical view (B).

FIGURE 8-4 Pseudofracture of C2. On the odontoid view (A), if the teeth project over the vertebral bodies, an air gap between the front teeth (arrows) can cause what appears to be a vertical fracture through either the odontoid process or the body of C2. The junction between the articular surfaces of lateral masses of C1 and C2 is indicated by the dotted lines. If a question remains, the pseudofracture artifact can be corrected by raising the maxilla and repeating the view (B).

Trauma

Of acute traumatic spinal fractures, 50% are due to motor vehicle accidents, about 25% to falls, and about 10% to sports injuries. The most common sites are the upper (C1 to C2) and lower (C5 to C7) cervical spine and the thoracolumbar junction (T9 to L2). Twenty percent of spinal fractures are multiple, and about 5% occur at discontinuous levels.

Dislocation of the skull from the cervical spine (atlantooccipital dislocation) is rare and usually fatal. Approximately 5% of cervical spine fractures involve C1. Fractures of the atlas can involve any portion of the bony ring. Combination fractures, or burst fractures of the ring of C1, are called Jefferson’s fractures. This bursting is usually secondary to axial loading as a result of the skull being smashed down onto the cervical spine (as in diving into a shallow pool) (Fig. 8-8, A).

Approximately 10% of all cervical spine fractures involve the odontoid process of C2. The most common type of odontoid fracture occurs at the base of the odontoid process. You can identify the fracture on the lateral view by being careful to trace the anterior and posterior cortex of the odontoid process. Often associated soft tissue swelling is found (Fig. 8-8, B). Note should be made that in
ligament injury may be some soft tissue swelling anterior to the vertebral bodies. Flexion views will sometimes demonstrate increased widening not only of the atlantoaxial space but also of the space between the posterior spinous processes. This type of subluxation also occurs as a complication of rheumatoid arthritis (Fig. 8-9).

A relatively classic fracture of C2 is the so-called hangman’s fracture. This involves fracture of the posterior elements of C2, often with associated spinal cord compromise. This fracture typically occurs secondary to hyperextension and compression of the upper cervical spine, and usually anterior subluxation of the body of C2 relative to C3 is found (Fig. 8-10). In spite of the name, this is not the usual fracture that occurs as a result of judicial hangings.

Two rather characteristic fractures of the midcervical spine vertebral bodies occur. The first of these is caused by hyperextension, which typically tears off either a superior or an inferior anterior portion of the cortex from a vertebral body (Fig. 8-11). A second type of fracture that commonly occurs in the middle cervical spine is a hyperflexion injury. In this, compression of the vertebral body is found, usually with anterior wedging and sometimes with a posteriorly displaced disk fragment, and usually with associated soft tissue swelling due to the hemorrhage. Evaluation with MRI may show compromise of the neural canal at the level of the fracture (Fig. 8-12).

In addition to fractures associated with subluxation, ligamentous injury may allow the facets of one vertebral body to become slightly subluxated, perched, or locked. These represent a more anterior subluxation of a superior vertebral body on a lower one. Generally these injuries occur in the lower half of the cervical spine and are caused by extreme flexion of the head and neck without axial compression. Occasionally a fracture or ligamentous injury
FIGURE 8-7 Normal appearance of the cervical spine and spinal cord on magnetic resonance imaging. A sagittal (lateral) view with a T1-weighted sequence (A) shows that the subcutaneous fat and marrow within the vertebral bodies have a high signal and appear white. The cerebrospinal fluid (CSF) appears almost black, and the cerebellum, pons, and spinal cord appear gray. On the T2-weighted sequence (B), the contrast is somewhat reversed, with fluid or CSF appearing white, and the fat becoming dark. The spinal cord remains gray.

FIGURE 8-8 A, Jefferson's burst fracture of C1. On this open-mouth anteroposterior view, widening of the space between the odontoid and the left lateral mass of C1 is apparent. The lateral aspect also projects past the lateral margin of C2 (arrow). B, Fracture of the odontoid. In a different patient, the lateral view of the cervical spine (B1) shows marked soft tissue swelling in front of the body of C2 (white arrows). Discontinuity of the cortex along the anterior surface of C2 (black arrows) is seen, indicating an odontoid fracture. A sagittal reconstruction on a computed tomography scan (B2) shows the fracture much more clearly.
FIGURE 8-9 Instability of the transverse ligament of C1. In this patient with rheumatoid arthritis, a lateral view of the cervical spine with the neck extended (A) shows very little space (which is normal) between the posterior aspect of the arch of C1 and the anterior portion of the odontoid (arrows). With flexion (B), this space markedly widens, and the odontoid is free to compress the spinal cord, which is posterior to it.

FIGURE 8-10 Hangman's fracture. The lateral view of the cervical spine demonstrates marked soft tissue swelling anterior to C1, C2, and C3 (small white arrows). A fracture line is seen just posterior to the body of C2 (large arrow).

FIGURE 8-11 Anterior avulsion fracture. A small avulsed fragment is seen along the superior and anterior aspect of C5 (arrows).

cannot be identified with plain x-rays. If a high suspicion of clinical injury exists in spite of negative plain x-rays, CT scanning (Fig. 8-13) or MRI may be useful. CT scanning is able to identify small cortical breaks, whereas the MRI scan can show areas of increased signal with hematoma or edema, suggesting at least ligamentous injury.

Three fractures of the lower portion of the cervical spine are easily missed. Occasionally oblique fractures of the lower cervical spine are seen only on the anteroposterior (AP) view (Fig. 8-14). The second fracture involves the posterior spinous process at the C6, C7, T1, or T2 level. This is called the clay-shoveler's fracture, and it is due predominantly to hyperflexion injury (Fig. 8-15). A third and most significant problem, relative to the lower cervical spine, is accepting a trauma lateral cervical spine image that does not include adequate evaluation of C6 and C7. Failure to visualize this region can result in missing significant subluxations and fractures, and for purposes of
complete evaluation, either a swimmer’s view or shallow oblique views through the cervicothoracic junction are necessary (Fig. 8-16).

Plain AP and lateral x-rays historically were the primary screening tool for spinal trauma. Two sets of decision rules have been developed to determine which patients are low risk and which benefit from plain x-ray studies. These are the National Emergency X-Radiography Utilization Study (NEXUS) and the Canadian C-Spine Rule (CCR). With NEXUS a patient is considered low risk and not needing an x-ray if he or she meets all of the following criteria:

- No posterior midline cervical spine tenderness
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- Or dangerous mechanism of injury: (1) fall from 3 feet or greater, (2) fall down five stairs, (3) axial load to the head, (4) motor vehicle accident at greater than 60 mph, (5) motor vehicle accident rollover or ejection, or (6) collision involving motorized recreational vehicle or bicycle
- Or paresthesias in extremities
- Has any low-risk factor that does not allow safe assessment of range of motion
- Cannot rotate neck actively (45 degrees right and left)

The CCR is more sensitive and specific than the NEXUS criteria. At the present time if a patient needs posttraumatic cervical spine imaging, a CT scan is usually done rather than simple radiographs. About 5% of the time, fractures are found that cannot be seen on plain x-rays. In addition, about 50% of the time, plain x-rays are unable to distinguish a vertebral body compression fracture from the more serious burst fracture. If a patient has severe head trauma requiring CT evaluation, most physicians simply continue the head scan down into the cervical spine to exclude occult fractures. MRI is better than CT for detection of the soft tissue and spinal cord components of the injury. If a patient has had a normal CT scan but there is still suspicion of ligamentous damage, an MRI may be indicated. Table 8-3 shows the indications for MRI of the spine.

Degenerative Changes

In terms of anatomic and mechanical design, the lower aspect of the cervical spine is less than optimal, and by the third or fourth decade of life, degenerative changes involving C4 through C7 almost always are found. Degenerative changes are visualized as decreased disk spaces, sclerosis

**FIGURE 8-14** Oblique fracture of C6. The anteroposterior view of the lower cervical spine (A) shows an oblique lucent line, representing a fracture, through the body of C6. This is the only view on which this fracture was seen. The lateral view in the same patient (B) was completely normal.

**FIGURE 8-15** Fracture of the posterior spinous process of C6 and C7. This fracture is identified only on the lateral view (arrows) and is referred to as a clay shoveler’s fracture.

- No evidence of intoxication
- A normal level of alertness
- No focal neurologic deficit
- No painful distracting injuries

With the CCR a patient is referred for an x-ray if he or she meets any of the following criteria:
- Is high risk, defined as follows:
  - Older than 65 years
FIGURE 8-16 C6-C7 subluxation. The initial lateral view of the cervical spine (A) in this patient with paraplegia looked normal; however, C7 was not visualized. When a swimmer’s lateral view (B) was obtained, a complete subluxation of C6 forward on the body of C7 was noted. (Dotted line shows anterior margin of vertebral bodies.)

TABLE 8-3 Indications for a Magnetic Resonance Imaging Scan* of the Spine

<table>
<thead>
<tr>
<th>Indication</th>
</tr>
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<tbody>
<tr>
<td>Radiculopathy: unchanged after 4 to 6 wk of limited activity and medications; worsening or extension after 2 wk of limited activity and medications</td>
</tr>
<tr>
<td>High-impact trauma</td>
</tr>
<tr>
<td>New or progressive neurologic deficit</td>
</tr>
<tr>
<td>Neurologic deficit inconsistent with radiographic findings</td>
</tr>
<tr>
<td>Suspected spinal tumor</td>
</tr>
<tr>
<td>Suspected spinal infection</td>
</tr>
<tr>
<td>Acute myelopathy (hyporeflexia, gait disturbance, clonus, numbness or paresthesia in legs)</td>
</tr>
<tr>
<td>Acute urinary retention or stool incontinence</td>
</tr>
<tr>
<td>Neurogenic claudication (differentiated from vascular claudication by partial relief with back flexion, onset with prolonged standing)</td>
</tr>
<tr>
<td>Cancer elsewhere with new spine pain, new spinal bone lesion on radiographic examination, new neurologic findings</td>
</tr>
</tbody>
</table>

*A computed tomography scan also can be used if a magnetic resonance imaging scan is not available.

TABLE 8-3 indicates the need for a magnetic resonance imaging scan in various clinical scenarios. For example, if there is no improvement in radiculopathy after 4 weeks of limited activity and medications, a scan may be necessary. The table also lists indications for high-impact trauma, new or progressive neurologic deficit, and suspected spinal conditions.

THORACIC SPINE

Anatomy

Plain x-rays of the thoracic spine are taken in AP and lateral projections. The AP projection is useful for examining spinal alignment, the paraspinal soft tissues (to exclude hematomas or other masses), and the pedicles (Fig. 8-19). The lateral thoracic spine is usually a difficult image to assess. In the upper portion the vertebral bodies are obscured by the shoulders; as mentioned in the discussion of the cervical spine, if you suspect pathology in the T1 to T5 region, often a swimmer’s view or shallow oblique view is necessary. The midthoracic and lower thoracic spine is usually well seen on the lateral view. When pathology is identified on the lateral view, it is often not easy to tell exactly the level of the vertebral body involved. Once you have identified pathology on the lateral view, you can usually go back to the AP view, look at the ribs, and then count up from T12. A common normal variant is seen on the lateral thoracic spine views in children. This apophysis that occurs along the superior and inferior anterior margins of the vertebral bodies should not be mistaken for a fracture (Fig. 8-20).

Trauma

Fractures of the thoracic spine typically are the result of motor vehicle accidents or of the normal aging process, with osteoporosis and resultant anterior wedging of vertebral bodies. Fractures due to significant acute trauma are sometimes seen well only on either the AP or the lateral view. On the AP view you should examine the spine for malalignment of the posterior spinous processes (Fig. 8-21) and for paraspinal soft tissue swelling. These are both signs that a fracture may be present. If you suspect a spinal fracture, both AP and lateral views should be examined. Sometimes significant subluxation of one vertebral body forward on another will be difficult to see on the AP view (Fig. 8-22). This usually occurs when a hyperflexion injury results in a compression burst fracture. Often retrospulsed fragments of both disk and bony material project...
of the vertebral bodies. It is almost impossible to tell whether any one of these fractures is new or old, but it usually does not make any difference clinically. If you suspect metastatic disease as a cause of back pain in an older patient, a plain x-ray and a nuclear medicine bone scan are usually satisfactory.

Degenerative Changes

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FIGURE 8-19 Normal anatomy of the thoracic spine in the anteroposterior (A) and lateral (B) projections.

FIGURE 8-20 Normal spinal apophyses. In children a normal apophysis can occasionally be seen on the lateral projection along the anterior superior and inferior margins of the vertebral bodies. These are normal, will be seen on multiple vertebral bodies, and should not be mistaken for avulsion fractures.

FIGURE 8-21 Laterally displaced thoracic spine fracture. An anteroposterior view of the upper thoracic spine in a paraplegic patient who was hit in the driver’s-side door during a motor vehicle accident shows lateral displacement of the upper thoracic vertebral bodies relative to the lower bodies. This can be assessed by looking at the line formed by the posterior spinous processes (dotted lines). Also note the lateral soft tissue swelling (arrows) due to the paraspinous hemorrhage resulting from the fracture. This type of fracture is difficult or impossible to visualize on the lateral view.
useful to count the number of vertebral bodies, because commonly six, rather than five, non–rib-bearing vertebrae may be found. The transverse processes should be examined to exclude fracture, and the pedicles at each level should be examined to make sure that they have not been eroded by a pathologic process. In addition, the sacrum and sacroiliac joints should be examined. The sacroiliac joints can become fused in various arthritic processes (such as ankylosing spondylitis) or can be widened by a pelvic fracture.

On the lateral view of the lumbar spine, a search is made for subluxation of the vertebral bodies; this is done by

**LUMBAR SPINE**

**Normal Anatomy and Imaging Techniques**

The standard views obtained of the lumbar spine are AP, lateral, and a lateral spot view of the L5 to S1 area (Fig. 8-25). The spot view is necessary because on the lateral view both iliac wings and a significant amount of additional soft tissue mean that more radiation exposure is necessary to penetrate and visualize the L5 to S1 area adequately.

On the AP view, examine the alignment of the spine and the visibility of the psoas margins bilaterally. It is often

**FIGURE 8-22 Anterior subluxation and fracture.** On the anteroposterior view of the lower thoracic spine (A), paraspinous soft tissue swelling (white arrows) due to hemorrhage is identified, although the vertebral bodies, including T12, look grossly normal. The lateral view (B) demonstrates a wedge compression of T12 and marked anterior subluxation of T11 on T12, causing the patient to be paraplegic. A transverse computed tomography scan (C) through the level of T12 shows multiple bony fragments (arrows) within the neural canal that have compromised the spinal cord.
looking down the contour lines formed by the anterior and posterior margins of the vertebral bodies. The height and shape of vertebral bodies and the disk spaces should be uniform. The posterior spinous processes also can be visualized.

Oblique views of the lumbar spine are useful for examining the facet joints. The typical anatomy on the oblique view is seen in the outline of a “Scottie dog” (see Figs. 8-25, D and 8-30, B). In this oblique projection the pedicle is the eye of the Scottie dog, and the transverse process represents the nose. The superior articular process forms the ears, and the inferior articular process forms the front legs.

A common normal variant of the lumbar spine is incomplete fusion of the posterior aspect of L5 or S1 (spina bifida occulta), which is seen on the AP view (Fig. 8-26, A). It is of no clinical significance and should be disregarded. A second common anomaly is sacralization, or partial fusion, of L5 with the sacrum (Fig. 8-26, B). This can occur just on one side, or it can be bilateral.

On any given view of the lumbar spine or pelvis, you can see normal bowel gas projecting over bone. This looks dark and can easily mimic a destructive bone lesion. I have seen several instances in which physicians told patients that they had “cancer of the spine,” which in reality was overlying bowel gas. Make sure that any bone lesion that you suspect is confined to the bone and stays within that bone on AP, lateral, and oblique views.

**Postsurgical Changes**

The most common postsurgical change involves either lower lumbar fusion or laminectomy. It is often not easy to appreciate laminectomy on the lateral image; however, on the frontal views, it is much easier to see that one or more posterior spinous processes are gone (Fig. 8-27). Noticing things that are missing is always harder than seeing abnormal objects that are present.
Fractures

The most common fractures of the lumbar spine are wedge-compression fractures and compression-burst fractures. These are similar to those already described in the thoracic spine. Progression of compression fractures can be arrested and pain sometimes can be relieved by a procedure known as vertebroplasty. In this procedure a cement or glue is injected into the vertebral body (Fig. 8-28). Note should be made, again, that the compression-burst fractures frequently have fragments that are retropulsed, and CT or MRI is often necessary to evaluate compromise of the spinal canal.

A somewhat unusual fracture occurs in the lumbar spine, typically at L1, L2, or L3, called a Chance fracture. In the past this most commonly was the result of a motor vehicle accident when a lap seat belt is worn without the shoulder harness. Under these circumstances, rotation of the trunk of the body occurs about the horizontal axis of the seat belt, resulting in a vertical distraction force along the lumbar spine. This essentially tears a vertebral body (horizontally) in half. On the AP view, this fracture is recognized by discontinuity of the outline of the pedicles, and on the lateral view, by a lucency extending through the posterior spinous process and lamina (Fig. 8-29).

The pars interarticularis of the vertebral body also can be fractured. This injury typically occurs at the L4 or L5 level. It can sometimes be seen on the lateral view as a lucency but more commonly is clearly identified as a break in the neck of the Scottie dog on the oblique view (Fig. 8-29).

FIGURE 8-25 Normal anatomy of the lumbar spine in the anteroposterior (A), lateral (B), lateral sacral (C), and oblique (D) views.
it is termed spondylolisthesis. The amount of offset caused by the slippage is used to grade the spondylolisthesis. If up to one fourth of the vertebral body is offset, this is grade 1; between one fourth and one half is grade 2, and so on (Fig. 8-31). In a young patient or athlete with low back pain and normal plain x-rays, a nuclear medicine bone scan with “slice” or single-photon emission CT (SPECT) technology may identify otherwise occult lesions (Fig. 8-32).
disk phenomenon. Actually, it is not a vacuum; nitrogen is in the joint space. This can appear or be accentuated as a result of hyperextension of the spine, but it is a finding of no special clinical significance.

A common degenerative change that occurs in the lower lumbar spine is a herniated disk or a protruded disk. A herniated disk often has a fragment that is asymmetric or loose in the neural canal, whereas a disk protrusion is a posterior central bulge of the disk. Both can be imaged with either CT or MRI (Fig. 8-35). Currently MRI is commonly used to make this diagnosis.

**Management of Low Back Pain**

This is probably one of the areas of greatest controversy in medical imaging. Low back pain affects 60% to 80% of the population at some time in their lives. The most common cause of low back pain is a herniated or bulging disk. Surprisingly, MRI and CT studies reveal a bulging disk in 25% to 50% of asymptomatic adults. Ninety percent of cases of lower back pain resolve within 4 to 6 weeks as a result of conservative therapy. Unless major acute trauma is present, plain x-rays of the lumbar spine are not of much use, because a patient can have a herniated disk and totally normal plain x-rays. Conversely, many people who have severe-looking degenerative changes are totally asymptomatic. A herniated disk is usually diagnosed by pain that extends past the knee in a dermatomal pattern. Footdrop or loss of gastrocnemius strength deserves careful monitoring rather than urgent surgery.

In the absence of serious or progressive neurologic deficit, neoplasm, spinal infection, or significant trauma, CT or MRI should not be part of the initial examination. Absence of a reflex or isolated sensory loss is not considered to be a progressive neurologic deficit. If the CT or MRI is nonspecific, a SPECT nuclear medicine bone scan may exclude occult fractures, osteoid osteomas, and spondylolysis. Indications for imaging cancer patients with back pain are given in a following section on neoplasms.

**Infections**

Most infections in the spine involve a disk space and will cause destruction of the vertebral body above and below (Fig. 8-36). It is rare for a tumor to involve or cross a disk space. Tumors typically will destroy a single vertebral body and then may extend above and below. Thus if you see a destructive process centered about a disk space, an infection should be your first choice. Evaluation of the bony destruction of a vertebral body is best visualized by CT scan, but if a neurologic deficit is present, MRI is more appropriate.

**Spinal Neoplasms and Metastases**

Although primary bony neoplasms of the spine occur, they are rare. The most common neoplastic involvement is from metastatic disease. The metastases may be destructive and cause holes (lytic lesions) in the bone, or they may be
Metastases do not begin in the bone cortex but rather in the red marrow, which has filtered the tumor cells out of the blood. After growing within the marrow space, the lesion becomes large enough to erode the bony cortex. The most sensitive method of finding metastatic disease in the spine is through use of MRI (Fig. 8-38). Unfortunately, MRI can focus only at limited portions of the body at one time. Therefore if you are thinking about metastatic...
FIGURE 8-33 Degenerative changes of the lumbar spine. An anteroposterior view of the lower lumbar spine shows extensive and florid bone spur formation as a result of degenerative change (arrows). The extent of these changes does not correlate well with the presence of back pain.

FIGURE 8-34 Degenerative disk disease of the lumbar spine. A lateral view of the lower lumbar spine shows spondylolisthesis and subluxation of L4 on L5. The degenerative changes noted are almost complete loss of the disk spaces at L4-L5 and L5-S1. The small dark area within the disk space (arrows) is nitrogen; this is referred to as a vacuum disk.

FIGURE 8-35 Disk herniation and protrusion. A transverse computed tomography scan (A) obtained at the L5-S1 disk space shows posterior protrusion of disk material (arrows) into the spinal canal. In a different patient the sagittal or lateral magnetic resonance imaging view (B) of the lumbar spine shows a posterior L5-S1 disk (arrows) protruding into the spinal canal.
Chapter 8 | Skeletal System

FIGURE 8-36 Osteomyelitis of the spine. A lateral view of the lower thoracic spine demonstrates destruction of the disk space (arrow) as well as destruction of the adjoining vertebral bodies.

FIGURE 8-37 Diffuse neoplastic involvement of the lumbar spine. In a patient with multiple myeloma, a lateral view of the lumbar spine (A) demonstrates vertebral bodies that are difficult to see owing to diffuse loss of calcium. Also note a vertebral body compression fracture. A lateral view of the spine (B) in a different patient with diffuse metastatic prostate cancer shows blastic or dense white metastases in most of the bones visualized.

FIGURE 8-38 Focal spine metastases. A sagittal or lateral T1-weighted magnetic resonance image of the lumbar spine shows the normal white or high signal in fat within the bone marrow. In many of the vertebral bodies, the high signal of normal marrow has been replaced by dark areas of metastatic deposits (m).
patients are positive for human leukocyte antigen (HLA)-B27. In this disease, calcification bridges the disk spaces. This is easily seen on the lateral plain x-ray and is referred to as a "bamboo spine." On the AP view you will notice fusion of the sacroiliac joints (Fig. 8-39), and sometimes you can see "whiskering" (also called enthesopathy) of the ischial tuberosities and along the lateral ilium. About 30% of the patients will have a peripheral arthritis that spares the hands but involves the feet.

Osteoporosis and Bone Mineral Measurements

The accurate measurement of bone mineral density (BMD) with noninvasive methods can be of value in the detection and evaluation of primary and secondary causes of decreased mass. This includes primary osteoporosis and secondary disorders such as hyperparathyroidism, osteomalacia, malabsorption, multiple myeloma, diffuse metastases, and glucocorticoid therapy or intrinsic glucocorticoid excess.

By far the largest patient population is affected by primary osteoporosis. Osteoporosis is an age-related disorder characterized by decreased mass and by increased susceptibility to fractures in the absence of other recognizable causes of loss. Primary osteoporosis is generally subdivided into type 1, or postmenopausal osteoporosis, which is related to estrogen deprivation, and type 2, or senile osteoporosis, which occurs as a result of aging.

Primary osteoporosis is a common clinical disorder and a major public health problem because of the significant number of related fractures occurring annually. Because the risk for vertebral and femoral neck fractures increases dramatically as BMD levels decrease to less than 1 g/cm²,
fracture risk in individual patients may be estimated. Furthermore, in estrogen-deficient women, BMD values may be used to make rational decisions about hormone replacement therapy and as follow-up in assessing the success of hormone replacement or specific bone-enhancing therapies.

A number of methods have been devised to permit the accurate and reproducible determination of bone mineral content. Plain x-rays generally require a loss of 30% or more of bone mineral for a change in density to be appreciated and are thus insensitive for the detection of the disease. Bone mineral measurements now are made by using dual energy x-ray absorptiometry (DEXA), which is accurate and reliable. Results are usually presented in terms of absolute BMD (g/cm²) and percentiles of reference in normal young adult and age-matched populations. Normal BMD is defined as being within 1 standard deviation of the young adult mean. Osteopenia is BMD 1 to 2.5 standard deviations less than the young adult mean. Osteoporosis is a BMD more than 2.5 standard deviations below the young adult mean.

The use of bone mineral measurement has been controversial, partly because of the wide variation of measurements in the normal population. The criteria for selecting the optimal skeletal site for evaluation have not been well defined, because bone mineral loss does not progress at the same rate at different body sites. In any case, the method can be used to determine the presence of osteopenia and to evaluate effectiveness of a therapeutic maneuver by using serial scans in which the patient acts as his or her own control. Normal results, or bone mineral content in the upper portion of the normal range, define patients in whom therapy may not be needed. Indications for using DEXA are given in Table 8-4.

**SHOULDER AND HUMERUS**

**Normal Anatomy and Imaging**

The standard view of the shoulder is obtained in an AP or a PA projection with the arm rotated internally and then externally. When the arm is in internal rotation, the humeral head looks generally smooth and spherical over the upper portion. In external rotation, a concavity of the bicipital groove is seen in the lateral aspect of the humeral head. In children the proximal humeral epiphysis and an epiphyseal plate are visualized. This can sometimes be confused with a fracture. If the epiphyseal plate is not parallel to the x-ray beam, several lucent lines traversing the proximal portion of the humerus can be seen, because the epiphyseal plate is tilted off axis relative to the x-ray beam (Fig. 8-40).

On a plain AP x-ray of the adult shoulder, the medial portion of the humeral head overlaps with the lateral aspect of the glenoid (Fig. 8-41). Sometimes the humeral head may project slightly lower or slightly higher than the center of the glenoid. Because the humerus is somewhat

### Table 8-4 Indications for Using DEXA to Measure Bone Mineral Density

| Intention to use hormone replacement or other medical therapy if osteoporosis is present |
| Suspect low bone mineral density based on osteopenia on plain radiographs |
| Low-impact or nontraumatic vertebral fractures by x-ray examination in a postmenopausal female (see text for additional factors) or premenopausal female or male with normal serum thyroid-stimulating hormone, serum calcium, alkaline phosphatase, and serum protein electrophoresis levels |
| Loss of height >2.5 inches |
| Risk factors for low bone mineral density include estrogen-deficient state, chronic liver or renal disease, thyroxine therapy, steroid therapy for >6 mo (baseline and 12-mo follow-up), hyperparathyroidism, hypogonadism in a male, and nutritional disorder |
| Follow-up hormone therapy (only if a change in management is being contemplated) |

**DEXA**, Dual-energy x-ray absorptiometry.
or near the intersection of the three lines. This view is usually obtained if a shoulder dislocation is suspected and also is useful to look for fractures of the scapular blade.

The second view often obtained is the axillary view, in which the elbow is elevated and the beam projection is directly down through the shoulder. This allows clear visualization of the relation of the glenoid to the humeral head (Fig. 8-44). Unfortunately, this view is difficult to obtain on patients who have a true dislocation. Be careful about ordering this projection if you suspect a humeral head or humeral shaft fracture, because the technologists may make the situation worse by elevating the patient's elbow in an attempt to obtain the axillary view.

Plain x-rays of the shoulder are really useful only to define bony anatomy. Many shoulder injuries involve soft tissues, and for evaluation of these the most useful imaging test is an MRI scan. The joint and soft tissues also can be visualized by injecting contrast directly into the joint and imaging with MRI or CT. MRI allows excellent visualization not only of the muscle but also of the joint space and the tendons (Fig. 8-45). Remember that what appears to be a white bone on an MR image is really fat within the marrow space, and the cortex of the bone is seen as a black line around the edge. Fat in the subcutaneous areas also is seen as white, and muscle is usually gray.

Trauma

Table 8-5 shows the high-yield areas to examine for upper extremity trauma. Probably the three most common acute shoulder injuries are fracture, shoulder separation (acromioclavicular separation), and dislocation of the humeral head.

Fractures

Most clavicular fractures occur either in the midportion or the distal third of the clavicle. Usually the fractures are clinically obvious (Fig. 8-46). Rarely dislocation of the proximal head of the clavicle from the sternoclavicular joint occurs; however, this also is clinically obvious. Fractures of the scapula are reasonably rare, although they can occur as the result of a direct blow. Often this is apparent on a routine shoulder radiograph and from the clinical history (Fig. 8-47). In many cases the fracture cannot be
FIGURE 8-45 A, Normal coronal view of the shoulder with a T1-weighted magnetic resonance scan. The osseous structures, including the humeral head, glenoid, acromion, and clavicle, are well seen. The muscular structures of the deltoid and the supraspinatus and its insertion also are seen. B, In a patient with a full-thickness rotator cuff tear, the fibers of the supraspinatus are retracted (arrow).

FIGURE 8-46 Midclavicular fracture.

FIGURE 8-47 Scapular fracture. A Y view of the shoulder clearly shows a fracture through the blade of the scapula (arrows).

TABLE 8-5 Examination of an X-ray of the Upper Extremity Done for Trauma

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<thead>
<tr>
<th>Shoulder</th>
<th>AP view</th>
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<tr>
<td></td>
<td>Anterior dislocation, humeral head inferior and medial</td>
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<tr>
<td></td>
<td>Posterior dislocation, humeral head not round and slightly lateral</td>
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<td></td>
<td>Acromioclavicular separation</td>
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<td></td>
<td>Clavicular fracture</td>
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<td>Scapular fracture</td>
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<td>Rib fracture</td>
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<td>Y view</td>
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<td></td>
<td>Dislocation</td>
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<td>Scapular fracture</td>
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<th>Elbow</th>
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<td></td>
<td>Radial head fracture</td>
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<td>Supracondylar fracture</td>
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<td>Lateral view</td>
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<td>Posterior fat pad (always abnormal)</td>
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<td>Bulging anterior fat pad</td>
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<td>Olecranon fracture</td>
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<td>Coronoid fracture</td>
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<td>Radial head alignment</td>
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<td>Ulnar styloid</td>
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<td>Navicular</td>
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<td>Widening between navicular and lunate</td>
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<td>Two distinct rows of carpals present</td>
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<td></td>
<td>Base of thumb</td>
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<td>Lateral view</td>
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<td>Alignment of radius, ulna, lunate, and distal carpals</td>
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<td>Dorsum (for triquetral fracture)</td>
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<tr>
<th>Hand</th>
<th>AP view</th>
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<td>Fifth metacarpal (boxer’s fracture)</td>
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<td>Base of first metacarpal (Bennett’s or Rolando’s fracture if intra-articular)</td>
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<td>Base of first proximal phalanx (gamekeeper’s thumb)</td>
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<td>Proximal interphalangeal joints, dislocations</td>
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<td>Distal phalanx, tuft fracture</td>
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<td>Lateral view</td>
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<td>Base of phalanges (volar plate fracture)</td>
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AP, Anteroposterior; PA, posteroanterior.
seen in its entirety as it traverses the blade of the scapula, and with any additional question a Y-view x-ray or a CT
scan may be useful.

Fractures of the mid humerus or proximal humerus present few problems in radiographic interpretation and thus are not considered further.

**Acromioclavicular Separation**

In this injury, superior dislocation of the distal clavicle occurs relative to the acromion (Fig. 8-48). Because the clavicle is slightly anterior relative to the acromion, if the patient is leaning back when the radiograph is taken, it sometimes looks as though a separation exists when none is present. If you have any question, a single view that includes both shoulders often is useful. Sometimes AP x-rays of the shoulders with the patient holding weights in both hands are ordered to see if this will accentuate a separation, but in practice this is rarely necessary.

**Dislocations**

More than 95% of shoulder dislocations occur with anterior dislocation of the humeral head relative to the glenoid. This is in contrast to the hip, in which the vast majority of femoral head dislocations are posterior. In an anterior shoulder dislocation the humeral head usually is seen to be inferior to the glenoid on the AP projection with medial displacement of the humeral head from its normal position relative to the glenoid (Fig. 8-49). As mentioned earlier, on the oblique view of the shoulder (the Y view), the humeral head should sit over the central portion of the “Y.” A Y view will clearly show the anterior and inferior dislocation of the humeral head (Fig. 8-50).

Three specific abnormalities may be found in addition to the dislocation. As a dislocation occurs, there is sometimes a fracture of a portion of the humeral head or of the glenoid. Some physicians relocate a dislocated shoulder without obtaining a prereduction image. If you do this, and the postreduction image demonstrates a fracture, the patient may accuse you of having been responsible for the fracture during the reduction. The second abnormality occurs in patients who have had repeated dislocations. Chronic trauma caused by interaction of the inferior edge of the glenoid with the humeral head produces a deformity or groove in the posterior lateral portion of the humeral head, known as a *Hill-Sachs deformity* (Fig. 8-51). This is best seen on the AP view with the arm internally rotated. Another abnormality occurring as a result of multiple anterior dislocations is a defect in the bone at the anterior inferior aspect of the glenoid rim (Bankart lesion).

Posterior shoulder dislocations are rare, and they are quite tricky to identify on a standard AP view of the shoulder. Remember that with internal rotation the humeral head on the AP projection is typically like the top half of a sphere. In a posterior shoulder dislocation the humeral...
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Superolateral aspect of the humeral head (Fig. 8-53). The major form of degenerative change is posttraumatic or degenerative arthritis. Because the glenohumeral joint is off axis relative to an AP x-ray beam, minimal joint-space narrowing is not easily evaluated. However, if the changes are severe enough (Fig. 8-54), it is easy to see that the joint is narrowed. Typically, associated sclerosis and often spurring and deformity of the humeral head and the inferior aspect of the glenoid are found. Degenerative change also includes rotator cuff tears. This is suspected when pain occurs with abduction and weakness at more than 60 degrees. If pain persists after 6 weeks of nonsteroidal

Shoulder Pain and Degenerative Changes

Most shoulder pain is due to degenerative change or degenerative arthritis. A degenerative change that can be seen on the plain x-ray is calcification of tendons. This usually appears as amorphous white densities over the superolateral aspect of the humeral head (Fig. 8-53). The head simply does not appear to be rounded (Fig. 8-52), and a slightly increased space is seen between the humeral head and the glenoid. The Y view will clearly show you the posterior dislocation.

**FIGURE 8-50** Anterior dislocation on the Y view. **A**, On the Y view the humeral head (H) is clearly anterior and inferior to the intersection of the “Y” of the scapula (arrow). **B**, After relocation the humeral head overlaps the “Y” formed by the scapula.

**FIGURE 8-51** Complications of shoulder dislocation. **A**, In a patient with an anterior dislocation of the humeral head (H), a fracture fragment arising from the humerus (arrow) can be identified. **B**, In a different patient, chronic anterior dislocations have caused a marked Hill-Sachs deformity, seen as a groove in the upper outer portion of the humeral head (arrows). G, Glenoid.
FIGURE 8-52 Posterior dislocation of the humeral head. A, An anteroposterior view of the shoulder initially looks fairly normal. However, an increased space (double-ended arrow) is present between the humeral head (H) and the glenoid (G); the fact that the humeral head is not spherical (dotted line) is another clue. B, On the Y view of the shoulder the humeral head can clearly be seen to be displaced posteriorly relative to the central portion of the “Y” formed by the scapula (arrow).

FIGURE 8-53 Calcific tendinitis. Small clumps of amorphous calcification can be identified over the superior and lateral portion of the humeral head (arrows).

antiinflammatory drug (NSAID) therapy and supervised physical therapy, and if surgery is contemplated, MRI is indicated. Rotator cuff tears are best visualized by using MR scanning. With the tear there may be a narrowing of the acromiohumeral space to less than 6 mm, an eroded inferior aspect of the acromion, and abnormal communication of the joint space with the subdeltoid bursa.

Tumors

Of the number of lesions that can be found in the shoulder, one of the most common benign tumors is the unicameral bone cyst (Fig. 8-55). This expansile, lytic, well-demarcated lesion almost always occurs in the proximal portion of the humerus in children or young teenagers. It probably is not a true cyst but may be the sequela of trauma or an intraosseous hematoma. It is usually discovered incidentally or when a fracture occurs through the weakened bone. As the child grows, the cyst usually becomes smaller and appears to progress down the shaft of the bone. Actually, it stays
in the same place but appears to move with time because of the longitudinal bone growth that occurs at the epiphyseal plate.

Malignant lesions also develop in the shoulder. Because the scapula is a flat bone, Ewing’s sarcoma can occur here. Remember that the proximal humerus is the third most frequent site of osteogenic sarcoma in children. This lesion is discussed further in the section on the knee, because the knee is a more common location.

Infection

Septic arthritis of the shoulder is seen initially as swelling of the shoulder joint with an effusion, followed by cartilage destruction and then bony destruction of both the glenoid and the humeral head. Early changes may be only widening of the joint space due to fluid or pus in the joint space. If there is a question, the joint is usually aspirated. The later changes are easily visible on a standard x-ray.

ELBOW

Normal Anatomy and Imaging

Most x-ray examinations of the elbow relate to trauma. The normal images obtained include an AP and oblique view with the elbow extended and a lateral view with the elbow flexed at 90 degrees (Fig. 8-56). The lateral view is the most promising to look for pathology in the elbow. A small dark area is seen just anterior to the distal humerus. This is the anterior fat pad, and, although it is normal to see this, it should be right up against the bone. A posterior fat pad is never seen normally. In a teenager, lack of fusion of the normal epiphyses and presence of apophyses can cause confusion. The last areas of fusion include the radial head and the medial epicondylar apophysis, which are located on the medial aspect of the elbow. In addition, an olecranon apophysis can be seen on the lateral view (Fig. 8-57). Normally these apophyses are not mistaken for fractures if you realize that they have well-defined margins without sharp edges and that the anterior fat pad is in normal position and a posterior fat pad is not seen.

Trauma

As mentioned earlier, the place to begin looking for traumatic injuries in an adult is on the lateral view. Immediately look for the anterior fat pad, which should lie against the anterior portion of the distal humerus. Anterior displacement of the fat pad is often referred to as the sail sign. This is because, when it is pushed forward by an effusion or hemorrhage, it resembles the spinnaker on a sailboat.
When you see either anterior displacement of the anterior fat pad or any visualization whatever of the posterior fat pad, you should indicate that a fracture is likely to be present, even if you do not see it on any of the views. Sometimes repeating the examination 7 to 10 days later will allow decalcification of the fracture to occur so that it will be more easily seen.

The most common fracture of the elbow seen in the adult is a radial head fracture (Fig. 8-58). Less common are fractures of the coronoid process of the ulna (Fig. 8-59) and fractures of the olecranon. Olecranon fractures are typically caused by falling directly on the elbow when it is flexed. Orthopedic hardware used to fix elbow injuries includes screws, wire, and fixation pins (Fig. 8-60). In evaluation of postreduction and postfixation images, look at alignment and residual angulation to see that healing occurs across the fracture, that the wires and screws have not migrated, and, finally, that no increasing lucency or
dark areas are present around either the screws or the pins to suggest osteomyelitis or loosening.

**FOREARM**

Typical normal views of the forearm are obtained in AP and lateral projections. If you suspect trauma or abnormalities of either the elbow or the wrist, a forearm view alone is not satisfactory. You should order forearm views only when you think that the abnormality is in the middle portion of either the radius or the ulna.

**Trauma**

Traumatic injuries are, by far, the most common reason for ordering forearm x-rays. Of the three classic fractures that you should be aware of, the first is the nightstick fracture, a single fracture through the midportion of the ulna (Fig. 8-61). It is called the *nightstick fracture* because it usually occurs when an individual raises his or her arm to protect against being hit with a stick. A direct blow to the upraised and slightly flexed forearm means that the impact of the stick will be directly on the midportion of the ulna, causing a fracture. Fractures of the forearm often heal by a simple reduction and casting, although occasionally a compression plate and fixation screws are used. In a compression plate the holes for the screws are somewhat elliptical, and

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**FIGURE 8-59** Coronoid fracture. The anteroposterior view in this patient looked normal; however, on the lateral view the coronoid process of the ulna has a lucent (dark) fracture line extending through it (arrows).

**FIGURE 8-60** Olecranon fracture. A, The initial lateral view of this patient who fell directly on the elbow demonstrates a fracture line extending into the joint space (arrows). B, In a different patient an olecranon fracture has been repaired by using two fixation pins and a tension wire. This patient also had a supracondylar fracture, accounting for the screws in the distal humerus.

**FIGURE 8-61** Nightstick fracture. A, An anteroposterior view of the forearm demonstrates a single fracture across the midportion of the ulna (arrow). This is called a *nightstick fracture* because it occurs when the person lifts the forearm to protect against being hit with a stick. B, In a different patient with a much more severe fracture of the radius and ulna, the fracture has been fixed by using a plate and screws. Notice the asymmetric holes in the plate, which allow compression of the fracture fragments.
this allows placement of the screws in such a manner that the ends of the fracture will be compressed together.

The two other classic (although uncommon) fractures of the forearm include the Monteggia fracture of the proximal ulna with dislocation of the radial head (Fig. 8-62). The dislocation of the radial head can be missed unless you realize that the radius and radial head should point toward the capitellum. The usual mechanism of this fracture is falling forward while carrying weight in the hands, such as a load of books. During the fall a direct blow is delivered to the ulna by a sharp object, such as the corner of a stair. The weight of the body is transmitted down the humerus to the elbow while the weight of the books is in the hands, and the corner of the stair is a fulcrum located at the proximal portion of the forearm between the two weights. The Galeazzi fracture is a fracture of the distal radius with dislocation of the ulnar head from the wrist joint (Fig. 8-63). The mechanism is somewhat similar to that of a Monteggia fracture, but with the fulcrum located more distally.

HAND AND WRIST

Normal Anatomy and Imaging

The typical views obtained when either hand or wrist x-rays are ordered are AP, oblique, and lateral (Fig. 8-64). Usually these are done for assessment of trauma or degenerative changes. The wrist has many little bones that have

FIGURE 8-62 Monteggia fracture/dislocation. A, The lateral view of the elbow shows a fracture of the ulna (U) that occurs at the direct point of impact (large white arrow) and dislocation of the radial head from its normal position (curved black arrow). B, On the anteroposterior projection the ulnar fracture is clearly identified, but the radial head dislocation is impossible to see. H, Humerus; R, radius.

FIGURE 8-63 Galeazzi fracture. A, A lateral view of the distal aspect of the forearm shows a fracture of the distal radius (R) and ulnar dislocation from the normal axis of the wrist (arrow). B, On the anteroposterior projection, only the radial fracture is seen. U, Ulna.
unusual shapes and that overlap. Examination of the wrist on the AP view begins with examination of the distal radius and ulna, particularly the styloid processes of each. Next, examine the two rows of carpals (the proximal row is crescentic). The carpal joint spaces are usually quite uniform, and you should look across the carpal/metacarpal and interphalangeal joints in a sequential process.

Wrist Pain

Carpometacarpal osteoarthritis usually occurs at the base of the thumb, and patients have pain and swelling or enlargement at the affected joint. Plain x-rays are indicated, and symptomatic patients have abnormal images with sclerosis, joint-space narrowing, and spur formation. Wrist pain also may be due to chronic ligamentous injury, usually involving the fibrocartilaginous complex. Tenderness, dorsal and volar subluxation at rest, and pain with stress are found. If pain persists after 6 weeks of NSAID therapy and a wrist splint, MRI may be indicated. Carpal tunnel syndrome is a compression neuropathy with loss of sensation in the tips of the first three digits and forearm and wrist pain. Physical examination and medical history are often diagnostic. Nerve-conduction velocity tests are indicated but not imaging. Similarly, imaging is not needed for evaluation or treatment of an uncomplicated dorsal ganglion.

Trauma

A subtle fracture often becomes more apparent on an x-ray a week or so after the initial injury (Fig. 8-65). The reason is that, in the early stages of a fracture, hyperemia occurs, which is accompanied by resorption of calcium along the fracture line. This is why radiologists will sometimes indicate that, although they do not see a fracture on a particular examination, if pain persists, a repeated view in 7 to 10 days may be useful. A second phenomenon is a more general loss of calcium and coarsening of the trabecular pattern in bones around a joint that has a fracture. This process may occur over several weeks and is the result of disuse osteoporosis (Fig. 8-66). Sometimes, even with minor trauma, joint pain can persist for months with associated vasodilatation. This is termed reflex sympathetic dystrophy (RSD). The radiographic manifestations are focal osteoporosis and a coarse trabecular pattern, in an articular and periarticular distribution (Fig. 8-67).

Common fractures of the wrist include the Colles fracture, a fracture of the distal radius with dorsal angulation of the distal fragment and an associated fracture of the ulnar styloid (Fig. 8-68). The mechanism of injury is typically falling on an outstretched hand with the palm facing down. A Smith’s fracture is essentially a reverse Colles’ fracture, with the distal radial fragment angulated toward the palmar surface (Fig. 8-69).

The most common fracture of the carpal bones is a fracture of the midportion of the carpals navicular. The navicular has an unusual blood supply. The arteries supply the more distal aspect of the bone and then circle back to the more proximal portion. A fracture through the midportion of the navicular can disrupt the blood supply to the proximal portion and cause aseptic necrosis. When this occurs, the proximal portion of the navicular becomes dense or white relative to the rest of the carpal bones (Fig. 8-70).

An injury that can result from impaction of the distal radius and the carpal bones is disruption of the ligaments between the navicular and the lunate. Sometimes this can be a subtle finding, but remember that the space between the distal radius and the carpal bones should be about the same as the distance between the lunate and the navicular. If you have a question as to whether this space is widened, an AP image of the other wrist can be used for comparison (Fig. 8-71). Tenderness over the dorsal aspect of the wrist should raise the possibility of a triquetral fracture. This fracture is usually seen only on
FIGURE 8-65 Increasing fracture visibility with time. A, Initial posteroanterior view of the wrist shows a longitudinal fracture with intra-articular extension (arrows). B, A radiograph obtained 1 week later with fixation pins in place shows that the fracture line is much more evident owing to interval decalcification, which is a normal process. This may make fractures much more visible a week or so after the injury than on the initial images.

FIGURE 8-66 Interval disuse osteopenia. A, An initial radiograph demonstrates fractures of the distal radius (R) and ulnar styloid (arrows). The carpal bones are well mineralized and clearly delineated. B, A repeat image 3 weeks later shows marked resorption of calcium in a periarticular distribution (between the dotted lines). This is due to disuse and increased blood flow. U, Ulna.

the lateral view and may be just a small avulsion fragment (Fig. 8-72).

Major falls can cause either lunate or perilunate dislocations of the carpal bones. The key to initial recognition of these dislocations on the AP view is that you no longer see a distinct proximal crescentic row of carpal bones and then a distal row. The lateral view usually makes the type of dislocation reasonably clear. In perilunate dislocation the lunate is in normal position at the end of the radius, but the remainder of the carpals are dislocated dorsally and are usually overriding with some shortening of the wrist (Fig. 8-73). In a lunate dislocation the rest of the carpals remain in a line along the axis of the radius; however, the lunate is usually rotated and dislocated toward the palmar surface (Fig. 8-74). Trauma of the lunate also can result in aseptic necrosis. This is typically referred to as Kienböck’s malacia.
FIGURE 8-67 Reflex sympathetic dystrophy (RSD). A, A radiograph in this patient who had relatively minor forearm trauma does not demonstrate any abnormality. B, The patient continued to complain of pain over the next 2 months, and another image of the wrist shows periarticular and carpal decalcification (between the dotted lines) due to increased blood flow. The exact cause of RSD is debatable.

FIGURE 8-68 Colles' fracture. A, An impacted distal radial fracture and a fracture of the ulnar styloid (white arrows) are identified on the posteroanterior view in this patient who fell on the outstretched hand. B, The lateral view of the wrist shows dorsal displacement and angulation (black arrow) as well as some impaction of the distal radius. If the fracture of the distal radius extended into the joint, it would be termed a Barton’s fracture. R, Radius; U, ulna.
FIGURE 8-69 Smith’s fracture. A, An anteroposterior view of the wrist shows an impacted fracture of the distal radius (white arrows). B, The lateral view shows volar displacement of the distal fragment (black arrow). If the fracture extended into the articular surface, it would be called a reverse Barton’s fracture.

FIGURE 8-70 Scaphoid or navicular fracture. A, A posteroanterior view of the wrist in a patient who fell on his outstretched hand shows a lucent line (black arrows) extending through the midportion of the navicular. B, A later complication in this patient is aseptic necrosis of the proximal fragment (large arrow). Note that this fragment has maintained normal mineralization because the blood supply has been interrupted. In contrast, the distal fragment (small arrow) and the remainder of the carpal bones demonstrate loss of calcium due to hyperemia and disuse after the fracture.
FIGURE 8-71 Scapholunate disassociation. A, A posteroanterior view of the wrist demonstrates a widened space between the navicular (N) and the lunate (L) (arrows) due to ligamentous disruption from an impaction injury. B, A normal wrist shows that the typical distance between the navicular and lunate (arrows) should be about the same as that between the navicular and the radius.

This may occur as a result of repeated minor traumas or one episode of trauma. The entity is recognized by irregularity and increased density of the lunate relative to the other carpal bones (Fig. 8-75).

HAND

Normal Anatomy and Imaging

Images of the hand and fingers taken for trauma should include AP, lateral (see Fig. 8-64), and oblique views. If the clinical issue is related to arthritis, single PA view of both hands is all that is needed. A relatively common finding in the hand involves shortening of a metacarpal, typically the fourth (Fig. 8-76). This is usually a normal variant, but the differential diagnosis includes Turner’s syndrome, pseudohypoparathyroidism, and a few other much less common entities.

Trauma

Plain x-rays of the hands may be taken for evaluation of foreign bodies. The most common are glass, pencil lead, metallic slivers, and pieces of wood. Glass is usually somewhat radiopaque and can be recognized by its very sharp corners or a geometric shape (Fig. 8-77). Metallic fragments are, of course, easy to spot, because they are so dense. Wood and pencil lead are typically not visible on an x-ray. Pencil lead is not visible because it is actually graphite and not lead.

Two relatively frequent fracture sites are found in the metacarpals. The most common of these is a fracture of
FIGURE 8-73 Perilunate dislocation. A, A posteroanterior view of the wrist does not show the normal two crescentic rows of carpal bones but rather shows significant overlap of the hamate (H) and the lunate (L) as well as the capitate (C) with the navicular (N). B, A lateral view shows that the lunate remains in alignment with the end of the radius (R), but the remainder of the carpal bones have been dislocated dorsally (arrow). U, Ulna.

FIGURE 8-74 Lunate dislocation. A, On the posteroanterior view of the wrist, significant overlap is seen of the capitate (C) and navicular (N) as well as the hamate (H) and the lunate (L). Furthermore, clear overlap appears between the navicular and the radial styloid. All these findings suggest dislocation. B, On the lateral view the carpal bones remain in alignment with the distal radius (R), but the lunate has rotated and dislocated in the palmar direction (arrow). U, Ulna.

The distal fifth metacarpal (the boxer’s fracture). The head of the fifth metacarpal is angled toward the palmar surface and may be somewhat impacted (Fig. 8-78).

The second common location for hand fractures is the base of the thumb. Bennett’s and Rolando’s fractures are triangular fractures of the base of the first metacarpal, with extension into the articular surface. Oblique fractures of the first metacarpal base may not extend into the joint (Fig. 8-79). Another rather classic fracture of the thumb is an avulsion fracture of the base of the proximal phalanx. Although this is called a gamekeeper’s thumb, a common mechanism of injury is getting a ski pole caught in the snow with the thumb being pulled backward.

Fingers not only can be fractured but also can be dislocated. Often, on PA projection dislocation cannot be appreciated except as slight joint-space narrowing and soft tissue swelling; however, on the lateral view the dislocation is usually obvious (Fig. 8-80). All dislocations are clinically
FIGURE 8-75  Aseptic necrosis of the lunate. A posteroanterior view of the wrist shows irregularity and increased density or sclerosis of the lunate (arrow), also referred to as Kienböck’s malacia.

FIGURE 8-76  Short fourth metacarpal. Although this can be a normal variant, it also has been associated with Turner’s syndrome, sickle cell disease, infections, and some metabolic bone diseases, such as pseudohypoparathyroidism.

FIGURE 8-77  Glass within the soft tissue of the hand. Most glass has enough density that it is radiopaque and can be recognized by the sharp corners (arrows) and the patient history. Remember that objects made of either wood or graphite usually are not visible on a radiograph.

FIGURE 8-78  Boxer’s fracture. This hand radiograph was obtained on a teenager who had hand pain after punching a wall. The fracture usually occurs at the neck of the fifth metacarpal, with volar angulation of the distal fragment. Contrary to its name, it is not often seen in professional boxers.
obvious, but if an unusual associated deformity or angulation is seen, it may be useful to get a prereduction image to see whether an associated fracture is present.

In children, fractures about articular surfaces can occur in a variety of ways. They may involve only the epiphyseal plates or various combinations of the epiphyseal plate and the metaphysis. The Salter-Harris classification, shown schematically in Figure 8-81, is used for describing childhood fractures about most joints. A Salter-Harris type II fracture of the fifth digit is shown in Figure 8-82. Another relatively common fracture of the fingers involves the base of the middle phalanx on the palmar surface. This small avulsion fracture is referred to as a volar plate fracture (Fig. 8-83). It is easily missed unless you look carefully at the lateral view. Of course, fractures of the terminal tuft of the distal phalanges occur frequently from people slamming their fingers in doors and other objects. These are quite obvious on the x-ray.

Infection

Infections are quite frequent in the hands and the feet. Often the clinical problem is differentiating between cellulitis, osteomyelitis, and septic arthritis. When the x-ray shows destruction of a single joint space with involvement of the bone on both sides of the joint, septic arthritis should be considered (Fig. 8-84). Osteomyelitis usually is radiographically identified by soft tissue swelling, lucent or destructive areas within the bone itself, or focal periosteal reaction. An illustration of osteomyelitis of the foot appears later (see Fig. 8-163). With cellulitis, only soft tissue swelling occurs without bone or joint changes. An infection of a distal phalanx in a gardener should raise the possibility of sporotrichosis.

Arthritis

Evaluation of the hands for arthritis can provide some general ideas about the type of arthritis, although commonly a number of patients have laboratory findings of rheumatoid arthritis that conflict with the x-ray appearance, which resembles degenerative arthritis. The reverse
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FIGURE 8-81 Salter-Harris classification of epiphyseal fractures in children. A type I fracture is straight across the epiphyseal plate and may have some lateral displacement of the epiphysis. This occurs 5% of the time. A type II fracture involves a portion of the epiphyseal plate and a corner fracture through the metaphysis. This occurs 75% of the time. A type III fracture involving part of the epiphysis occurs only about 10% of the time. A type IV fracture involving part of the epiphysis and part of the metaphysis occurs about 10% of the time. A type V fracture is direct impaction and has the most serious consequences for further growth.

FIGURE 8-82 A Salter-Harris type II fracture of the fifth proximal phalanx.

FIGURE 8-83 Volar plate fracture. This fracture is seen only on the lateral view and is a small avulsion fracture (arrow), most commonly occurring at the base of the middle phalanx.

Also is true. Thus the radiographic diagnosis should not be leaned on too heavily.

Rheumatoid arthritis (RA) occurs most frequently in female patients, and they initially are seen with morning stiffness, swelling of one or more joints, and subcutaneous nodules. General radiographic findings of RA include narrowing of the carpal joints, subchondral cysts, and erosion of the bones at the lateral edges of the joints. Patients with clinically obvious RA can often have normal-looking images of the hand and then undergo rapid progression. In addition to the findings already described, ulnar deviation at the metacarpophalangeal joints is relatively characteristic (Fig. 8-85), but it can occasionally occur with systemic lupus erythematosus. Any arthritis but RA can be seen with normal mineralization of bones. Diffuse osteoporosis is mostly seen with RA, but periarticular demineralization also is quite common.

In advanced RA the patient’s hands may develop the boutonnière deformity, which is hyperextension of the distal interphalangeal (DIP) joint and flexion in the proximal interphalangeal (PIP) joint. Another deformity is almost the reverse of this. The swan neck deformity can result from hyperextension of the PIP joint and flexion of the DIP joint. If the metacarpophalangeal joints have been completely destroyed, it is possible to replace these with silicone prostheses.

Findings of RA in other bones include penciling or erosion of the distal clavicle and narrowing and erosions of the shoulder, hip, and knee joints, as well as atlantoaxial subluxation. Finally, a widened space between the carpal lunate and navicular bone can be seen (the Terry Thomas sign). Remember that these patients also can have interstitial lung changes, pulmonary nodules, and various forms of carditis.

When an arthritis involves DIP joints with relative sparing of the proximal ones, erosive osteoarthritis and psoriatic arthritis become the more likely diagnoses (Fig. 8-86). Pseudogout can cause calcification within cartilage.
It causes a lucent area in the central portion of the shaft with some expansion and inner table thinning of the cortex. Pathologic fractures through these areas may occur as a result of the bone thinning (Fig. 8-88).

PELVIS

Normal Anatomy and Imaging

When you order a plain x-ray of the pelvis, only an AP view normally is obtained. On the AP view, clear
demonstration exists of the iliac wings, ischium, pubis, and both hips, as well as the lower lumbar spine. You should be able to look at the image and determine not only whether the person is male or female but also the general age of the patient. The inlet of the male pelvis is generally somewhat triangular (Fig. 8-89), whereas the female pelvis has a much more ovoid shape (Fig. 8-90). Occasionally the genitalia are included on the image.

The general age of the patient is ascertained by the presence or absence of degenerative changes in the lower lumbar spine and hip joints. In children, incomplete fusion of the acetabulum is present; in slightly older children, you

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**FIGURE 8-86** Psoriatic arthritis. Involvement of the distal and proximal interphalangeal joints is most common. Asymmetric changes also are common. Erosions can be aggressive and usually involve the intra-articular joint spaces.

**FIGURE 8-87** Calcium pyrophosphate deposition disease. Acute synovitis, sometimes called pseudogout, may be found. Here, calcification is seen in the cartilage of the wrist (arrows).

**FIGURE 8-88** Enchondroma. A lucent lesion in a metacarpal or phalanx is most likely to be an enchondroma. It may be somewhat expansile (arrows), and fracture may be noted through the area of weakened bone. A healing fracture with some periosteal reaction is seen in the midportion of this lesion.

**FIGURE 8-89** Normal anatomy of the teenage male pelvis. Note the generally triangular (android) shape of the pelvic inlet.

**FIGURE 8-90** Normal anatomy of the adult female pelvis. Note the general ovoid (gynecoid) shape of the pelvic inlet.
will be able to see clearly the apophysis of the greater trochanter and the epiphyseal plate of the hip. In the middle to late teens, an apophysis appears on the iliac crest and on the inferior ischium (Fig. 8-91). Although these apophyses can sometimes be mistaken for avulsion fractures, the symmetry from one side of the pelvis to another and their location are usually enough to identify them clearly. Several normal variants or results of common conditions are found. These are symmetric sclerotic areas (white) about the pubis or the sacroiliac (SI) joint. These

are essentially normal findings and occur much more commonly in women, probably as the result of pelvic widening during childbirth (Fig. 8-92).

**Trauma**

A number of traumatic lesions can occur in the pelvis. A relatively common, and probably inappropriate, examination to order is a view of the coccyx. Demonstration of a

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**FIGURE 8-91** Normal apophyses. During the midteen and late teen years, an apophysis can be seen over the iliac crest (A; arrows) and along the inferior aspect of the ischium (B; arrows). These should not be mistaken for avulsion fractures.

**FIGURE 8-92** Benign sclerotic pelvic lesions. A, Osteitis condensans pubis with sclerosis along both sides of the pubis (arrows). This condition commonly occurs in women and is believed to be the result of childbirth trauma. This image is from a postvoid view of an intravenous pyelogram, accounting for the contrast in the bladder and left ureter. B, Osteitis condensans illi is seen in a different patient as sclerosis lateral to both sacroiliac joints (arrows).
coccx fracture does not change treatment. When a pelvic fracture is suspected, an AP x-ray is the initial view to order. You should examine the symphysis pubis. A widening of the symphysis of more than 1 cm is definitely abnormal. If the symphysis is widened, also look for widening of one of the SI joints (Fig. 8-93) or the sacrum itself (Fig. 8-94). The reason is that the pelvis is essentially a bony ring, and it is difficult to widen it or break it in one place without causing a traumatic injury elsewhere. Many pelvic fractures are accompanied by internal pelvic hematomas. When a fracture in the pubic region is identified, you should exclude urethral and bladder injury. A cystogram is often performed to rule out bladder rupture. Sometimes the resultant hematoma is large enough to displace the bladder superiorly and laterally (Fig. 8-95).

**FIGURE 8-93** Pelvic fracture. Marked diastasis of the pubis (white arrow) and widening of both sacroiliac joints is present, but the right is greater than the left (black arrows). Whenever the pelvic ring is interrupted (as in this case), the fracture is unstable.

**FIGURE 8-94** Pelvic and sacral fracture. An anteroposterior image of the pelvis (A) clearly shows a left lower pelvic fracture. Not initially obvious is a sacral fracture. Note that the sacral arcuate lines are intact on the right (dashed line), but they are discontinuous on the left. The fracture is confirmed on a computed tomography scan (B) of the pelvis (arrows).

**FIGURE 8-95** Fracture of the acetabulum. An anteroposterior view of the pelvis (A) clearly shows the corners of the fracture (arrows) as well as a hematoma (H) displacing the bladder (B) to the right. To see the exact nature of the acetabular injury, often a computed tomography scan (B) is required; in this case it shows a complex fracture involving both the anterior and the posterior portions of the acetabulum.
Benign Lesions

Paget’s disease is a common benign lesion of the pelvis, usually with involvement of only the right or left half of the pelvis. The iliopectineal line becomes thickened; coarsening of the trabecular pattern is seen; and the bone expands as the cortex becomes thickened (Fig. 8-96). If a nuclear medicine bone scan is done, markedly increased blood flow to the bone will result in increased radioactivity in the affected areas. A generalized coarse trabecular pattern and patchy sclerosis of the whole pelvis and other bones can be due to renal failure. A diffuse increase in bone density can occur as a result of myelofibrosis, fluoride poisoning, osteopetrosis (“marble bone” disease) (Fig. 8-97), or diffuse sclerotic metastases.

Malignant Lesions

Gas within the bowel commonly projects over the pelvic bones. These gas bubbles can sometimes be difficult to tell from a lytic bone lesion. If a question remains, oblique views will show the gas rotating anteriorly. True focal lesions of the flat bones of the pelvis are often malignant. The differential diagnosis depends to a large extent on the age of the patient. In a young patient you may suspect Ewing’s sarcoma (Fig. 8-98). Chondrosarcomas tend to arise in the pelvis of adults. On an x-ray these tumors often have cauliflower or popcorn calcifications extending from the bone (Fig. 8-99). In older patients, favorite choices for multiple lytic or destructive lesions are metastases from lung, breast, or renal cell carcinoma and multiple myeloma (plasmacytoma). Dense or sclerotic lesions of the pelvis include metastases from prostate carcinoma (Fig. 8-100) and occasionally breast cancer.

HIP

Images of the hip are done in the AP and frog-leg (abducted) projections. Lateral views usually are difficult to obtain and even more difficult to interpret. You should examine the relation of the femoral head to the acetabulum, look for

FIGURE 8-96 Paget’s disease. A, On an anteroposterior view of the pelvis, enlargement of the left iliac crest with cortical thickening (arrowheads) and sclerosis and thickening of the left iliopectineal line (arrows) can be seen. These findings typically affect only one side of the pelvis. A posterior view from a nuclear medicine bone scan (B) shows markedly increased activity in the left hemipelvis (arrows) as a result of the increased blood flow that occurs in this disease.

FIGURE 8-97 Osteopetrosis. In this disease, also called marble bone disease, an abnormality in osteoclast function occurs. As a result, the bones become very dense or white, but they are almost chalklike and fracture easily. The patient broke his femur by just falling out of bed. Differential diagnoses of uniformly increased bony density would include fluorosis and myelofibrosis.
cortical discontinuities to suggest fractures, and examine the trabecular pattern to look for potential osseous lesions. In young teenagers, notice the apophysis of both the greater and the lesser trochanter. Children younger than 10 or 12 years will not have fusion of the midportion of the acetabulum (Fig. 8-101).

**Hip Pain**

Acute hip pain can be due to inflammatory arthritis, septic arthritis, trauma, and tumors. These entities were discussed earlier. Chronic hip pain can result from a number of conditions. The most common is degenerative arthritis. Complaints are typically of groin or thigh pain or loss of mobility. Physical examination initially shows a loss of internal rotation, and as the disease advances, external rotation is lost. The initial workup should include plain x-rays, even though symptoms may be present before radiographic changes occur. Conversely, about 90% of persons older than 40 years have degenerative changes of the hip, but only about 30% of them have symptoms. Degenerative changes include joint-space narrowing, subchondral cyst formation, and bone spurs. Advanced imaging...
techniques are usually not needed. Follow-up imaging examinations are indicated if hip rotation has decreased by 20% or more or if function has changed dramatically. Pain in the upper outer thigh and tenderness in the midtrochanteric region should suggest trochanteric bursitis.

Aseptic necrosis of the hip is most commonly manifested by flattening, irregularity, and sclerosis of the superior aspect of the femoral head. It can have a number of causes, and a mnemonic is ASEPTIC. This refers to anemia (sickle cell), steroids, ethanol, pancreatitis, trauma, idiopathic, and caisson disease (Fig. 8-102). The most sensitive imaging study for early aseptic necrosis is MRI. If this is not available, a nuclear medicine bone scan can be used. Late changes of aseptic necrosis with femoral head deformity can easily be seen on plain x-rays.

A common problem associated with a prosthetic hip is pain due to loosening, infection, or dislocation. Dislocations are easily visualized on a plain x-ray examination. Pain may occur with loosening of the prosthesis or infection. If the prosthesis is loose and wiggling, the distal tip moves more than the rest of the shaft. A plain x-ray examination may show thinning of the bone cortex near the tip of the prosthesis. With loosening, a nuclear medicine bone scan shows increased activity near the distal tip of the prosthesis. A nuclear medicine abscess (labeled white blood cells) scan can be ordered to exclude infection.

**Trauma**

Table 8-6 shows the high-yield areas to examine for lower extremity trauma. Dislocations of the hip are usually the result of motor vehicle accidents. By far the most common dislocation is posteriorly, and on the AP image the head of the femur appears to be superiorly and laterally displaced. When the hip is anteriorly dislocated, the femoral

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**FIGURE 8-101** Normal apophyseal structures in a 10-year-old child. **A,** An anteroposterior view of the hip clearly shows the apophysis of the greater trochanter (arrow). **B,** An oblique view shows another apophysis of the lesser trochanter (arrow). Also notice that at this age the acetabulum is not completely fused.

**FIGURE 8-102** Aseptic necrosis of the hips. **A,** Aseptic necrosis can occur from a number of causes, including trauma and steroid use. In this patient an anteroposterior view of the pelvis after intravenous contrast shows a transplanted kidney (K) in the right iliac fossa. Use of steroids has caused this patient to have bilateral aseptic necrosis. The femoral heads are somewhat flattened, irregular, and increased in density. **B,** Aseptic necrosis in a different patient is demonstrated on a magnetic resonance imaging scan as an area of decreased signal in the left femoral head (arrows). This is the most sensitive method for detection of early aseptic necrosis.
head appears inferior and medial to the acetabulum (Fig. 8-103). With any dislocation, associated fracture fragments from the rim of the acetabulum may be found. As the hip is relocated, these small fragments may be caught in the joint space. Sometimes they are difficult to see on a plain x-ray, but if the fragment is in the joint, the distance from the head of the femur to the acetabulum will be widened. CT scanning can be of value in such cases (Fig. 8-104).

Fractures of the hip are most common in the region of the femoral neck and in the intertrochanteric region (Fig. 8-105). Stress fractures of the femoral neck may appear only as an ill-defined sclerotic (white) band extending across the femoral neck. In older persons a hip fracture may be difficult to see because so little calcium exists in the bone.

A number of orthopedic devices are used to fix hip fractures. These include plate and screws or multiple pins through the femoral neck. Prosthetic replacement of the femoral head and neck (Fig. 8-106) is often necessary for degenerative changes. The prosthetic devices may or may not use cement in the femoral shaft. Depending on the degree of degenerative change in the acetabulum, orthopedic surgeons also may use an acetabular component or an articulating (bipolar) section in the prosthetic femoral neck.

**TABLE 8-6 Examination of an X-ray of the Lower Extremity Done for Trauma**

<table>
<thead>
<tr>
<th>Hip</th>
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<tbody>
<tr>
<td>AP and frog-leg view</td>
<td>Widening of joint space</td>
<td>Posterior dislocation (femoral head up and out)</td>
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<td></td>
<td></td>
<td>Anterior dislocation (femoral head in and down)</td>
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<td></td>
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<td>Fractures, femoral neck or intertrochanteric</td>
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<td>Pelvic or acetabular fracture</td>
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<tr>
<th>Knee</th>
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<tbody>
<tr>
<td>AP view</td>
<td>Tibial plateau fracture</td>
<td>Patellar fracture</td>
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<td></td>
<td>Tibial spine fracture</td>
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<td></td>
<td>Lateral view</td>
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<td></td>
<td>Joint effusion above patella</td>
<td>Fat/fluid level in effusion</td>
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<tr>
<td></td>
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<td>Patellar fracture</td>
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<th>Ankle</th>
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<tr>
<td>AP view</td>
<td>Medial and lateral malleolus for soft tissue swelling and fracture</td>
<td>Ankle mortise for asymmetric widening</td>
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<td></td>
<td>Lateral view</td>
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<td></td>
<td>Posterior malleolar fracture</td>
<td>Distal fibular fracture</td>
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<td>Bulging of fat planes about joint (effusion)</td>
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<td>Talar neck for fracture</td>
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<td>Calcaneus for fracture</td>
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<td></td>
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<td>Base of fifth metatarsal fracture</td>
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<th>Foot</th>
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<tr>
<td>AP view</td>
<td>Base of fifth metatarsal fracture</td>
<td>Fracture of distal portions of second to fifth metatarsals</td>
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<td></td>
<td>Widening of the space between the base of the first and second metatarsal base</td>
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<td></td>
<td>Lateral view</td>
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<td>Dislocations of the toes</td>
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**FIGURE 8-103 Hip dislocation.** This patient, who was in a motor vehicle accident, has both an anterior and a posterior dislocation of the hips. Posterior dislocation occurs 90% of the time and is seen here on the left, with the femoral head displaced superior and lateral to the acetabulum. On the right an anterior dislocation appears, with the femoral head displaced inferiorly and medially.

**FIGURE 8-104 Fracture fragment after hip dislocation.** A, In this patient with a posterior right hip dislocation, pain and limitation of motion occurred after relocation. Asymmetric widening is noted on the right between the femoral head and the acetabulum (arrows). No fracture fragment could be seen; however, with a transverse computed tomography scan (B), a bony fracture fragment is seen in the joint space (arrow).
Normal Anatomy

The normal osseous anatomy of the femur is quite obvious and is not discussed here. The normal image projections are AP and lateral. Fractures of the femur also are obvious. As expected, they may be transverse, spiral, or comminuted, with various degrees of angulation and overriding of the fragments.

Benign Lesions

It is important to be able to assess bone lesions and the likelihood of their being benign or malignant. Signs that a bone lesion may be benign are as follows: (1) it is small; (2) it does not have associated reaction of the periosteum; (3) it has a narrow zone of transition between the normal bone and the lesion; and (4) it has a thin, well-defined sclerotic (white) margin.

The bones of the leg are favored places for a benign fibrous cortical defect. These are usually located near but not at the ends of the bones and are usually well marginated. As the name suggests, they are present predominantly in the cortex of the bone rather than having their epicenter in the marrow space (Fig. 8-107). Another lesion, called a nonossifying fibroma, has the same characteristics, but it is bigger. Whether these lesions are truly different or simply a spectrum of the same lesion is unknown.

Fibrous dysplasia usually is a lytic lesion that looks like a hole in the bone. Fibrous dysplasia may present as a single lesion (monostotic) (Fig. 8-108), or it may be in multiple areas throughout the skeleton (polyostotic). It is centered in the marrow cavity and can be single or lobular. Lytic fibrous dysplasia thins the cortex on the inner margins. Most fibrous dysplasia lesions are found in children or young adults. In addition to the lucent, sort of cystic, variety, a form is found in which the bone is diffusely involved and softened. When this happens in the femur, deformity occurs with lateral bowing. This is referred to as a shepherd’s crook deformity.

Amorphous or scattered calcifications projecting within the marrow space are usually the result of benign lesions, such as enchondroma (Fig. 8-109) or bone infarcts (Fig. 8-110). Bone infarcts are relatively common in patients with sickle cell disease and also can be a result of decompression sickness from diving.
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**FIGURE 8-107** Fibrous cortical defect. This is probably the same lesion as a nonossifying fibroma. These are most commonly seen in the lower extremity of teenagers, particularly the femur and tibia. Here the lesion is lucent and seen to have a sclerotic or dense margin (arrows). These lesions will fill in and become dense with time, and they are clinically insignificant.

**FIGURE 8-108** Fibrous dysplasia. Bone lesions of fibrous dysplasia can be single (monostotic) or multifocal (polyostotic) and represent a benign developmental anomaly with fibrous tissue in the medullary space. Typically there is a very narrow zone of transition between the lesion and normal bone (black arrow), and the lesion may scallop or thin the normal cortex from the inner side (white arrows). The bone also may be slightly expanded.

**FIGURE 8-109** Enchondroma. This lateral view of the knee shows a dense lesion that is somewhat amorphous and projects within the medullary space of the bone (arrows). A well-defined lesion such as this is most likely an enchondroma, although a low-grade intramedullary chondrosarcoma also must be considered.

**FIGURE 8-110** Bone infarcts. Diffuse and amorphous calcification within the medullary space is seen here in the distal femur. Bone infarcts such as this can occur in patients with sickle cell disease or as a result of decompression sickness after underwater diving accidents.
Infections also can cause periosteal reaction. Osteomyelitis that has been present for several weeks can cause minimal periosteal reaction, and chronic osteomyelitis that has been present for months and years can cause a florid calcified periosteal reaction (Fig. 8-112).

Malignant Lesions

A lytic (destructive) lesion of bone that does not have a sclerotic margin in an adult should be regarded as a malignancy until proven otherwise. Breast cancer, lung cancer, and a host of other neoplasms commonly produce lytic lesions of bone. A number of primary bone lesions can produce this appearance, including plasmacytoma and eosinophilic granuloma.

Chondrosarcomas tend to occur in the femur, pelvis, and ribs. In the femur they are most common in the metaphysis. They can be variable in appearance from purely destructive, destructive with a chondroid (irregular calcification) matrix, to exostotic, or projecting from the cortex of a bone. The mean age for occurrence is 40 to 45 years.

Even if a patient has known metastatic disease elsewhere, it is important to identify metastatic sites in the pelvis and lower extremities. This is because these sites are weight bearing and are susceptible to pathologic fractures that can disable the patient (Fig. 8-111). Early detection can allow placement of a medullary rod or radiation therapy, which will allow a terminally ill patient to ambulate rather than being bedridden for the remaining months of life.

Periosteal Reaction

Periosteal reaction can be due to either benign or malignant lesions. Obviously, local periosteal reaction will be seen about a healing fracture. However, this is normally obvious and does not cause any confusion in interpretation. Generalized periosteal reaction can occur along the long bones of the extremities in patients with lung cancer. This condition is known as hypertrophic pulmonary osteoarthropathy. The reason for the periosteal reaction is unclear.

Infections also can cause periosteal reaction. Osteomyelitis that has been present for several weeks can cause minimal periosteal reaction, and chronic osteomyelitis that has been present for months and years can cause a florid calcified periosteal reaction (Fig. 8-112).
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Normal Anatomy

The normal imaging projections that are obtained of the knee are AP and lateral views (Fig. 8-115). The lateral view is taken with the knee partially flexed. The AP view is important for assessing whether joint-space narrowing is present. This view also will show whether calcification of the cartilage has occurred in the joint space. Sometimes the tibial plateaus are at slightly different angulations so that the x-ray beam does not go horizontally through both medial and lateral compartments.

Two special views of the knee are commonly requested. The first of these is the sunrise view, a tangential view of the anterior portion of the flexed knee, looking from the top down. The advantage of this view is that the relation of the patella to the anterior femur is clearly shown. Another view is the tunnel view. In this the knee is flexed more than on the routine lateral view, and the x-ray beam is directed horizontally across the tibial plateau through the “tunnel” created by the femoral condyles. This affords a very good look at the anterior and posterior tibial spines as well as the femoral condyles.

Myositis Ossificans

Calcification can occur in soft tissues. The muscles of the thigh are particularly prone to trauma, and bleeding within the soft tissue can subsequently calcify. This condition is referred to as *myositis ossificans* (Fig. 8-114) and may require surgery after the calcification has matured.

FIGURE 8-113 Osteogenic sarcoma of the knee. A lateral view of the knee (A) in a 19-year-old man shows a sunburst type of periosteal reaction (arrows). Knowing that the distal femur is the most common site of osteogenic sarcoma, that periosteal reaction is a feature, and that this patient is a teenager should make osteogenic sarcoma high on your differential diagnostic list. Another common presentation (B) is a predominantly destructive central lesion, seen here in the distal femur of an 8-year-old girl.

In young patients (age 5 to 20 years), periosteal reaction in the midportion (diaphysis) of a long bone should raise the suspicion of a Ewing’s tumor; if located around the joint such as the knee, it should raise the suspicion of an osteogenic sarcoma (Fig. 8-113). Sunburst (radiating) type of periosteal reaction is particularly worrisome for malignancy.

FIGURE 8-114 Myositis ossificans. The soft tissues of the thigh are a common location for blunt traumatic injury. In this case, dystrophic calcification has developed within the soft tissue (arrows), significantly limiting the range of motion of this young soccer player.
Knee Pain and Degenerative Changes

The diagnosis of chronic meniscal tear is based on a history of pain, knee catching, locking, giving way, snapping, or clicking. On physical examination, tenderness may be found along the joint line and reproduction of the clicking sound by manipulation (McMurray's sign). Radiography is indicated to exclude significant osseous injury. With acute meniscal injury, often loss of motion, joint effusion, and acute muscle spasm are found. Again, an x-ray is indicated to exclude a fracture. A difference of opinion exists as to whether to then proceed with arthroscopy or to do an MRI scan. Both approaches are used.

Chronic knee pain may be due to degenerative change. On physical examination, usually limited motion or pain with motion is seen and, unlike RA, no systemic symptoms are noted. Redness or swelling over the joint appears, as well as deformity. Laboratory tests are not needed. Plain

In children the epiphysseal plate of the distal femoral epiphysis and the proximal tibial epiphysis is well seen until at least age 10 years. Complete fusion typically occurs in girls at about the age of 15 years, and in boys, several years later (Fig. 8-116). In teenagers it is important to note on the lateral view that the anterior portion of the proximal tibial epiphysis folds down to form the attachment for the inferior aspect of the patellar tendon. It almost looks like a horn projecting downward from the anterior portion of the proximal tibia, and this is normal. A fairly common normal variant is the fabella. This is a small sesamoid bone in the tendons posterior to the knee joint, easily seen on the lateral view (Fig. 8-117). With MRI the soft tissues, including the tendons, ligaments, and cartilage of the knee, can be exquisitely visualized (Fig. 8-118). Structures of particular interest on these images are those that are commonly involved in trauma, such as the cruciate ligaments and the medial and lateral menisci.
Other signs of degenerative change are small overhanging spurs at the edges of the joints. No other imaging is indicated unless symptoms significantly progress or surgery is planned, and then plain x-rays are again ordered.

Osteochondritis dissecans is a rare but important cause of joint pain, particularly in active adolescents involved in high-impact sports. Usually there is pain and swelling of the joint, which may occasionally lock during movement. It involves focal loss of articular cartilage or subchondral bone due to loss of blood supply. This is most commonly seen in the femoral condyle of the knee. In adolescents it may heal, or the fragments may become loose and move into the joint space. Plain x-ray may be sufficient to make the diagnosis (Fig. 8-120), but it is also easily seen with either CT or MRI.

Occasionally, degenerative changes of the joint can involve disruption of pieces of cartilage that come loose and are a nidus calcification. These calcifications are often within the joint space and can be single or multiple. If they are single, they are called a loose body. If they are multiple and extensive, the condition is termed synovial chondromatosis (Fig. 8-121). Internal derangement of the knee is usually suspected on the basis of clinical findings (clicking, locking, giving way, limitation of motion, or pain with passive range of motion). An MRI is indicated if plain x-rays are nonspecific and only if some form of therapy is anticipated.

**Trauma**

A knee joint effusion is easiest to identify superior to the patella and anterior to the distal femur. You should look...
FIGURE 8-118 Normal anatomy of the knee on a magnetic resonance scan. Images are presented in the coronal view near the front of the knee (A) and in the midportion of the knee (B). Additional sagittal or lateral magnetic resonance views are identified through the middle of the knee (C) and in the lateral compartment (D).

FIGURE 8-119 Early degenerative osteoarthritis. A, A supine anteroposterior plain x-ray of the knee shows what appears to be normal joint space width (arrow). B, On a slightly flexed standing view, significant narrowing of the medial compartment is noted (arrows).
The two most common soft tissue injuries of the knee involve the cruciate ligaments and the menisci. As mentioned earlier, the imaging study of choice for these is MRI, with which the cruciate ligaments can be well seen, and tears or partial tears of these ligaments can be easily identified (Fig. 8-123). Repair of cruciate ligaments often

for this on the lateral view (Fig. 8-122). The effusion is basically water or blood, which has the same density as muscle, and it is visualized only because anterior displacement of the normal fat line is present. It is not appropriate to order a knee x-ray to exclude or identify an effusion, because this is much better done by clinical examination. Knee effusions are usually identified as an incidental finding in patients who have had trauma and for whom the examination was ordered because a fracture was suspected.

FIGURE 8-120 Osteochondritis desiccans. An anteroposterior view of the knee shows a divot-like irregularity in the articular surface of the medial femoral condyle (arrows).

FIGURE 8-121 Synovial chondromatosis. These are small calcified loose bodies within the joint space (arrows). This is sometimes referred to as housemaid's knee or nun's knee.

FIGURE 8-122 Large knee effusion. Knee effusions are best detected on the lateral view by looking above the patella and seeing anterior displacement of the dark fat line by soft tissue or water density (arrows). Knee effusions are even more easily and accurately detected by clinical examination.

FIGURE 8-123 Posterior cruciate ligament tear. A lateral or sagittal view of the knee on magnetic resonance imaging scan demonstrates disruption (arrow) of the normal dark posterior cruciate ligament.

The two most common soft tissue injuries of the knee involve the cruciate ligaments and the menisci. As mentioned earlier, the imaging study of choice for these is MRI, with which the cruciate ligaments can be well seen, and tears or partial tears of these ligaments can be easily identified (Fig. 8-123). Repair of cruciate ligaments often
A number of arthritides can affect the major joints. RA is a major player and can cause synovial destruction with joint-space narrowing. One of the tip-offs to RA is the hemorrhagic effusion. Because tibial plateau fractures can sometimes be difficult to see, if you see a fat/fluid level on the lateral knee image, you should look very hard to find a tibial plateau fracture.

Arthritis

A number of arthritides can affect the major joints. RA is a major player and can cause synovial destruction with joint-space narrowing. One of the tip-offs to RA is the
presence of subchondral cysts just under the bony cortex on both sides of the joint space (Fig. 8-128).

Sometimes calcification can be seen within the articular cartilage of the knee. This finding is called chondrocalcinosis (Fig. 8-129); it is usually easy to distinguish from loose bodies within the joint space, because it is calcification in a horizontal linear fashion. Chondrocalcinosis may be due to degenerative change, hypercalcemic states, and pseudogout, as well as some other less common entities.

When degenerative changes of the knee are extensive enough, a prosthetic knee replacement may be required (Fig. 8-130). A number of prostheses are available, but in general they have a femoral condylar component as well as a proximal tibial and patellar component. Sometimes the patellar component is not installed. On the AP view these prostheses may look as if they are not touching each other when they are in contact. This is because of a plastic surface that is not visible on the x-ray. Abnormalities to look for with a prosthesis involve infection and loosening.

**FIGURE 8-126** Bipartite patella. On this anteroposterior view of the knee, a fragment can be seen in the upper outer portion of the patella (arrows). Note that this is rounded and that the location in the upper outer portion of the patella indicates that this is a normal variant of no clinical significance; it should not be mistaken for a patellar fracture.

**FIGURE 8-127** Tibial plateau fracture. An anteroposterior view (A) shows a vertical lucent line extending into the upper portion of the tibia. A cortical step-off (white arrow) also is seen just medial to the intercondylar tubercle. The true extent of these fractures may be difficult to appreciate on plain radiographs. A lateral cross-table view of the knee (B) shows a typical fat/fluid level (arrow) in the suprapatellar region. This actually is not fat but settling blood in a hemarthrosis.

**FIGURE 8-128** Rheumatoid arthritis of the knee. Diffuse joint space narrowing with subchondral cyst formation is present (arrows). A distinguishing feature between this and degenerative arthritis is that in rheumatoid arthritis, degenerative osteophytes or spurs are not usually seen.
Both are seen as a lucent line or rarefaction of bone around the screws or the base of the implant.

**Tumors**

A benign tumor, called a *giant cell tumor*, commonly occurs around the knee, particularly in the proximal tibia. It is a lytic lesion that is often quite large and characteristically occurs between the ages of 20 and 35 years. The tumor appears to arise from the old epiphyseal plate and to extend in both directions. It is not seen before epiphyseal closure, and when it is present, it typically crosses the fused epiphyseal plate (Fig. 8-131). Usually it is not confused with a malignant lesion, because it typically occurs during the late teens or in young adults. This is beyond the age for most osteogenic sarcomas and before the age for most metastatic lesions. In addition, its single focus and location peripherally in an extremity would be unusual features of a metastatic lesion.

**FIGURE 8-129** Chondrocalcinosis. Calcification of the cartilage in this knee is seen particularly well in the lateral compartment (arrows). This is due to calcium pyrophosphate deposition disease (CPDD). Calcification is not seen in all patients with CPDD, and not all patients with chondrocalcinosis have CPDD.

**FIGURE 8-130** Total knee replacement. An anteroposterior view of the knee (A) demonstrates the distal femoral and proximal tibial portions of a semiconstrained prosthesis. The two pieces do not appear to sit directly on each other, because a plastic or Teflon spacer in between is not seen on the x-ray. The lateral view (B) demonstrates that this is a tricompartment replacement with a prosthetic posterior patellar portion as well.

**FIGURE 8-131** Giant cell tumor. An anteroposterior view of the knee in this 25-year-old man demonstrates a destructive lesion that is centered at the fused epiphyseal plate and has extended into the metaphysis and the epiphysis. These lesions most commonly occur in the tibia or femur. The lesion is often expansile and can be locally aggressive. About one third of these patients will have a pathologic fracture.
Osteogenic sarcoma is discussed later in the pediatric section of this chapter. A few unusual forms of osteogenic sarcoma do occur at older ages. Periosteal osteosarcomas, which constitute about 4% of all osteosarcomas, are broadly based, typically in the posterior aspect of the femoral shaft. They occur in persons about 40 years of age. Periosteal osteosarcomas are about half as common, have a saucer-shaped depression of the cortex, and occur at 10 to 20 years of age. Remember that osteosarcomas in older adults can be produced by malignant degeneration of Paget's disease and may occur at any age as a consequence of radiation therapy.

**TIBIA AND FIBULA**

**Normal Anatomy**

Typical imaging views include AP and lateral projections. You should be sure that the image includes the entire length from the tibial plateau to the ankle joint. The anatomy is fairly obvious.

**Trauma**

A few points about tibial fractures should be discussed. Spiral fractures usually involve the distal tibia and often occur as the result of boot-top ski injuries. When a spiral tibial fracture is present, you should look carefully to see if overriding of the fragments is present (Fig. 8-132). Many times only an ankle x-ray has been ordered, and the tibial fracture is clearly identified. Notice that it is not possible to shorten the tibia without associated trauma of the fibula, because the two bones are essentially hooked together at both ends. If you see only a tibial fracture, you should order a complete view of the tibia and fibula, and often you will find an associated fracture of the proximal portion of the fibula. Typical orthopedic hardware used in the fixation of fractures of the middle or distal tibia includes intramedullary rods (Fig. 8-133). These rods also can be used for fractures in the midportion of the femur. Occasionally fractures of long bones do not heal because fibrous tissue grows between the ends of the bone. This is called a non-union. It can be identified by the presence of a lucent line on the image that is persistent and extends across the fracture site several months after the fracture occurred (Fig. 8-134).

**Tumors**

Some benign bone tumors occur in long bones, particularly in the lower extremity. The first of these is simply an outgrowth of bone and is called an osteochondroma. The cortex of the bone typically sticks out on a stalk and has a bulbous or mushroom-shaped cap. The cap is covered with cartilage. This growth almost invariably arises near a joint, with the stalk always pointing away from the joint (Fig. 8-135). These lesions are usually asymptomatic unless they stick out far enough to be traumatized easily. If there is enlargement of such a lesion or associated pain without
previous trauma, malignant transformation should be suspected. In a form of hereditary multiple exostoses, the number of exostoses may vary from a few to hundreds, but they are usually bilaterally symmetric.

An osteoid osteoma usually occurs along the cortex of a bone. It has a central area of lucency with a little sclerotic (white) nidus within it (Fig. 8-136). About 75% of cases occur in persons between the ages of 11 and 26 years. This lesion incites a large amount of reaction, causing dense surrounding bone and sometimes local periosteal reaction. It is typically painful, and the pain is relieved by aspirin. On a nuclear medicine bone scan in a different patient with an osteoid osteoma in the left lower tibia shows increased activity (arrows) at the site of the lesion.
bone scan, these lesions are intensely hot. If all you see is an area of dense sclerosis near the cortex of a bone and you are unable to visualize a nidus or central lucent area, sometimes a CT scan can demonstrate the nidus.

With the exception of metastatic disease, most bone tumors are quite obvious and quite rare. Because the differential diagnosis depends on the age, location, imaging characteristics, and clinical history, always seek consultation with a radiologist before assuming that the lesion you are looking at is benign.

ANKE

Normal Anatomy

Normal imaging projections of the ankle are AP, lateral, and oblique. Although oblique views of most bones and joints are not always obtained, this is important in the traumatized ankle because a number of oblique fractures that occur in the ankle are not easily seen on the AP or lateral view. The oblique view also allows a better look at the ankle mortise (Fig. 8-137).

FIGURE 8-137 Normal anatomy of the ankle in the anteroposterior projection (A) and in the lateral projection (B). C, Oblique view of the ankle. This projection is the best one to show the ankle mortise and the relation of the talus to the medial and lateral malleolus.
An interesting phenomenon occurs often on ankle x-rays but also can occur on any image on which the dense cortex of bones overlaps. Where the cortices of two bones cross, occasionally a dark or lucent line will appear along the anterior edge of one cortex, and this dark line looks as though it is actually extending through the cortex of the other bone. This is an artifact called the *Mach effect*. The point is that if you see a lucent line through the cortex of a bone, you should make sure that another overlapping bone at this exact point is not causing a pseudofracture artifact (Fig. 8-138, A). Sometimes a lucent line can be seen extending through the cortex of a bone as a result of a blood vessel passing through a nutrient canal (Fig. 8-138, B), and this should not be mistaken for a fracture.

The ankle of a child demonstrates an epiphysis in the distal tibia and fibula. In children between the ages of 7 and 12 years, you also will see a calcaneal apophysis on the lateral view. This is seen as a crescentic density over the posterior aspect of the heel, and it should not be mistaken for a fracture (Fig. 8-139).

**Trauma**

The vast majority of ankle x-rays are obtained to evaluate the effects of trauma. On the lateral view of the ankle, look for an anterior thin, dark fat line right in front of the joint space. If it is displaced or bowed forward, an effusion,
hemorrhage, or infection is present in the ankle joint (Fig. 8-140).

The most common fractures of the ankle involve either the medial or the lateral malleolus. Less commonly, fractures are found of the medial and lateral malleoli (bimalleolar fracture; Fig. 8-141, A). With very severe trauma, fractures are noted not only of both medial and lateral malleoli but also of the posterior aspect of the tibia (trimalleolar fracture). Whenever the posterior malleolus is fractured, almost always an associated medial or lateral malleolar fracture is seen. The extreme force and disruption necessary to cause a trimalleolar fracture disrupts ligaments as well, often causing subluxation of the distal tibia relative to the talus (Fig. 8-141, B).

The Weber classification is usually used to describe fractures of the fibula. It allows evaluation of the severity of injury to the tibiofibular ligament. This ligament is located just slightly above the ankle joint. A fracture of the fibula below the ligament is a Weber A fracture. When the fracture is at the ligament level, it is a Weber B, and above the ligament, it is a Weber C fracture. The most common fracture is a Weber B, caused by supination and external rotation. Weber B and C fractures are usually unstable.

Malleolar fractures can be treated in a number of ways, including screws and pins (particularly in the medial malleolus) and sometimes plates and screws. Occasionally, in the case of an infected compound fracture, antibiotic beads will be placed in the wound. These can be visualized on the plain x-ray (Fig. 8-142). As with other joints, when orthopedic hardware is present and follow-up images are performed, you should look for destructive areas along the shafts of the screws as well as sclerosis that is not associated with the fracture itself. These are findings that suggest infection and osteomyelitis (Fig. 8-143).

Just because the bony structures of the ankle look normal on the plain x-ray does not mean that no soft tissue pathology is present. Significant ligamentous disruption may not be appreciated. If clinical suspicion persists about ligamentous disruption and laxity of the ankle, stress views can be performed. These are images taken while the ankle is being twisted, and they can show widening of the ankle joint (Fig. 8-144). MRI is rarely indicated for most ankle trauma.

**FIGURE 8-140** Ankle effusion. An ankle effusion is best seen on the lateral view. The dark fat stripe (arrows) is displaced and bowed anteriorly by fluid within the joint.

**FIGURE 8-141** Ankle fractures. A, In this bimalleolar fracture the horizontal fracture medially and an oblique fracture laterally mean that this was an eversion injury. An inversion injury usually results in a horizontal fibular fracture and oblique fracture of the medial malleolus. B, Trimalleolar fracture in a different patient. The lateral view is necessary to show a fracture of the posterior malleolus (arrows). Also note the anterior subluxation of the distal tibia on the talus.
Benign Nontraumatic Abnormalities

Three fairly common dense bone abnormalities are seen typically in the distal tibia. These lesions do occur in other bones, but the ankle is imaged so frequently that questions about them come up more often relative to the ankle. The first of these are horizontal dense lines in the metaphysis of the tibia (Fig. 8-145). These are called *growth arrest lines*, and they represent a time when some interference occurred with the normal longitudinal growth process of the bone, perhaps periods of sickness during the individual’s life. Occasionally, dense lines such as these reflect heavy metal ingestion (lead poisoning or ingestion of bismuth or phosphorus). Growth arrest lines are of no clinical significance whatever at the time they are seen, because they are a representation of a historical event.

Small oval sclerotic or dense lesions can occur in most bones. These are called *bone islands*, and their origin is uncertain. They are completely benign lesions and should be regarded as a normal variant. They rarely measure more than 5 or 6 mm in width and 1 cm in length. The long axis of the oval is always in the long axis of the bone or aligned with the trabecular pattern (Fig. 8-146). Benign fibrous cortical defects and nonossifying fibromas have been discussed in relation to the femur (see Fig. 8-107). If the lesions are large, they may fracture, but many heal spontaneously during young adult life, leaving behind an area of dense bone (Fig. 8-147).

FOOT

As with the ankle, typical imaging projections of the foot after trauma include AP, lateral, and oblique. For purposes of an arthritis workup, AP and lateral views are sufficient (Fig. 8-148). A special view of the foot called the *calcaneal view* is taken when a fracture of the calcaneus is suspected. The foot is flexed, and the x-ray beam is angled down through the posterior aspect of the heel. This provides a good view of at least the posterior half of the calcaneus (Fig. 8-149).

You should be aware of a few congenital and developmental abnormalities of the foot, such as fusion or a bony
bridge across the proximal bones, for example, between the talus and the calcaneus or between the calcaneus and the navicular. Many times these can be seen on plain radiographs, although occasionally CT scanning is needed to identify the abnormality.

A wide variety of small accessory bones are seen about the ankle and tarsal bones (Fig. 8-150). These are variable but usually can easily be distinguished from fractures, because accessory bones are well corticated and typically round or oval. Another common developmental abnormality is a cystic-looking area that occurs in the anterior and midportion of the calcaneus. Although this sometimes is called a calcaneal cyst, MRI has shown that a large number of them are intraosseous lipomas. Why they tend to occur...
in this location is unknown (Fig. 8-151). Generally they are not clinically significant, but if they are large, the weakened bone may result in a pathologic fracture.

**Trauma**

A number of foot x-rays are ordered to look for foreign bodies that the patient stepped on. If the suspected object is metallic, it can normally be visualized (Fig. 8-152). As was discussed in the section on the hand, most glass also can be seen. If the object is not visible externally, a radiologist may operate a fluoroscope while another physician is locating the object. Digging around in the sole of the foot often causes residual painful scars, and the more easily an object can be located, the less scarring should occur. Remember that wooden objects or graphite from pencils will not be visualized by x-ray examination.

**FIGURE 8-147** Healed nonossifying fibroma. These lesions are usually discovered incidentally in young adults. Ninety percent are found near the metaphysis of the tibia or fibula. The dense nature and lack of periosteal reaction indicate that this is a benign lesion, and no further workup is called for.

**FIGURE 8-148** Normal anatomy of the foot in the lateral projection (A), anteroposterior projection (B), and oblique projection (C).

**FIGURE 8-149** Calcaneal view. This view is taken to look for subtle fractures of the posterior aspect of the calcaneus by placing the foot on a detector and shooting down along the backside of the ankle.
Fractures of the foot can involve any bone. Fractures of the talus are rare but almost always involve the neck of the talus (Fig. 8-153). This is the so-called aviator’s fracture, because it occurred when early pilots crashed and slammed their feet into the front of the cockpit. Obviously, today the fracture is much more often due to motor vehicle accidents. Calcaneal fractures often can be difficult to appreciate on the lateral view and are almost impossible to see on an AP view. For this reason the calcaneal view that we discussed earlier should also be ordered (Fig. 8-154). Sometimes patients with persistent foot pain have normal plain x-rays. A nuclear medicine bone scan can sometimes localize a bone in which an occult fracture is present (Fig. 8-155).

A common fracture of the foot involves the base of the fifth metatarsal. Frequently an apophysis on the lateral aspect of the fifth metatarsal base is found, and this is often confused with a fracture. The way to tell the two apart is by noting that the long axis of the apophysis is parallel to the long axis of the metatarsal. Fractures, conversely, typically are transverse or perpendicular to the long axis of the bone (Fig. 8-156).

Most fractures of the metatarsals are fairly easy to recognize. Two unique fractures can occur in this region. The
first is the so-called Lisfranc fracture, actually a fracture and lateral dislocation of the second, third, fourth, and fifth metatarsals relative to the tarsal bones. This historically happened as a result of falling out of a saddle while horseback riding and getting a foot caught in the stirrup but now is more common from snow- and wakeboarding injuries (Fig. 8-157).

Another classic fracture of the metatarsals is the march fracture. This is a stress fracture that typically occurs in army recruits who have to march long distances and are not used to it, but it also is seen in athletes and dancers. The distal third of the second, third, or fourth metatarsal is the usual location. If you look carefully in this region, sometimes you can see slightly increased sclerosis or

**FIGURE 8-154 Calcaneal fracture.** The lateral view of the calcaneus (A) shows a subtle lucent (dark) line through the calcaneus. This extends into the subtalar joint about 75% of the time. This fracture also has been called a lover’s fracture (probably from tales of disappointed lovers jumping off buildings or bridges). A calcaneal view (B) in the same patient makes the fracture much more obvious (arrows), particularly at the lateral margins.

**FIGURE 8-155 Occult calcaneal fracture.** A, In this patient who had a normal x-ray of the foot and continued to have pain, a nuclear medicine bone scan was performed. A lateral image of the foot shows an area of markedly increased activity (arrow) along the anterior portion of the calcaneus. B, A computed tomography scan was then performed with thin sections over the area of interest, and the calcaneal fracture was identified (arrows). T, Talus; C, calcaneus.
periosteal reaction (Fig. 8-158). If the x-ray is normal, a stress fracture may still be present, and in this circumstance it is usually easily visualized as an area of intensely increased activity on a nuclear medicine bone scan.

A form of aseptic necrosis most commonly involves the head of the second metatarsal. This is manifested as flattening of the articular surface with associated sclerosis (Fig. 8-159) and is called a Köhler-Freiberg infraction. The lesion is seen less frequently in the head of the third or first metatarsal. This injury is believed to be a type of stress fracture, and it is often found during late adolescence. Degenerative joint disease is a late complication of this condition.

Degenerative and Arthritic Conditions

Views of the feet obtained for arthritis evaluation are often unrevealing or nonspecific, and if any imaging is ordered for arthritis evaluation, the highest yield usually is obtained with an AP view of the hands. As pointed out earlier, the radiographic findings, although somewhat characteristic, are not as specific as laboratory findings. The major metabolic abnormality that occurs in the foot is gout (Fig. 8-160), typically manifested as swelling over the first metatarsophalangeal joint. On plain x-ray these are erosions in the periarticular region with overhanging edges. These are late findings, and again the diagnosis is best made by laboratory analysis.

Diabetes and Complications

In patients with diabetes, peripheral neuropathy and vascular insufficiency may develop (Figs. 8-161 and 8-162). The latter is particularly acute in the toes, and often concomitant infection is found. X-rays of the feet can demonstrate changes of osteomyelitis to help distinguish it from cellulitis. The characteristic signs of osteomyelitis include soft tissue swelling, focal loss of trabecular pattern, periosteal reaction, and frank bone destruction (Fig. 8-163). The differentiation of osteomyelitis from cellulitis is important because the therapy for osteomyelitis involves weeks of intravenous therapy. If the bone changes that have been described are found, you can conclude that osteomyelitis is present. Osteomyelitis, however, can be present with a normal x-ray, and if clinical suspicion is high, evaluation with a three-phase nuclear medicine bone scan is often useful. Other plain x-ray changes that are characteristic of diabetic involvement of the foot include marked vascular calcification and occasionally air within the soft tissue due to infection and gangrene.

PEDIATRIC MUSCULOSKELETAL IMAGING

Skull

Anatomy

Typical views of the skull in a child are the same as in adults: AP and lateral. The differences in normal anatomy
FIGURE 8-158 Stress fracture. A, A college student who had walked 400 km in Spain during the summer and had foot pain had a negative initial x-ray. A nuclear medicine bone scan (B) at the same time was intensely positive. Another x-ray 10 days later (C) showed a subtle cortical fracture (arrow). A follow-up examination 3 weeks later (D) clearly shows developing callus (arrows). This also is referred to as a march fracture. These fractures can be difficult to appreciate even when you know where to look.

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consist of dark or lucent lines that represent the cranial sutures (Fig. 8-164) and a small face in comparison with the cranium. Cranial sutures usually remain partially open until at least midlife, and it is particularly important that they remain open in the early years of life to allow growth of the brain. The sutures of the skull can close prematurely (cranosynostosis). The sagittal suture is most commonly involved, and the coronal suture less so. Premature closure of the sagittal suture results in growth of the skull in the areas where the coronal and lambdoid sutures remain open, and the skull becomes much longer than normal (scaphocephaly) (Fig. 8-165). If the coronal suture closes prematurely, growth continues to occur along the sagittal suture, and the skull becomes much wider than normal. A skull radiograph is often not necessary, because the shape of the skull and a ridge of bone over the closed suture are clinically apparent. On a skull radiograph the prematurely closed suture may be dense (white) at the edges or may just be difficult to see.

Trauma
Fractures are seen as very sharply defined lucent lines that do not correspond to sutures. The margins of the sutures are somewhat wiggly, especially as they near closure. Sometimes it can be difficult to differentiate between a fracture and a vascular groove. Most vascular grooves are seen on the lateral view of the skull and radiate superiorly and posteriorly from a position just above the ear. In addition, if you look carefully, the vascular groove is a lucent line that is bounded by a sclerotic (white) margin before you reach the normal bone of the skull. A skull fracture will be a lucent line (dark) and then normal skull.

Occasionally a fracture line will widen progressively during the first weeks or months after injury. The widening is due to formation of an underlying leptomeningeal cyst, which causes pressure and subsequent atrophy of the bone at the edges of the fracture line. The dura is torn at the time of injury, allowing this process to occur. Sometimes this lesion is referred to as a growing skull fracture of...
FIGURE 8-159 Aseptic necrosis of the second metatarsal head. This usually occurs in teenagers and is referred to as a Köhler-Freiberg infraction. Subsequent degenerative arthritis in this region is common.

FIGURE 8-160 Gout. The first metatarsal phalangeal joint is the most commonly affected. This large tophus has caused erosion at the margins of the joints; in general, however, the joint space itself is reasonably well preserved.

FIGURE 8-161 Vascular calcifications. A lateral image of the foot shows extensive vascular calcifications. When this is seen, the patient almost always has diabetes.

FIGURE 8-162 Neuropathic ankle and foot secondary to diabetes. On a lateral view of the foot and ankle, extensive destruction of the ankle joint and tarsal bones is seen. Note that in spite of the destruction, the bones are not demineralized, indicating use, and by inference, the absence of pain.

childhood, and it usually will not heal without surgery (Fig. 8-166).

Another common traumatic lesion of childhood is a cephalohematoma. These lesions are caused by traumatic hemorrhage into the neonatal scalp during labor, although they also can occur after cephalic injury during infancy or childhood. With healing, usually a new shell of subperiosteal bone is seen over the hematoma, which then thickens and calcifies. Clinically, cephalohematomas can disappear in weeks to months, although the x-ray finding(s) may persist long afterward (Fig. 8-167).

Neoplastic lesions of the skull can occur during childhood. Almost all appear as multiple lucent holes (Fig. 8-168). Typical malignant lesions in very young children are due to histiocytosis X, although with slightly older children, metastatic lesions occur from neuroblastoma.

Many clinicians order sinus views to look for sinusitis. This is often the result of parental concern rather than medical need. You should remember that the sinuses are not developed at birth and are progressively pneumatized over the first 10 years of life. The first sinuses to appear are the maxillary sinuses; the frontal sinuses come much later. For both children and adults it is inappropriate to order sinus views for what clinically appears to be routine sinusitis (Fig. 8-169).
FIGURE 8-163 Osteomyelitis of the foot. A, In this diabetic patient, significant soft tissue swelling and destruction of the bony structure of the distal phalanx of the great toe are noted. B, Even when x-rays are normal, osteomyelitis may be present. A nuclear medicine bone scan is more sensitive and will show increased blood flow in the first seconds after radionuclide injection, increased blood pooling at 20 min, and more focal and intense radioactivity on the 3-hour images.

FIGURE 8-164 Normal newborn skull. A, The lateral view clearly shows the lambdoid (L), squamous (Sq), and coronal (C) sutures. B, An anteroposterior view clearly shows the sagittal suture (Sag).
**FIGURE 8-165** Premature closure of the sagittal suture. Closure of the sagittal suture has allowed growth of the skull only in the anteroposterior direction; here the coronal and lambdoid sutures can be seen to be widened.

**FIGURE 8-166** Growing skull fracture of childhood. A, A parietal skull fracture is easily seen on this lateral view of the skull (arrows). B, A repeat skull radiograph 2 months later shows that the fracture line has become very wide (arrows) due to a leptomeningeal cyst and continued pressure erosion of the bone.

**FIGURE 8-167** Cephalohematoma. A, A lateral view of the skull shows a lucent multilocular and expansile lesion (arrows). B, An anteroposterior tangential view of the skull shows that this lesion is primarily bulging out from the normal skull cortex because of calcification of the hematoma.

**FIGURE 8-168** Histiocytosis X of the skull. Multiple lucent holes of varying sizes are seen in this lateral projection of the skull. A large scalloped lesion has destroyed the cortex over the posterior aspect of the skull and has beveled edges, characteristic of this disease.
FIGURE 8-169 Normal sinuses in a 5-year-old child. The maxillary sinuses (M) are poorly developed at this age and only partially pneumatized, and the frontal sinuses (F) are only beginning to develop.

FIGURE 8-170 Normal variations of the cervical spine in children. A, A lateral view in a newborn child shows a cleft where the odontoid is not yet completely fused to the body of C2. This is normal. B, Pseudosubluxation of C2 on C3 is a common normal variant in children; it occurs only at this level, particularly when the neck is straight or slightly flexed.

**Spine**

Spine trauma imaging has been evaluated, and several studies in older children suggest that the NEXUS criteria (discussed earlier) are reliable. There are few data about use in younger children. Often plain x-rays are used before CT because of concerns about radiation dose. In children with a known spine fracture at one level, it is important to evaluate the rest of the spine with plain x-ray to exclude other fractures.

Two items cause confusion in interpretation of cervical spine views in children. The first is that the odontoid process and the body of C2 form as separate ossification centers, and fusion occurs in the first year or so of life (Fig. 8-170, A). Occasionally nonfusion can persist into adulthood. The differentiation from an odontoid fracture can be made by the absence of sharp, angulated corners and the absence of soft tissue swelling. Another surprising but common finding in children is a pseudosubluxation at C2 and C3. This is simply a normal variant and occurs when the child has his or her neck slightly flexed (Fig. 8-170, B). If this occurs in children older than approximately 5 years, you should suspect a traumatic cause rather than a normal variant.

A number of congenital spinal abnormalities occur, including hemivertebra and butterfly vertebra, which often result in scoliosis. Severe abnormalities are usually diagnosed soon after birth, but more minor abnormalities may not be found until a scoliosis workup is performed in adolescence or adulthood.

A rather unusual spinal abnormality of childhood is called diskitis. This usually occurs in the lumbar spine and appears radiographically as a decreased disk space (Fig. 8-171). On a nuclear medicine bone scan, increased activity of the vertebral body is noted both above and below the affected level. The origin of this entity is uncertain, but it may represent a low-grade infection.

**Upper Extremity**

**Humerus**

Lesions in the proximal humerus that are lytic, somewhat expansive, and quite well demarcated are usually unicameral bone cysts (see Fig. 8-55). Care should be taken,
FIGURE 8-171 Diskitis. A, A lateral view of the lumbar spine in this child with back pain shows a decreased disk space at L3-L4 (arrow). Sometimes the disk space is not appreciably narrowed, and the diagnosis can sometimes be made with a nuclear medicine bone scan (B). Here, on an anterior view of the lumbar spine, increased radioactivity is seen at L3 and L4, compatible with the diagnosis of diskitis.

however, in the diagnosis, because the third most common site of osteogenic sarcoma is the proximal humerus.

Elbow
The pediatric elbow can cause difficulties in interpretation owing to the development of various ossification centers. The epiphysis of the radial head initially appears at ages approximately 3 to 5 years, and the olecranon appears between 8 and 11 years. The capitulum of the distal humerus appears at younger than 1 year, the medial epicondyle at 3 to 6 years, the trochlea at 7 to 9 years, and the lateral epicondyle at 12 to 14 years. The development may even be asymmetric between right and left, depending on which arm is dominant (Fig. 8-172). The asymmetric appearance of the lateral condylar ossification center can often be mistaken for a fracture, and clinical correlation is essential. Note should be made that avulsion fractures of the lateral condyle are quite rare, whereas avulsion fractures of the medial condyle are much more common.

When this occurs, it is sometimes called Little Leaguer’s elbow (Fig. 8-173).

In examining the elbow for fracture, remember that visualization of the anterior fat pad lying up against the anterior aspect of the distal humerus is a normal finding. A posterior fat pad should never be seen, and the anterior fat pad should not be displaced or bowed forward (Fig. 8-174, A). In addition, the apophysis of the olecranon should not be mistaken for a fracture.

A relatively common fracture in children is a supracondylar fracture that extends across the distal aspect of the humerus. When this occurs, there is almost always bowing forward of the anterior fat pad and visualization of the posterior fat pad. You should evaluate the anterior humeral line. This line should extend down into the middle third of the capitellum (Fig. 8-174, B).

Destructive lesions involving a joint space usually are produced by inflammatory lesions. They may be the result of infection in the joint space (septic arthritis) or of other chronic inflammatory processes, such as inflammation due to intermittent bleeding within the joint in patients with hemophilia (Fig. 8-175). Significant joint involvement also occurs in children who have juvenile rheumatoid arthritis.

Forearm, Wrist, and Hand
Fractures of the forearm and wrist are common in children; a number of the types that occur in adults have already been discussed. Whenever multiple fractures are found, especially those that appear to be in different stages of healing, child abuse should be suspected. The fact that the fractures are of different ages can be ascertained by periosteal reaction or callus around some, but not around other, fracture sites. If child abuse is suspected, additional views of the skull, ribs, pelvis, and both upper and lower extremities should be obtained (Fig. 8-176).

Young children have bones that are relatively plastic, and two unique childhood fractures occur as a result of this plasticity. The first is a “buckle” or torus fracture. Sometimes on a single view all you will identify is a slight outward bulge of the cortex, whereas on other views you may actually see a buckling of the cortex (Fig. 8-177). The other fracture is the greenstick fracture. In this the bone is bent but typically fractured only on one side of the cortex, similar to the breaking of a green twig (Fig. 8-178).

At the end of any long bone a number of the Salter-Harris–type fractures described earlier can be seen (see Fig. 8-81). One of the most difficult fractures to see is a nondisplaced, or minimally displaced, Salter-Harris type I fracture through the epiphyseal plate. Often the x-ray at the time of injury will be normal; however, a repeated examination 1 to 2 weeks later will reveal increasing sclerosis (white lines) across the epiphyseal plate, indicating a
FIGURE 8-172 Normal variation and development of the elbow in children. A, On an anteroposterior view of the left elbow, the medial epicondyle is visualized, but the lateral is not. B, On the right side the lateral epicondyle is seen. This asymmetric development from one side to the other can occur normally. Because lateral epicondyle fractures are rare, you should suspect that this is an apophysis.

FIGURE 8-173 "Little Leaguer’s elbow." A, An anteroposterior view of the elbow shows an abnormally wide space between the medial epicondyle and the distal humerus (large arrow). An olecranon fracture also is seen (small arrow). B, The opposite elbow is shown for comparison with the normal position of the medial epicondyle.
FIGURE 8-174 Supracondylar fractures. This is the most common elbow fracture in children. A, A lateral view of the elbow shows marked anterior displacement of the anterior fat and visualization of the posterior fat pad (arrows), a sign that a fracture is almost certainly present. B, In a younger child a fracture is seen because of the posterior displacement of the capitellum from the anterior humeral line. An incomplete cortical fracture also is seen (arrow).

FIGURE 8-175 Hemophilia. A lateral view of the elbow shows marked destruction of the joint space. Chronic bleeding within the joint has destroyed the cartilage. Similar findings may be seen with juvenile rheumatoid arthritis.

In a child younger than 10 years, it is rare to have fractures of the carpal bones. Typical hand fractures in children involve either Salter-Harris fractures of the fingers or fractures of the terminal phalanges (because children usually get their fingers caught in doors and other objects).

Osteomyelitis in very young children often involves both the distal metaphysis and the epiphysis of a bone because the epiphysis receives its blood supply from the shaft of the bone. In older children the epiphysis has its own separate blood supply, and osteomyelitis usually involves the metaphysis just proximal to the epiphyseal plate. With hematogenous spread of bacteria, multiple bones can be involved. The x-ray findings of osteomyelitis include soft tissue swelling, bone destruction, and periosteal reaction. As with adults, if a clinical question remains about the presence of osteomyelitis or even septic arthritis, a radionuclide bone scan is often helpful (Fig. 8-181).

Pelvis and Hips
Dislocation of the hip in children is usually congenital and occurs more often in girls than in boys. The radiographic diagnosis may be made in a number of ways. Radiographic diagnosis of a congenital hip dislocation is unreliable in the neonate because the ossification center for the femoral head is not developed. Perhaps the simplest imaging method is evaluation of Shenton’s line, which is formed by the medial aspect of the obturator foramen and the medial aspect of the femoral neck. Together, these should form a nice smooth, curved arc (Fig. 8-182). A frog-leg view with the legs abducted is useless, because in this position the hip is reduced. X-ray diagnosis of congenital hip dislocation should be done rarely, if ever, because the clinical

healing fracture (Fig. 8-179). Fortunately, nondisplaced Salter-Harris type I fractures are not important clinically.

Normal growth of the bones in the hand includes appearance and development of the carpal bones and of epiphyses at the end of the radius and ulna, the distal second through fourth metacarpals, the proximal first metacarpal, and the proximal aspects of the phalanges. At birth, essentially no ossification centers of the carpal bones or epiphyses are seen in the hand. As a general rule, one carpal bone appears each year from age 1 year to about age 7 years (Fig. 8-180). Variation may occur in the appearance of the epiphyses and ossification centers between the two hands, and the growth pattern is usually somewhat more advanced in girls than in boys of the same age.
FIGURE 8-176 Child abuse. A, A view of the forearm in this child shows extensive periosteal reaction (small arrows) and transverse fracture lines (large arrows). Fractures of long bones in children, particularly with different stages of healing, are very suggestive of a battered child. B, A lateral view of the lower extremity in the same child also reveals fractures of the distal fibula and tibia (small arrows) as well as a metaphyseal corner fracture (large arrow) of the distal femur. This latter fracture also is typical of child abuse.

FIGURE 8-177 Torus or buckle fracture. A, An anteroposterior view of the wrist shows slight bulging of the cortex in the metaphyseal region (arrows). B, A lateral view of the wrist shows buckling of the dorsal cortex (arrow). (Case courtesy of L. Mettler.)

finding of an audible click when the hips are abducted should be sufficient to make the diagnosis. If any doubt remains, ultrasound examination should be obtained.

Occasionally aseptic necrosis of the epiphysis of the femoral head (Legg-Calvé-Perthes disease) can develop in children. Boys are more commonly affected than girls. Clinical signs are a limp and pain, with limitation in motion of the hip. The imaging findings are irregularity, sclerosis (increased density), and fragmentation of the epiphysis. Often a resulting deformity is followed by a disabling osteoarthritis decades later (Fig. 8-183).

Another pediatric hip abnormality is slipping of the epiphysis of the femoral head. The cause of this is unknown, and it usually does not happen in children younger than 9
years. The diagnosis is made from the images by noting a thickened epiphyseal plate and medial displacement of the femoral head relative to the femoral neck (Fig. 8-184). The lateral or abducted frog-leg view of the hip offers the best view of these findings. When the epiphysis fuses, no more slippage occurs, but the deformity that has occurred will be permanent, and later degenerative disease will be a complication.

**Lower Extremities**

Although systemic bone diseases are quite rare in children, two entities are important to be aware of. The first is osteogenesis imperfecta. This is a hereditary disease, with abnormal collagen fibers and a disorder of the osteoblasts. Fragile bones or teeth, thin skin, and sometimes blue sclera are noted. Two forms of the disease are found, one noted immediately at birth and one appearing later. The disease is characterized on imaging by multiple healing fractures and bowing deformities of the bone (Fig. 8-185).

Arthritic changes in children are rare, with the exception of juvenile rheumatoid arthritis and hemophilia. Both these diseases can cause fluid collections within the joint and destruction of the cartilage, followed by degenerative change. Hyperemia also may result in overgrowth of the epiphyseal region of the bone. The joint effusions, irregularity of the articular surface, and subsequent degenerative changes are easily visualized on x-rays (Fig. 8-186).

Ewing's tumor typically occurs in the shaft of the long bones or in flat bones, such as the pelvis, scapula, and ribs. In contrast, osteogenic sarcomas occur most commonly in the distal femur, less commonly in the proximal tibia and proximal humerus, and rarely elsewhere. An osteogenic sarcoma may initially appear as a destructive lesion in the central portion of the bone or with periosteal reaction and soft tissue swelling (Fig. 8-187). Often an MR scan is useful to show the soft tissue extent of the tumor.

A number of characteristic traumatic tibial lesions occur in children. As mentioned earlier, the proximal tibial

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**FIGURE 8-178** Greenstick fracture. In the humerus of this elementary school child, a direct blow from the direction of the arrow has caused an incomplete transverse fracture.

**FIGURE 8-179** Occult Salter-Harris fracture of the distal radius. A, An anteroposterior view of the wrist at the time of the injury does not show any cortical disruption or displacement. B, A repeated examination 10 days later shows sclerosis across the epiphyseal plate, indicating healing of an occult Salter-Harris type I fracture.
FIGURE 8-180 Normal development anatomy of the hand during childhood. A 2-year-old boy (A), 5-year-old boy (B), 7-year-old boy (C), and 15-year-old boy (D). In general the approximate age can be guessed, because the number of carpal bones usually is close to the child’s age in years up to about 7 years.

FIGURE 8-181 Multifocal osteomyelitis. A, An anteroposterior view of the hand demonstrates metaphyseal destruction of at least three sites (arrows). This hematogenously spread osteomyelitis usually will not cross the epiphyseal plate if the child is more than several years old. B, Detailed view of the hand showing the areas of metaphyseal destruction (arrows). C, A nuclear medicine bone scan of both hands in this child shows additional areas of abnormality (arrows) that were clinically unsuspected.
FIGURE 8-182 Congenital dislocation of the hip. An anteroposterior view demonstrates dislocation of the right hip. The dotted line, which should be continuous, is called Shenton’s line. The right acetabulum also is at a steeper angle on the right than on the left. Diagnosis of congenital dislocation of the hip should be made on the basis of clinical examination.

FIGURE 8-183 Legg-Calvé-Perthes disease. A, An anteroposterior view of the pelvis demonstrates fragmentation and sclerosis of the right femoral epiphysis in this 6-year-old boy (arrow). B, A follow-up image obtained 8 years later shows continuing deformity due to the osteonecrosis. Significant degenerative arthritis (C) developed by age 12 years.

FIGURE 8-184 Slipped capital femoral epiphysis. A, An anteroposterior view of the pelvis in this overweight teenage boy shows slipping of the left femoral epiphysis relative to the femoral neck (arrows). This essentially is a Salter-Harris type I fracture. B, Follow-up image of the left hip 10 years later shows significant deformity, which will result in degenerative arthritis.

FIGURE 8-185 Osteogenesis imperfecta. This lateral view of the lower extremities shows marked bowing of the bones due to softening and multiple fractures that occur as a result of this congenital bone dysplasia.
epiphysis normally has an anterior projection that slopes down over the front of the tibia. On plain x-rays this is best seen on the lateral view (see Fig. 8-116). This appearance can look a little bit irregular, however, if a small fragment is pulled off, and if the patient has pain, this is consistent with the diagnosis of Osgood-Schlatter injury. This is relatively frequent in children age 10 to 15 years, particularly in boys who participate in active sports. It probably represents a partial avulsion of the anterior tubercle by the inferior patellar tendon, and it heals with rest (Fig. 8-188).

In children between the ages of 3 and 5 years, a spiral or oblique fracture of the midtibia or distal tibia may occur. It is usually referred to as a toddler’s fracture. Sometimes a history of twisting the leg or jumping off a chair is found, but often these injuries are found in children who simply refuse to bear weight on the extremity. If this particular entity is suspected, AP, lateral, and oblique views of the tibia should be obtained (Fig. 8-189).

Salter-Harris–type fractures are common in the ankle. As mentioned in the discussion of the wrist, Salter-Harris type I fractures may not be displaced and may be seen only as increased density about the epiphyseal plate 1 or 2 weeks after the injury. If significant displacement and disruption of the epiphyseal plate is found, the diagnosis is usually not a problem. Sometimes even a Salter-Harris type III fracture can be subtle (Fig. 8-190). The fractures with the worst prognosis are the impacted Salter-Harris type V (see Fig. 8-81).

Occasionally in a patient who has a history of foot trauma or pain, you may notice irregularity and increased density or sclerosis of the tarsal navicular (Fig. 8-191). This is referred to as Köhler’s disease. Whether this condition is a result of trauma or aseptic necrosis is uncertain; it is often seen incidentally in a child with a twisted ankle. The patient occasionally may have pain over the navicular. This condition essentially always heals without any intervention. For some reason, the other tarsal bones are rarely, if ever, involved in this process. You should almost regard this finding as a normal variant.

**FIGURE 8-186** Hemophilia. An anteroposterior view of the knee shows marked joint-space narrowing (arrows) with destruction due to repeated bleeding into the joint space; a square intercondylar notch is present. Similar findings are seen in juvenile rheumatoid arthritis.

**FIGURE 8-187** Central osteosarcoma. A, A destructive lesion is seen in the metaphysis on this anteroposterior view of the knee in a young teenager with pain. B, A magnetic resonance scan of both legs shows the soft tissue extent of the tumor (arrows).
FIGURE 8-188  **Osgood-Schlatter disease.** A lateral view of the knee demonstrates a tiny avulsion fracture of the anterior tibial tuberosity in this young male athlete (arrow). This disease is quite common and usually is self-limited.

FIGURE 8-189  **Toddler’s fracture.** This 3-year-old child refused to walk because of leg pain. An x-ray of the lower leg shows an oblique fracture (arrows) of the distal tibia. This fracture may be the result of weight bearing and should not be confused with the fractures of child abuse.

FIGURE 8-190  **Salter-Harris fractures of the ankle.**  

A, A Salter-Harris type I fracture is seen with marked lateral displacement of the epiphysis relative to the tibial metaphysis (arrow).

B, A Salter-Harris type III fracture through the epiphysis (black arrows) and widening of the lateral aspect of the epiphyseal plate (white arrows). This also is called a Tillaux fracture and probably occurs because the growth plate fuses from medial to lateral, making the medial side stronger.

FIGURE 8-191  **Aseptic necrosis of the tarsal navicular.** This usually occurs between the ages of 4 and 8 years and most commonly is recognized incidentally. Increased density of the tarsal navicular (arrows) is seen on oblique (A) and lateral (B) views. This also is called Köhler’s disease. The abnormality is almost always self-limited and requires no therapy. Whether this condition is a result of trauma or interruption of blood supply is uncertain.

**Suggested Textbooks on the Topic**


Pediatric musculoskeletal imaging was covered in a special section at the end of Chapter 8. Congenital cardiac lesions were covered in Chapter 5. Table 9-1 shows the appropriate imaging test for common pediatric problems.

**HEAD**

**Imaging Techniques**

Imaging of the fetal and infant brain can be done by using ultrasound as long as the fontanels remain open. Structures that can normally be visualized include the lateral ventricles, choroid plexus, thalamus, temporal lobes, and posterior fossa (Fig. 9-1). The two most common indications for ultrasound of baby heads are (1) evaluation of ventricular enlargement (hydrocephalus) and (2) hemorrhage either within the parenchyma of the brain or within the ventricles (Fig. 9-2). The major advantages of ultrasound in this application are that the imaging can be done in the neonatal intensive care unit and that ionizing radiation is not used. This is important, because these studies are repeated multiple times for continuing evaluation. If the fontanels are closed, computed tomography (CT) is usually used for evaluation of suspected hydrocephalus or hemorrhage.

Brain tumors in children are evaluated by CT or magnetic resonance imaging (MRI). With MRI, sedation is necessary, and pediatric monitoring of respiration and other functions in a very high magnetic field is difficult. CT scanning is easier to perform. About half of brain tumors in children are astrocytomas; medulloblastomas (20%), ependymomas (10%), and craniopharyngiomas (5% percent) are less common.

**Trauma**

Head trauma and the appropriate imaging studies are presented in Chapter 2 and also in Table 9-1. In general, following significant acute head trauma of a child, a non-contrasted CT scan is the procedure of choice. This will reveal skull fractures, as well as evidence of bleeding. Subacute injuries with neurologic or cognitive problems usually will have a noncontrasted MRI.

**Childhood Seizures**

Seizures may be provoked by infection, trauma, toxins, metabolic abnormality, tumor, hypoxia, cerebrovascular disease, cerebral malformation, or congenital abnormality. They also may occur without obvious cause. Febrile seizures usually occur between the ages of 6 months and 4 years, and most are generalized tonic/clonic seizures. Imaging is recommended for children with new-onset seizures who have experienced head trauma or partial seizures and for those who have an abnormal neurologic examination or an abnormal electroencephalogram. Imaging is not necessary for uncomplicated febrile seizures or in a patient with an obvious provoking cause. MRI is the usual imaging modality of choice, although noncontrasted CT is used initially if intracranial hemorrhage or recent trauma is suspected. For those children with a history of seizures, imaging usually is done only if the seizures are poorly controlled or are associated with a new neurologic deficit, or to follow up known abnormalities such as a tumor.

**NECK**

**Croup and Epiglottitis**

Lateral soft tissue views of the neck are often done for evaluation of the pediatric airway. This is important in cases of suspected croup or epiglottitis. As you evaluate these lateral images, you should look to see that the child’s neck has been extended. In a young child when the neck is flexed, the trachea can buckle forward, causing the appearance of a retropharyngeal mass. To avoid this artifact, simply extend the neck and lift the chin (Fig. 9-3).

Acute epiglottitis usually occurs in older children (between ages 2 years and 7 years) and most commonly is due to *Haemophilus influenzae*. This can be a life-threatening disease, and the clinical findings are severe sore throat, high fever, a muffled voice, and stridor. The patients often can breathe more easily sitting up, and they drool because they cannot swallow. This is a true pediatric emergency. Because intubation can be necessary on very short notice, a physician should accompany the child to the x-ray department. The lateral soft tissue view of the neck shows a thickened epiglottis, often appearing bulbous (in the shape of a thumb) (Fig. 9-4). Remember that the normal epiglottis is a delicate, thin, curved structure. Other findings include ballooning of the hypopharynx and subglottic edema in about one fourth of cases.

Croup typically occurs in young children (between ages 6 months and 3 years), and it usually is caused by respiratory syncytial virus (RSV). The children often have a brassy cough (like the barking of a seal) and inspiratory stridor. Occasionally the airway may have enough edema that placement of an artificial airway is necessary. The findings on the lateral view are marked ballooning of the
<table>
<thead>
<tr>
<th>SUSPECTED PROBLEMS</th>
<th>IMAGING TEST OF CHOICE</th>
</tr>
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<tbody>
<tr>
<td>Neonatal hydrocephalus or intracranial hemorrhage</td>
<td>Cranial ultrasound</td>
</tr>
<tr>
<td>Uncomplicated febrile seizure</td>
<td>No imaging needed</td>
</tr>
<tr>
<td>Seizure</td>
<td>MRI without contrast</td>
</tr>
<tr>
<td>Neurologic deficit, partially unresponsive to therapy, new without obvious provoking factor</td>
<td>MRI without contrast</td>
</tr>
<tr>
<td>Neonatal</td>
<td>Noncontrast CT or US cranial</td>
</tr>
<tr>
<td>Ataxia</td>
<td>MRI with and without contrast</td>
</tr>
<tr>
<td>Headache</td>
<td>No imaging needed</td>
</tr>
<tr>
<td>Isolated, no neurologic findings</td>
<td>CT without contrast or MRI</td>
</tr>
<tr>
<td>With neurologic signs</td>
<td>No imaging needed</td>
</tr>
<tr>
<td>Acute “thunderclap” headache</td>
<td>No imaging needed</td>
</tr>
<tr>
<td>Migraine without neurologic signs</td>
<td>No imaging needed</td>
</tr>
<tr>
<td>Head injury</td>
<td>No imaging needed</td>
</tr>
<tr>
<td>Acute, mild, GCS &gt; 13, without neurologic findings</td>
<td>CT without contrast</td>
</tr>
<tr>
<td>Acute, mild-moderate, &lt; 2 years of age</td>
<td>CT without contrast</td>
</tr>
<tr>
<td>Acute, penetrating, or moderate-severe</td>
<td>MRI without contrast</td>
</tr>
<tr>
<td>Acute, suspected skull fracture</td>
<td>CT without contrast</td>
</tr>
<tr>
<td>Subacute, cognitive or neurologic findings</td>
<td>MRI without contrast</td>
</tr>
<tr>
<td>Sinusitis</td>
<td>No imaging needed</td>
</tr>
<tr>
<td>Uncomplicated</td>
<td>CT without contrast</td>
</tr>
<tr>
<td>Recurrent, unresponsive, suspected complication</td>
<td>CT without contrast</td>
</tr>
<tr>
<td>Croup or epiglottitis</td>
<td>Lateral soft tissue view of neck</td>
</tr>
<tr>
<td>Suspected inhaled foreign body</td>
<td>Inspiration/expiration or decubitus chest</td>
</tr>
<tr>
<td>Difficulty breathing</td>
<td>Chest x-ray</td>
</tr>
<tr>
<td>Fever</td>
<td>No imaging needed</td>
</tr>
<tr>
<td>Without obvious source, no respiratory symptoms</td>
<td>Chest x-ray</td>
</tr>
<tr>
<td>Neonatal or respiratory symptoms or increased WBC</td>
<td>Chest x-ray</td>
</tr>
<tr>
<td>Esophageal atresia or tracheoesophageal fistula</td>
<td>Lateral radiograph with soft feeding tube in place</td>
</tr>
<tr>
<td>Asthma</td>
<td>No imaging needed</td>
</tr>
<tr>
<td>Uncomplicated</td>
<td>Chest x-ray</td>
</tr>
<tr>
<td>Poor response to therapy, complicated</td>
<td>Chest x-ray</td>
</tr>
<tr>
<td>Suspected pneumonia</td>
<td>Chest x-ray</td>
</tr>
<tr>
<td>Congenital heart disease or congestive heart failure</td>
<td>Chest x-ray, echocardiogram</td>
</tr>
<tr>
<td>Gastroesophageal reflux</td>
<td>Barium swallow or nuclear medicine reflux study</td>
</tr>
<tr>
<td>Vomiting (recurrent 0-3 mo of age)</td>
<td>X-ray and UGI</td>
</tr>
<tr>
<td>Pyloric stenosis</td>
<td>Ultrasound</td>
</tr>
<tr>
<td>Duodenal atresia, stenosis, or midgut volvulus</td>
<td>Plain x-ray (use air as contrast)</td>
</tr>
<tr>
<td>Meconium ileus</td>
<td>Plain x-ray and meglumine diatrizoate (Gastrografin) enema</td>
</tr>
<tr>
<td>Appendicitis</td>
<td>CT with IV contrast or US (if experienced operator is available)</td>
</tr>
<tr>
<td>Intussusception</td>
<td>Plain x-ray followed by reduction using air or Gastrografin enema</td>
</tr>
<tr>
<td>Necrotizing enterocolitis</td>
<td>Plain x-ray of the abdomen and possible left lateral decubitus views (to look for free air)</td>
</tr>
<tr>
<td>Crohn’s disease</td>
<td>CT with IV contrast or CT enterography</td>
</tr>
<tr>
<td>Hirschsprung’s disease</td>
<td>Barium or Gastrografin enema</td>
</tr>
<tr>
<td>Biliary atresia or neonatal hepatitis</td>
<td>Nuclear medicine hepatobiliary scan</td>
</tr>
<tr>
<td>Abdominal mass</td>
<td>Plain x-ray of abdomen and ultrasound or CT</td>
</tr>
<tr>
<td>Meckel’s diverticulum</td>
<td>Nuclear medicine Meckel’s scan</td>
</tr>
<tr>
<td>Urinary tract infection</td>
<td>US kidneys and bladder</td>
</tr>
<tr>
<td>Hematuria</td>
<td>US kidneys and bladder</td>
</tr>
<tr>
<td>Isolated</td>
<td>CT without contrast</td>
</tr>
<tr>
<td>Painful or posttrauma</td>
<td>CT without contrast</td>
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</table>
pharynx and hypopharynx. On the anteroposterior (AP) view the upper portion of the trachea is shaped like a steeple (Fig. 9-5). The “steeple sign,” caused by subglottic edema, is not pathognomonic, because it also can occur in some children who have epiglottitis.

### CHEST

#### Normal Anatomy and Imaging

One of the major differences between the normal chest of an adult or child and a neonate is the presence of the thymus. It is routinely identified on chest x-rays from birth to approximately age 2 years. The thymus is usually seen as a widening of the soft tissues of the upper mediastinum, although occasionally it may appear to project out into the lung (the “sail sign”) (Fig. 9-6). Some people mistakenly think that the sail sign is an indication that a pneumothorax is present. This is not true.

Imaging of the chest in infants and children can be difficult because of their uncooperative nature, especially...
enough, hypoinflation of the chest is usually not a problem in interpretation of pediatric chest x-rays. Most children with pneumonias, bronchiolitis, or reactive airway disease have hyperinflation. In most normal young children the most superior portion of the hemidiaphragm is at the level of the posterior eighth rib. If the diaphragms are lower than this, hyperinflation should be considered, and pathology may well be present. Rotation of the patient can cause problems in interpretation. As the patient is rotated to the left, the right cardiac border projects over the spine, and the right lower lobe pulmonary vessels are indistinct and can mimic an infiltrate (Fig. 9-7).

A favorite x-ray examination is the “babygram.” This is an AP view of both the chest and the abdomen. In extremely small babies the x-ray exposure can be adequate to visualize pulmonary vasculature, bowel gas, and skeletal structures. Conversely, if you are interested only in the chest, a chest x-ray is what you should order to avoid unnecessary radiation exposure.

**Foreign Bodies**

Foreign bodies can be either aspirated or ingested. Most foreign bodies consist of vegetable material (such as peanuts) or plastic. Remember that vegetable and plastic items are usually not visible on a plain x-ray. When a foreign body is aspirated into a bronchus, two possibilities exist. The first is that the object will become completely impacted and will not allow air to pass during either inspiration or expiration. In this case the air distally will become resorbed, and postobstructive atelectasis or a focal infiltrate with associated volume loss will be found.
The second possibility is that the object is only incompletely obstructing the bronchus. This occurs because during inspiration the bronchus becomes larger in diameter, and air can pass around the object. During expiration the bronchus becomes narrower due to pressure in the lung, and the air distal to the object cannot escape. The object acts as a ball valve. Thus if you are suspicious of the presence of an inhaled foreign body, be sure to order an inspiration and an expiration image. On the inspiration image you may see postobstructive atelectasis, or the chest x-ray may be normal. If the chest is normal, a ball-valve phenomenon may still exist, and on the expiration view, air will be trapped on the affected side, whereas the unaffected lung will decrease in volume. When this happens, a resultant shift of the mediastinum toward the normal unaffected side will be seen (Fig. 9-8).

Swallowed objects may be caught within the esophagus. In children the objects that are large enough to remain in
tubes and catheters that are of specific interest in children are endotracheal tubes and umbilical artery and vein catheters. The tip of an endotracheal tube should be at least as far down as the level of the medial clavicles or at the level of the vertebral body of T1 or T2. The endotracheal tube also should have its tip located 1 or 2 cm proximal to the carina. If the carina cannot be easily visualized, you should remember that on an AP or a posteroanterior (PA) chest x-ray, a tube with its tip projecting over the vertebral body of T5 is probably too low. Endotracheal tubes that are too low usually will go down the right main stem bronchus, because this is more vertical in orientation than the left main stem bronchus. Initially an endotracheal tube positioned in the right main stem bronchus may demonstrate

the esophagus are typically coins. These may be lodged at the level of the thoracic inlet, or they may sit in the esophagus just above the level of the aortic arch (Fig. 9-9). Another common foreign object that may lodge in either the hypopharynx or the esophagus is a fish bone or chicken bone. Chicken bones may be visualized on plain x-rays, but most fish bones are composed of cartilage and are essentially invisible.

**Tubes and Lines**

A discussion of central venous catheters, jugular catheters, and pleural tubes has been included in Chapter 3. The

**FIGURE 9-8** Foreign body in right main stem bronchus. **A,** An inspiration view of the chest looks essentially normal. **B,** An expiration view shows that the left lung has decreased in volume (as expected) but that a shift of the heart to the left has occurred (arrows). The right lung remains hyperinflated due to the inability of the air to escape the ball-valve phenomenon caused by the foreign body.

**FIGURE 9-9** Coin in the esophagus. **A,** A posteroanterior view of the chest demonstrates a quarter (arrow) that is lodged in the esophagus just at the thoracic inlet. **B,** The lateral view also shows the coin behind the trachea in the esophagus (arrow).
Umbilical artery and vein catheters are easily differentiated on the lateral view of the abdomen and chest. The umbilical artery catheter (UAC) proceeds inferiorly from the umbilicus down into the pelvis and then turns and comes up the aorta (Fig. 9-11). Usually the tip of a UAC is positioned at approximately the level of the vertebral body of T8. If a UAC is advanced too far, it can proceed up into the great vessels of the head and neck or go anteriorly in the aortic arch. An umbilical vein catheter (UVC) also is best identified on the lateral view. It can be seen progressing immediately superiorly from the umbilicus and then posteriorly along the liver and into the inferior vena cava and right atrium.

If both a UAC and a UVC are present on an AP view, it is not often easy to tell them apart, especially because you will be seeing the portions of the catheters that are inside and outside the baby. What you should do is imagine where the umbilicus should be. A catheter that goes straight up and slightly to the right of the midline is a UVC, and one that goes down toward the pelvis and then toward the head is a UAC.

Another catheter that can sometimes be confusing is a ventriculoperitoneal shunt catheter. These shunts, which are placed for relief of hydrocephalus, extend from the lateral ventricle of the brain down along the soft tissues of the neck and anterior chest wall and then into the peritoneal cavity (Fig. 9-12). Less commonly, the distal shunt tip may be placed in the region of the right atrium.

**Respiratory Disease in the Newborn**

A number of entities can cause neonatal respiratory difficulty (Table 9-2). You should be able to recognize a congenital diaphragmatic hernia, because it is a cause of respiratory distress in the neonatal period, and it carries a mortality rate well in excess of 50%. Clinical manifestations are a scaphoid abdomen and bowel sounds in the chest. Cyanosis due to pulmonary hypoplasia and pulmonary hypertension also may be present. These hernias occur more commonly on the left and will displace the heart and tracheal structures to the right. An opacity within
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the chest often has visible bowel or at least air-filled spaces within it (Fig. 9-13).

At birth, meconium aspiration can occur. *Meconium* is the term used for the first stool evacuated after birth, and it is composed of mucus, epithelial cells, bile, and debris. In fetal distress, evacuation of meconium into the amniotic fluid may occur. Only about 10% of the time does this cause respiratory problems. At birth, as a result of this, coarse patchy infiltrates and hyperinflation of the lungs may be found, which clears in about 3 to 5 days. Pneumothorax or pneumomediastinum occurs in about 25% of cases.

Another cause of respiratory distress within 48 hours of birth is transient tachypnea of the newborn (TTN). Lung volumes may be larger than normal, and there may be linear or streaky opacities that usually clear within 2 days. TTN is really a clinical and not a radiographic diagnosis; it is due to delayed resorption of intrauterine pulmonary liquid.

**TABLE 9-2 X-ray Findings of Respiratory Distress in the Newborn**

<table>
<thead>
<tr>
<th>ENTITY</th>
<th>TIME</th>
<th>LUNG VOLUME</th>
<th>LUNG FINDINGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diaphragmatic hernia</td>
<td>At birth</td>
<td>Compressed</td>
<td>Bowel in chest</td>
</tr>
<tr>
<td>Meconium aspiration</td>
<td>At birth</td>
<td>Increased</td>
<td>Coarse, patchy infiltrates</td>
</tr>
<tr>
<td>Transient tachypnea</td>
<td>0–2 days</td>
<td>Normal or increased</td>
<td>Homogeneous diffuse or linear infiltrates</td>
</tr>
<tr>
<td>Hyaline membrane disease</td>
<td>0–7 days</td>
<td>Decreased*</td>
<td>Granular infiltrates</td>
</tr>
<tr>
<td>Neonatal pneumonia</td>
<td>Variable</td>
<td>Variable</td>
<td>Granular or patchy infiltrates</td>
</tr>
<tr>
<td>Pneumothorax</td>
<td>Variable</td>
<td>Decreased</td>
<td>Lucent dark area at lung edge†</td>
</tr>
</tbody>
</table>

*Can be increased if the patient is on positive-pressure ventilation (PEEP).
†Pneumothorax is much more common in children who are on PEEP.
Look carefully for a basilar, medial, or anterior pneumothorax, because the images are usually done supine.

**FIGURE 9-11** Differentiation of umbilical artery from umbilical vein catheters. A, On the anteroposterior view babygram, if you imagine the position of the umbilicus (at the position of the “X”), the catheter that initially goes inferiorly and then turns and goes superiorly just to the left of midline is the umbilical artery catheter (UAC) (black arrows). A catheter that goes into the umbilical region and immediately progresses cephalad and slightly to the right of the midline (white arrows) is the umbilical vein catheter (UVC). B, A lateral view of the same infant demonstrates the inferior and then the posterior and superior course of the umbilical artery catheter, and the immediate superior course of the umbilical vein catheter progressing toward the inferior portion of the liver.

**FIGURE 9-12** Ventriculoperitoneal shunt for hydrocephalus. A, An anteroposterior view of the chest shows a catheter coming down from the cervical region and progressing across the chest (arrows), but not in a pathway that would represent vascular or other mediastinal structures. B, The lateral view of the chest shows the catheter progressing along the anterior soft tissues down into the abdomen (arrows).
Hyaline membrane disease (HMD) is caused by surfactant deficiency and results in low lung volumes (unless the infant is intubated) and granular or ground-glass opacities of both lungs. Any opacity in the lungs of a premature infant should be considered to be HMD until another cause is established. Air bronchograms are often present, and, rarely, a pleural effusion is found. HMD typically becomes radiographically apparent at 4 to 6 hours after birth.

With HMD or pneumonia, infants may need positive-pressure ventilation. The complications of this respiratory therapy include pulmonary interstitial emphysema (PIE) and bronchopulmonary dysplasia (BPD). PIE refers to accumulation of air outside of alveoli and in interstitial or perivascular spaces. The imaging features include tortuous linear lucencies that radiate outward from the hilum and may extend all the way to the periphery of the lung. If you look carefully, these do not resemble the pattern of a typical bronchial tree but are more tortuous (Fig. 9-14). You should be able to recognize PIE, because it may rapidly result in life-threatening complications, such as pneumothorax, pneumomediastinum, or pneumopericardium (Fig. 9-15).

Because the AP chest x-rays of newborns or neonates are usually obtained with the infant in a supine position, a pneumothorax may be difficult to appreciate. This is because the air is usually located anteriorly (and not superiorly or laterally) in the pleural space. You may be able to see lucencies either at the base of the lung or along the medial aspect of the lung. Often a lateral projection taken with the child lying on the back is necessary to show you the (anterior) pneumothorax (Fig. 9-16).

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BPD is thought to be the result of oxygen toxicity or barotrauma associated with respiratory therapy. BPD usually progresses as either HMD or neonatal pneumonia is resolving. BPD is usually seen progressing from approximately 1 week to 1 month of life. The lungs typically become hyperinflated, although they may have diffuse opacity with linear densities caused by fibrosis. Areas of rounded lucency may appear within the lung.

**Bronchiolitis, Reactive Airway Disease, and Pneumonia**

Neonatal pneumonia may result in a lung that is low in volume, normal, or hyperinflated. The lung opacities are typically granular, and the time course is variable. Neonatal pneumonias are due to transplacental infection (from toxoplasmosis, other agents [congenital syphilis and viruses], rubella, cytomegalovirus, herpes simplex virus [TORCH]) or from perineal flora acquired as a result of premature rupture of the membranes or while passing through the birth canal.

Children from several weeks to 1 year of age may have a viral pneumonia caused either by RSV or by *H. influenzae*. With these the early stage is bronchiolitis. About 15% of children younger than 2 years will develop bronchiolitis and will initially have rhinorrhea, sneezing, cough, and low-grade fever followed by the rapid onset of tachypnea and wheezing. Most cases occur during winter and early spring. These patients will not have infiltrates on the chest x-ray, and hyperinflation is the only radiographic clue. Bronchiolitis most commonly is due to RSV. As these viral pneumonias progress, perihilar or peribronchial opacities also may develop. This can be seen as peribronchial cuffing or hilar adenopathy. Again, many of these patients show associated hyperinflation. The peribronchial cuffing can be...
Cystic Fibrosis

Cystic fibrosis is caused by a dysfunction of the exocrine glands producing thick mucus that accumulates in the lungs, causing bronchitis and recurrent pneumonias. It is an autosomal recessive disorder and is the most common lethal genetic disease affecting whites. Pulmonary findings are present in essentially all cases by the time a child is age 10 years or older. The most obvious finding is hyperinflation. Essentially the chest x-ray looks like that of an adult with chronic obstructive pulmonary disease, with an increased AP diameter and flattening of the hemidiaphragms. In addition, the lungs generally appear “dirty.” Peribronchial thickening and bronchiectasis are found with many pulmonary markings at the lung bases (Fig. 9-18). These are not lobar or segmental infiltrates.

Children with cystic fibrosis also are prone to a wide variety of gastrointestinal (GI) problems, including meconium ileus, meconium peritonitis, rectal prolapse, volvulus, intussusception, pancreatitis, jaundice, and growth failure or vitamin deficiencies. You should suspect cystic fibrosis in any child with recurrent respiratory or GI symptoms.

PEDIATRIC ABDOMINAL IMAGING

Congenital diaphragmatic hernia has already been mentioned, but you should be aware of a number of other congenital abnormalities of the bowel in neonates.

Esophageal Fistula

Tracheoesophageal fistula (TEF) may be suspected in an infant who has had polyhydramnios. This is usually clinically apparent, because of excessive salivation; as soon as an attempt is made to feed the child, aspiration, coughing, and choking occur. Ninety-five percent of patients with a TEF will have a blind-ending esophagus. The diagnosis is usually made by passing a small, soft feeding tube down the esophagus to the blind end and taking a lateral x-ray. If necessary, air can be injected to help visualization. Instillation of barium or other contrast material is rarely, if ever, indicated. In those few patients with an “H-type” fistula and a patent esophagus, it may take months to arrive at the diagnosis, but the disorder should be suspected in a child with recurrent pneumonias or chronic cough. You should remember that 40% of patients with TEF have associated cardiac and other GI anomalies. The VATER syndrome describes the association among vertebral anomalies (hemivertebra), anal atresia, tracheoesophageal fistula, and radial limb dysplasia.

Acute Gastroenteritis

The usual clinical presentation is acute onset of diarrhea, vomiting, or both. Dehydration is the major complication. Acute gastroenteritis is usually due to viruses (Rotavirus or Norwalk virus). In extremely ill patients a stool culture or toxin assay is indicated. If the patient has abdominal pain
or distention, the differential diagnosis includes appendicitis, intussusception, or bowel obstruction. In these circumstances a plain and upright radiograph of the abdomen or a CT scan may be helpful. These are discussed in more detail in Chapter 6. For simple gastroenteritis no imaging studies are indicated.

**Bowel Obstruction**

Air should normally be seen in the abdomen of the neonate in the following temporal progression: in the stomach 2 hours after birth, in the small bowel at 6 hours, and in the rectum by 24 hours. Hypertrophic pyloric stenosis is the second most common GI condition requiring surgery in the first 2 months of life. Pyloric stenosis is more common in male infants and should be suspected if a maternal or sibling history of the condition exists. The typical clinical symptom is nonbilious vomiting during the second to fourth week of life. A palpable olive-shaped mass may be found to the right of the umbilicus. A plain x-ray of the abdomen will show a stomach that is dilated to more than 7 cm, and peristaltic waves can sometimes be seen, giving the stomach a caterpillar appearance. The diagnosis is confirmed by using abdominal ultrasound to visualize the thickened pyloric muscle. The pyloric muscle should not be more than 4 mm in thickness (mucosa to outside wall) or greater than 18 mm in length (Fig. 9-19).

Duodenal atresias, midgut volvulus, and pyloric stenosis are apparent because they produce obstruction and vomiting. Under these circumstances consult the radiologist as to what imaging procedure would be best. The approximate level of obstruction in the bowel is typically determined on the plain radiograph by seeing how far bowel gas has progressed through the GI tract. If gas is seen only in the stomach or the stomach and duodenum (the double bubble sign), a proximal obstruction is likely. Duodenal atresia or midgut volvulus should be suspected in a birth with polyhydramnios and an infant who has bile-stained vomiting. Duodenal atresia is the most common cause of the double bubble sign, with annular pancreas being the next most common. Duodenal bands, webs, and midgut volvulus are less frequent. Duodenal atresia has been associated with Down syndrome. Midgut volvulus, although less common, is important to consider, because a high mortality rate occurs without intervention. A midgut volvulus occurs when the small bowel and proximal colon rotate about the axis of the superior mesenteric artery; this can cause arterial compromise and gangrene.

If air is seen beyond the duodenum but not into the distal small bowel or colon, you should think of midlevel lesions. Atresias can occur in the jejunum and ileum. With any of these entities, even with x-ray contrast studies, it is not possible to tell with certainty either the site of or the length of the atresia or even to differentiate an atresia from a midgut volvulus. As a result, most pediatric surgeons are content with the plain x-ray findings before proceeding to surgery. Occasionally some will request a barium enema to look for a microcolon before surgery.

If gas is seen throughout most of the abdomen of a neonate but not in the region of the rectum, a distal small bowel or colon obstruction should be suspected. This may be the result of either a meconium ileus or Hirschsprung’s disease. A note of caution should be entered here relative...
telescoping into colon. Forty percent of patients are initially seen between ages 3 months and 18 months, most with pain and vomiting. A lesser number have an associated abdominal mass or rectal bleeding. Intussusception is rare in neonates. Clinically the children have an acute onset of colicky pain, and they may cry, draw up their knees, and vomit. Sometimes a sausage-shaped mass can be felt in the upper abdomen. Radiographically, plain x-rays are often normal. If the intussusception has occurred within 24 hours before the patient is seen, a radiologist has a good chance of reducing it with a water-soluble contrast enema. Currently, however, most radiologists prefer to the appearance of bowel gas in a neonate or very young child. Gas in the small bowel and colon look exactly the same, and you should not allow yourself to think that you can tell the difference. Rather, differential diagnoses are made on the basis of whether gas is seen in the proximal or distal “bowel.”

Meconium ileus is seen in 50% of patients with cystic fibrosis. On an enema performed with water-soluble contrast, the colon is seen to be very small (microcolon), because it was unused during fetal life (Fig. 9-20). Hirschsprung’s disease is due to the absence of neural cells in the distal segment of the colon; these children are seen in the first 6 weeks of life with obstruction or constipation. This disorder should be suspected in any infant who fails to pass meconium in the first 24 hours of life. In about 75% of patients the abnormal segment is restricted to the rectosigmoid colon. On a barium enema a narrowed segment may be identified (Fig. 9-21).

Intussusception is invagination of a segment of bowel into more distal bowel and usually occurs with ileum.
Necrotizing Enterocolitis

Necrotizing enterocolitis is the most common GI emergency in premature infants. It usually develops within the first week after birth but can be seen up to 2 months after birth. Clinical signs are abdominal tenderness, rectal bleeding, and a septic shock–like appearance. The earliest radiographic sign is air within the wall of the bowel (pneumatosis) or a bubbly appearance of the bowel. Another early finding is small bowel dilatation due to an adynamic ileus (Fig. 9-23). Common complications and indications for surgery include free air within the peritoneal cavity, which indicates a bowel perforation. Gas in the portal vein also may be identified. In contrast with adults, in whom this condition generally portends a fatal outcome, the outcome in children with portal venous air is not so bad. On a supine view if a large amount of free air is noted within the peritoneal cavity, the air will outline the falciform ligament of the liver (the “football sign”) (Fig. 9-24). This is a fairly subtle sign; a large amount of air may be present in the peritoneal cavity, and on a supine image you may easily overlook it. For this reason, a left lateral decubitus view, which will show air over the lateral margin of the liver, is often recommended.

Meckel’s Diverticulum

Meckel’s diverticulum is a vestigial remnant of the omphalomesenteric duct, and it may contain gastric mucosa. Clinical signs are painless rectal bleeding and occasionally intestinal obstruction. Meckel’s diverticulum follows what is known as the rule of twos. It occurs in 2% of the population, it usually is first seen before age 2 years, and the diverticulum is usually located in the ileum within 2 feet
Neonatal Jaundice

In some infants who are 2 to 3 weeks old, jaundice may develop. The usual diagnostic dilemma is whether the infant has neonatal hepatitis or biliary atresia. The imaging test of choice is a nuclear medicine hepatobiliary scan. This involves giving a small amount of radioactive tracer that is concentrated by the liver and then excreted via the biliary system. If any excretion into the small bowel is detected on the images, biliary atresia is excluded. Occasionally in patients with severe hepatitis, follow-up images are needed at 24 hours after injection, to be certain of the diagnosis.

Abdominal Masses

Abdominal masses in children are usually initially worked up by clinical examination and a plain x-ray of the abdomen. The differential diagnosis of an abdominal mass varies with the child’s age. A mass in the abdomen of a child of any age most likely arises from the kidneys. In a neonate, 55% of masses are renal in origin (hydronephrosis or multicystic dysplastic kidney), and the remainder are usually GI duplications, cysts, and hemangioendotheliomas of the liver.

If a mass appears to be in the flank in an older infant or child, Wilms’ tumor, neuroblastoma, and hydronephrosis account for about 80% of the lesions. Other possibilities include abscesses, cysts, and hepatoblastomas. Neuroblastomas have calcification approximately 90% of the time (Fig. 9-26) and are usually seen in patients younger than 2 years. They appear as masses external to the kidney and tend to displace the kidney rather than deform it. Because neuroblastomas arise from neural tissue, they also are relatively common in the region of the adrenal glands, along the sympathetic chain, and in the posterior mediastinum.
(Fig. 9-27). Wilms’ tumor begins within the kidney, and on an intravenous pyelogram it will be seen as a mass within the kidney, deforming the normal collecting system (Fig. 9-28). Wilms’ tumors are bilateral 10% of the time and are rarely calcified. The average age of presentation is 2 years to 3 years, which is older than the usual age for neuroblastomas.

Appendicitis

In cases of suspected appendicitis in adults, CT scan of the abdomen and pelvis with intravenous contrast is the procedure of choice. Although graded-compression ultrasound can be used, the accuracy is quite dependent upon the skill of the operator. Obviously the appeal of
ultrasound for children is that no ionizing radiation is used. Published studies show that for children, CT scanning has minimally better sensitivity and specificity than ultrasound. Often CT scanning is done because of unavailability of an experienced ultrasound operator. In cases of children with atypical presentation, ultrasound is sometimes done first and if negative or equivocal, it may be followed with a CT scan.

Rectal Bleeding

Rectal bleeding in children should be classified as dark or bright red and painless or painful. Dark red blood usually indicates upper GI origin, and the differential diagnosis includes foreign body, varices, peptic ulcer, and bowel duplication. Painful dark or bright rectal bleeding is associated with volvulus, mesenteric thrombosis, and Meckel's diverticulum. Bright red painless bleeding may be due to a polyp, neoplasm, colitis, or sigmoid intussusception. Painful bright red bleeding is most commonly due to an anal fissure, hemorrhoids, or rectal prolapse; for these, no imaging studies are usually needed. Rectal bleeding in young children can also be due to an allergy to formula.

The workup of any rectal bleeding should begin with a rectal examination. If an obvious cause is not identified and particularly if associated pain, vomiting, guarding, rebound, or abdominal distention is present, a surgical consultation should be obtained. The imaging workup depends on which of the causes is thought to be most likely, although either endoscopy or a plain x-ray of the abdomen with an air or barium enema is often obtained.

Urinary Abnormalities

Two relatively common urinary problems in children are hydronephrosis and ureterovesicular reflux. The most common cause of hydronephrosis in a child is an obstruction at the junction of the lower portion of the renal pelvis and the upper ureter (ureteropelvic junction [UPJ]). The entity is bilateral in 20% of cases. The initial imaging test of choice is a CT scan with intravenous contrast. Although the dilated collecting system can be visualized with ultrasound, usually not enough anatomic detail of the ureter is found, and no information about renal function is provided. Postoperative follow-up functional studies in these children are usually done with a nuclear medicine furosemide (Lasix) renogram, because the radiation dose is lower with no risk for a contrast reaction. If only information about the degree of dilatation of the collecting system is desired, ultrasound is the test of choice.

Ureterovesicular reflux is due to maldevelopment of the flap valve that is created as the ureter crosses obliquely through the bladder wall. Less commonly, it can be due to ectopic insertion of a ureter when ureteral duplication is found or to a ureterocele. On a contrast study any visible reflux of urine from the bladder into a ureter is abnormal. If severe, it is surgically repaired because of the increased risk for infection. The most common imaging method is a cystogram. A catheter is placed, contrast is put into the bladder, and the radiologist looks for contrast in the ureters. This involves a relatively high radiation dose to the child's gonads, but the anatomic resolution is good. If repeated evaluations of reflux are necessary, a nuclear medicine cystogram can provide good quantitative information with a much lower dose.

Multicystic dysplastic kidney is a unilateral process resulting from a severe UPJ obstruction in utero. As a result, no functional renal parenchyma is present, and the kidney is represented by a large number of noncommunicating cysts. Calcification may be present, with absent or only very small renal vessels. A retrograde pyelogram shows a blind-ending ureter. Surgery is not immediately necessary. Another congenital condition is called multicystic nephroma, which has large cystic areas. Calcifications in this entity are rare.

Neonatal or infantile polycystic disease is not initially seen with a dominant abdominal mass. Each has ectasia of renal tubules, but no obvious cysts are visible by imaging methods. Ultrasound is the test of choice in the neonatal form; most tubules are ectatic, and death usually occurs in months or years. Little associated hepatic fibrosis develops. In the infantile form about 20% of the tubules are ectatic, and symptoms do not appear for 3 to 6 months. Moderate hepatic fibrosis is seen. In the juvenile form fewer tubules are ectatic, and symptoms appear at age 1 to 5 years. The liver fibrosis is severe in this form, and death results from portal hypertension.

Suggested Textbooks and Website on the Topic


Appendix

**TABLE A-1 Typical Price Range of Some Imaging Procedures**

<table>
<thead>
<tr>
<th>DIAGNOSTIC RADIOLOGY</th>
<th>$45-370</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest</td>
<td>45-240</td>
</tr>
<tr>
<td>Abdomen</td>
<td>45-350</td>
</tr>
<tr>
<td>Hand</td>
<td>45-180</td>
</tr>
<tr>
<td>Ankle</td>
<td>45-180</td>
</tr>
<tr>
<td>Barium enema</td>
<td>155-330</td>
</tr>
<tr>
<td>Mammogram (bilateral)</td>
<td>115-300</td>
</tr>
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</table>

**Computed Tomography**

<table>
<thead>
<tr>
<th>Brain without contrast</th>
<th>200-1150</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest without contrast</td>
<td>210-1450</td>
</tr>
<tr>
<td>Chest CT angiography</td>
<td>950-5400</td>
</tr>
<tr>
<td>Abdomen</td>
<td>240-2175</td>
</tr>
<tr>
<td>Pelvis</td>
<td>240-2325</td>
</tr>
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</table>

**Magnetic Resonance**

<table>
<thead>
<tr>
<th>Brain without contrast</th>
<th>550-2550</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lumbar spine</td>
<td>450-2000</td>
</tr>
<tr>
<td>Knee</td>
<td>420-1500</td>
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**Nuclear Medicine**

<table>
<thead>
<tr>
<th>Bone</th>
<th>250-600</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myocardial perfusion with wall motion</td>
<td>690-2000</td>
</tr>
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**Ultrasound**

<table>
<thead>
<tr>
<th>Fetal</th>
<th>120-850</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right upper quadrant</td>
<td>110-400</td>
</tr>
</tbody>
</table>

*Price includes hospital and physician payments. Prices can vary tremendously for the identical procedure. The lower end of the range is the approximate fee paid by Medicare, and the upper end is the U.S. average total fee charged (not the payment actually accepted). Many contracted imaging services offer 20% to 40% discounts on charged fees. Considerable additional charges for contrast agents or radiopharmaceuticals can be hundreds of dollars per procedure. If possible, patients should try to ascertain the cost or negotiate a price before a procedure.

**TABLE A-2 Radiation Doses From Various Examinations**

<table>
<thead>
<tr>
<th>EXAMINATION</th>
<th>EFFECTIVE DOSE* (mSv)</th>
<th>GONADAL DOSE (mGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Routine X-rays</td>
<td>0.01</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Extremities</td>
<td>0.22</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Skull</td>
<td>0.1</td>
<td>0.01</td>
</tr>
<tr>
<td>Chest (2 views)</td>
<td>0.7</td>
<td>½†</td>
</tr>
<tr>
<td>KUB (abdomen 1 view)</td>
<td>1.5</td>
<td>2.2/7.2</td>
</tr>
<tr>
<td>Lumbar spine</td>
<td>0.6</td>
<td>2.1/6.0</td>
</tr>
<tr>
<td>Pelvis or hips</td>
<td>8.0</td>
<td>1.75/9.00</td>
</tr>
<tr>
<td>Barium enema</td>
<td>8.0</td>
<td>1.75/9.00</td>
</tr>
</tbody>
</table>

**CT Scans**

<table>
<thead>
<tr>
<th>Head</th>
<th>2.0</th>
<th>—</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest</td>
<td>7.0</td>
<td>—</td>
</tr>
<tr>
<td>Abdomen and pelvis (together)</td>
<td>14</td>
<td>—</td>
</tr>
</tbody>
</table>

**Nuclear Medicine Scans**

<table>
<thead>
<tr>
<th>Bone</th>
<th>6.3</th>
<th>0.9/1.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lung</td>
<td>2.5</td>
<td>2.3/0.3</td>
</tr>
<tr>
<td>Cardiac (sestamibi stress-rest)</td>
<td>9.4</td>
<td>3.1/12.2</td>
</tr>
<tr>
<td>Hepatobiliary</td>
<td>3.1</td>
<td>0.2/2.8</td>
</tr>
</tbody>
</table>

**Ultrasound or Magnetic Resonance Imaging**

| None | None |

*CT, Computed tomography; KUB, kidney, ureter, and bladder (plain image of the abdomen).

*The effective dose from natural background radiation in the United States is 3 mSv per year. The approximate risk for radiation-induced fatal cancer from an effective dose of 100 mSv is about 0.5%. This can be compared to the risk for spontaneous fatal cancer of 22%.

†Refers to male/female. Gonadal dose in the female approximates dose to the fetus in a pregnant female.