Figure 4-13. (A) CT scan of the same patient as in Figure 4-11 shows mediastinal shift to the left, consolidation of the entire left lung, and an endobronchial lesion in the left mainstem bronchus (asterisk). (B) Lung window shows that the right lung is overexpanded to compensate for the left lung atelectasis.

Figure 4-14. (A,B) Case 4-3: 61-year-old man with dyspnea.
**Radiologic Findings**

4-3. In Figure 4-14, there is opacity in the right upper lung that is sharply marginated on its inferior border. Volume loss is evidenced by the slight displacement of the trachea into the right hemithorax, the position of the right heart border further to the right of the thoracic spine than normal, and the slight elevation of the right hemidiaphragm, which is normally 1 to 1.5 cm higher than the left hemithorax. The pulmonary vessels of the right hilum are obscured by opacity in the right upper thorax. The configuration of the inferior margin of the opacity is that of a reverse S or S on its side. The “S-sign of Golden” describes the appearance of the minor fissure in right upper lobe collapse, which is due to bronchogenic carcinoma. In this case, bulky right hilar lymph-node enlargement has caused extrinsic compression of the right upper lobe bronchus and has resulted in right upper lobe collapse. The right hilar mass tethers the medial aspect of the minor fissure to its normal midthoracic position, whereas the lateral aspect of the minor fissure moves freely and collapses superiorly. In patients in whom the minor fissure is incomplete, collateral air drift across the canals of Lambert and the pores of Kohn may allow a lobe to remain aerated despite complete obstruction of its bronchus.

In Figure 4-14 A, hyperexpansion of the superior segment of the right lower lobe produces the ovoid lucency on the medial aspect of the collapsed right upper lobe. On the lateral radiograph, a V-shaped opacity is seen at the lung apex. A mass-like opacity is superimposed on the suprahilar area, corresponding to a combination of tumor and atelectatic lung (B is the correct answer to Question 4-3). In patients with right upper lobe collapse without a hilar mass, the fissure is able to rotate in a straighter line and does not result in the reverse S sign. The major fissure is oriented in a coronal plane and is not normally visualized on the frontal chest radiograph. Therefore, the major fissure would

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**Figure 4-15. (A,B) Case 4-4: 45-year-old man with chronic cough.**
not account for the opacity seen on the frontal chest radiograph, either with or without a hilar mass.

4-4. In Figure 4-15 A,B, the right heart border is obscured by adjacent opacity on the PA radiograph. The lungs are hyperinflated. The heart is in the midthorax in approximately its normal position. The heart border has not been displaced to the left. On the lateral radiograph, a narrow triangular opacity is superimposed on the heart. The apex of the triangle points toward the hilum, and the base of the triangle is against the anterior chest wall. This is a collapsed right middle lobe. The right hemidiaphragm is slightly elevated, but there are no other signs of significant volume loss. Right middle lobe collapse may have minimal impact on the overall volume in the right hemithorax because it is the smallest of the pulmonary lobes, and the upper and lower lobes can expand to compensate for its volume loss. Right middle lobe collapse, unlike other lobar collapse, is often due to benign causes, such as extrinsic pressure by enlarged lymph nodes, which totally surround the bronchus. This enlargement is most frequently due to granulomatous disease of an infectious or noninfectious nature (B is the correct answer to Question 4-4).

4-5. When the left lower lobe collapses, the result is a triangular opacity, which can be quite subtle, behind the heart. Secondary signs of volume loss, however, should prompt one to look closely for the collapse. These signs include shift of the trachea and heart to the left (note that the right heart border is now superimposed on the thoracic spine), inferior displacement of the left hilum, and elevation of the left hemidiaphragm. On the lateral radiograph, the right hemidiaphragm is visible along its entire contour. However, the left hemidiaphragm is obscured posteriorly because it is "silhouetted" by the collapsed left lower lobe. Because it is tethered medially by the inferior pulmonary ligament, the left lower lobe collapses posteriorly and medially (Figure 4-18). The major fissure is displaced posteriorly, as well as rotated into a more sagittal orientation than the normal coronal orientation (D is the correct answer to Question 4-5). You may have noted the large

\section*{Figure 4-16. (A,B) Case 4-5: 62-year-old man with a cough productive of blood-tinged sputum.}
4-6. The primary sign of volume loss in Figure 4-17 B is anterior displacement of the left major fissure on the lateral radiograph. The collapsed left upper lobe is opaque as a result of both airlessness and postobstructive pneumonitis. When there is little pneumonitis within the obstructed lobe, the left upper lobe can collapse completely behind the anterior chest wall, so that only a narrow band of opacity is visible behind the sternum. In this situation, the diagnosis may be suggested by the secondary signs of volume loss. Note the shift of the trachea to the left and the slight elevation of the left hemidiaphragm. The left lower lobe is hyperexpanded. The hyperexpanded superior segment of the left lower lobe produces a crescent of air around the transverse section of the aortic arch on the PA radiograph. A thin
opaque line is visible at the apex of the left hemidiaphragm on the PA radiograph. Presence of this line, called a juxtaphrenic peak, should prompt one to look for upper lobe collapse. The hilum may be displaced anteriorly in left upper lobe collapse, but it is never displaced inferiorly. Option E, inferior displacement of the left hilum, is therefore false (A is the correct answer to Question 4-6). Because the lingular bronchus arises from the left upper lobe bronchus, the lingular segment of the left upper lobe is collapsed as well in this patient. The lingula is adjacent to the left heart border and is responsible for the obscuration of the left heart border in left upper lobe collapse.

Discussion

The term atelectasis refers to volume loss, or airlessness, within the lung. The term collapse is often used to describe complete atelectasis of an entire lobe or an entire lung. Atelectasis can occur as a result of several pathophysiologic processes. Obstruction of a bronchus by bronchogenic carcinoma should always be considered in an adult with lobar atelectasis. The tumor may be within the bronchus (endobronchial), as occurs with squamous-cell carcinoma or small-cell undifferentiated carcinoma. The tumor may be outside the bronchus, and enlarged lymph nodes may cause extrinsic compression of the bronchus. In a child, aspiration of a foreign body is a more likely cause of obstruction of a bronchus. Complete obstruction of a lobar bronchus may not always result in lobar collapse because pathways of collateral ventilation are present within the lung. The pores of Kohn and the canals of Lambert allow collateral air drift between adjacent areas of lung but do not extend across pleural surfaces. The visceral pleural surface that covers the lung creates the interlobar fissures (minor fissure, major fissure) that separate lobes of the lungs. These fissures are not always complete, however, and may not extend entirely across the lung. When the right upper lobe bronchus is occluded, for example, the right upper lobe may remain partially aerated as a result of collateral air drift from the right middle lobe, around an incomplete minor fissure. Obstruction of smaller Airways can occur as a result of mucus plugs, which are often present in intubated patients and in patients with chronic small airway disease.

Passive atelectasis (see Figure 4-10) occurs as a result of a space-occupying process within the pleural space. This is also called relaxation atelectasis, because the lung is no longer exposed to the negative intrapleural pressure that normally keeps the lung apposed to the chest wall. Any space-occupying pleural process, including a large pneumothorax (air in the pleural space), pleural effusion, hemothorax (blood in the pleural space), or pleural tumor, can cause atelectasis within the underlying lung. Compressive atelectasis is the term used to describe atelectasis caused by a space-occupying process within the lung itself. Cicatrization atelectasis describes the volume loss that occurs as a result of pulmonary scarring. Adhesive atelectasis occurs when there is a loss of the pulmonary surfactant that maintains the surface tension that keeps alveoli open. Adhesive atelectasis occurs with pulmonary embolism, and with respiratory distress syndrome of the newborn. Atelectasis of small areas of lung is often referred to as subsegmental atelectasis and may be recognized as linear bands of opacity, often at the lung bases (Figure 4-19).

It is helpful to remember the normal positions of the hemidiaphragms, trachea, mediastinum, and hila so that displacement of these structures can be readily noted. In most patients, the left hilum appears slightly higher than the right, because the left hilar opacity is predominantly due to the left pulmonary artery arching over the left main bronchus. The right hemidiaphragm is usually 1.0 to 1.5 cm higher than the left hemidiaphragm. The trachea should be in the midline, and the spinous processes of the upper thoracic vertebrae should be superimposed on the center of the tracheal air column. The right heart border normally lies just to the right of the thoracic spine. Subtle signs of volume loss may be more readily appreciated by comparison of the patient’s radiograph with baseline radiographs taken previously.

Figure 4-19. Axial CT image of the left lung base demonstrates linear bandlike opacities extending to the pleural surface in the periphery. This is an example of subsegmental atelectasis.
EXERCISE 4-3. AIRSPACE DISEASES

4-7. Which of the following is the best descriptor of Figure 4-20 A,B?
A. Diffuse airspace disease
B. Lobar airspace disease
C. Interstitial pattern
D. Unilateral airspace disease

4-8. For Figure 4-21, which one of the following best explains the opacity in the right hemithorax?
A. Collapse of the right upper lobe due to bronchial obstruction
B. Airspace consolidation of the right middle lobe
C. Empyema loculated within the right major fissure
D. Carcinoma in the right upper lobe

Radiologic Findings
(Both of these patients have airspace opacities)

4-7. In this case (Figure 4-20), the opacity involves multiple lobes bilaterally (A is the correct answer to Question 4-7.).

4-8. In this case (Figure 4-21), the opacity is in the right middle lobe and obscures the medial margin of the heart. On the lateral view of this patient, the margins are sharply demarcated by the fissures, indicating the lobar nature of the process. Radiolucent structures that exhibit a branching pattern are noted to arborize through both opacities (B is the correct answer to Question 4-8.).

Discussion
The patient in Figure 4-20 has pulmonary hemorrhage as a consequence of underlying Wegener’s granulomatosis, manifested as multilobar airspace disease bilaterally, also seen on CT (Figure 4-22). The patient in Figure 4-21 has pneumococcal pneumonia (Streptococcus pneumoniae) in the right middle lobe. The opacity seen on both radiographs is best described as airspace disease. The alveoli, or airspaces, that are normally filled with air have become filled with exudate. The exudate-filled alveoli surround the bronchi, so that the air-filled bronchi are visible as radiolucent branching structures within the more radiopaque background (Figure 4-23). Airspace disease is often lobar (Figure 4-21), multilobar, or diffuse (Figure 4-20) in distribution. The process may initially appear as multiple ill-defined nodules that rapidly coalesce. These nodules are the shadows of fluid-filled acini. They are 6 to 10 mm in diameter and always have ill-defined margins. The margins of these coalescing opacities are difficult to outline. Although there can be associated volume loss as the surfactant within the alveoli is lost, the signs of volume loss are
often subtle and do not account for the opacity seen within the lung. Once airspace disease is identified, an attempt should be made to determine its cause. Airspace disease that appears suddenly or exhibits change over hours to days is due either to pulmonary hemorrhage or to contusion, pneumonia, or pulmonary edema (blood, pus, or water). The patient's clinical history, physical examination, and laboratory data help to determine the most likely diagnosis. In patients likely to have infectious disorders, the responsible organism is usually not identified at first treatment, and the patient is just given antibiotics. In patients who do not respond to this initial treatment, an attempt should be made to identify the organism.

In a patient with fever and productive cough, pneumonia is likely. On the other hand, a patient with rib or sternal fractures as a result of blunt chest trauma is more likely to have pulmonary contusion. Pulmonary edema, which may occur as a result of either cardiogenic or noncardiogenic disease, is discussed later in this chapter.

A reticular pattern is one in which the opacities are linear in nature and the lines range from quite thin to several millimeters thick. The opacities are oriented in multiple directions and
appear to overlap so as to create the appearance of a net. This pattern is not present.

**EXERCISE 4-4. DIFFUSE LUNG OPACITIES**

4-9. Which of the following best describes the chest radiograph in Figure 4-24?
A. Alveolar pulmonary edema
B. Interstitial pulmonary edema, and small bilateral pleural effusions
C. Unilateral interstitial disease
D. Oligemia in the right lung

**Radiologic Findings**

4-9. Frontal chest radiograph (Figure 4-24) shows mild enlargement of the heart and indistinct vascularity, particularly at the lower lungs. Interlobular septal lines are visible adjacent to both lower costophrenic angles. (B is the correct answer to Question 4-9)

**Discussion**

Pulmonary edema can be divided into two major categories: cardiogenic edema and noncardiogenic edema. Cardiogenic edema occurs as a result of elevation of pulmonary capillary pressure, which is usually due to pulmonary venous hypertension. Noncardiogenic edema occurs as a result of disorders that increase pulmonary capillary permeability. With both types of edema, there is a net movement of fluid out of the microvasculature and into the pulmonary interstitium and alveoli. The most common cause of pulmonary edema is left ventricular failure, which may be due to atherosclerotic coronary artery disease, mitral or aortic valvular disease, myocarditis, or cardiomyopathy. Cardiogenic edema is preceded by pulmonary venous hypertension, which is associated with redistribution of pulmonary blood flow from dependent regions of the lung to nondependent regions. In the erect patient, the radiographic sign of this redistribution is an increase in size of vessels in the upper lungs and a decrease in the caliber of pulmonary vessels in the lung bases. Radiographically, it is often difficult to distinguish pulmonary arteries from pulmonary veins, but for purposes of determination of flow redistribution, the distinction is ignored and multiple vessels are measured at equal distances from the hilum or chest wall.

When seen end-on, normal bronchoarterial bundles may appear as adjacent circles of equal diameter, with the artery opaque and the bronchus lucent. The pulmonary arteries and
bronchi are located together in the same interstitial space and arborize adjacent to each other. The pulmonary veins return blood to the heart in a separate interstitial space and have a slightly different arborization pattern. As the pulmonary venous pressure increases, fluid leaks from the pulmonary capillaries into the adjacent interstitium. This interstitial pulmonary edema may be identified by peribronchial cuffing, indistinctness of the perivascular margins, perihilar haziness, and thickening of the interlobular septa and interlobar fissures. Septal thickening results in Kerley A (arrow) and Kerley B (arrowhead) lines on chest radiograph (Figure 4-25). As the pulmonary capillary pressure increases further, fluid spills into the alveoli, producing a symmetrical appearance of airspace filling that is predominantly perihilar (central) and basilar in distribution. Cardiogenic edema is greatest in dependent regions of the lungs. In supine patients, the dependent regions are the posterior segments of the upper lobes, and the superior and posterior basilar segments of the lower lobes. The central pattern of pulmonary edema has been called “bat-wing” edema (Figure 4-26). As the pulmonary edema worsens, the pulmonary and pleural lymphatics clear fluid from the lungs, and pleural effusions will develop. In congestive heart failure, the pleural effusions are generally small to moderate in size, and there is typically more fluid within the right pleural space than the left. Isolated left pleural effusion is unlikely to be due to congestive heart failure. In cardiogenic edema, the heart size will be increased. The cardiothoracic ratio is a guide to determining cardiac enlargement. The transverse dimension of the heart is divided by the transverse diameter of the thorax at the same level. When the cardiothoracic ratio is greater than 0.5, cardiomegaly is often (but not always) present. When possible, both the PA and lateral projections should be used to determine cardiac volume. Cardiomegaly may be more readily recognized when comparison is made with prior radiographs. Comparison requires a similar depth of inspiration and similar positioning of the patient (AP versus PA, supine versus erect).

Noncardiogenic edema (Figure 4-27), or “capillary leak” edema, may be due to a number of conditions, including adult respiratory distress syndrome, fat embolism, amniotic fluid embolism, drug overdose, near drowning, and acute airway obstruction. The cause of pulmonary edema in patients with intracranial injury or tumor (neurogenic pulmonary edema) is uncertain. Similarly, the etiology of high-altitude pulmonary edema is incompletely understood. The common radiographic findings in noncardiogenic edema are symmetric, diffuse areas of airspace filling that is often patchier in appearance and more peripheral in distribution. The heart size is usually normal; pleural effusions and septal lines are typically absent. The vascular pedicle is of normal width.
Renal failure and volume overload may result in pulmonary edema, which may be chronic. When the degree of edema is small to moderate, patients are often reasonably well compensated and are able to carry out many activities of daily living.

EXERCISE 4-5. AIRWAY DISEASE

4-10. The most accurate description of this chest radiograph (Figure 4-28 A,B) is
A. decreased lung volume.
B. diffuse thickening of the bronchial walls.
C. cardiomegaly.
D. pleural effusion.
E. mediastinal shift.

Radiologic Findings

4-10. In this case, the most prominent radiographic finding in Figure 4-28 A is coarse thickening of the bronchovascular bundles as they radiate from the hila. Thickened bronchial walls may be identified as tram-track lines, which refers to the appearance of the nearly parallel walls of bronchi oriented longitudinally. Careful inspection shows that these are present throughout both lungs and are located near the hila. Bronchial walls also project as ring-shaped opacities near the hila when the bronchus is seen end-on. Both of these structures represent the thick walls of dilated bronchi (bronchiectasis). The hila themselves are slightly enlarged as a result of a combination of enlarged hilar lymph nodes and mild pulmonary arterial hypertension. The lung volume is increased. The anterior clear space (retrosternal area) is larger and more radiolucent than normal. (B is the correct answer to Question 4-10).

Discussion

The cause of this patient’s bronchiectasis is cystic fibrosis. The mucus in patients with cystic fibrosis is thickened, and these patients do not have normal tracheobronchial clearance. This abnormal clearance may cause mucoid impaction, and atelectasis and pneumonia are frequent complications. Bronchiectasis can also occur as a result of pneumonia in patients without cystic fibrosis. In patients with pneumonia, the bronchiectasis is more likely to be confined to a single lobe, often a lower lobe. Bronchiectasis is divided into three groups: cylindrical, fusiform (or varicose), and saccular (or cystic). These three groups not only describe the appearance of the abnormal bronchi, but also give an indication as to its severity. Cylindrical bronchiectasis (Figure 4-29 A), the mildest form, is reversible and appears as thick-walled bronchi that fail to taper normally. The more severe forms, fusiform and saccular, are irreversible. Fusiform (Figure 4-29 B) bronchiectasis has a beaded appearance, whereas the bronchi in saccular (Figure 4-29 C) bronchiectasis end with clubbed, cystic areas. If the severe forms are localized, surgical resection may be curative. Medical therapy with bronchodilator and, when necessary, antibiotics is used when surgery is not indicated.

CT is the method of choice for determining the presence and extent of bronchiectasis. When the bronchus is perpendicular to the CT plane of section, bronchiectasis is identified as a ring shadow adjacent to an opaque circle. The ring represents the thickened dilated bronchial walls. The opaque circle represents the pulmonary artery adjacent to the dilated bronchus. This is called the “signet ring” sign (Figure 4-30). Bronchi and arteries travel together throughout the lung and are normally of the same caliber.

EXERCISE 4-6. SOLITARY PULMONARY NODULE

4-11. Characteristics suggesting that a nodule is benign are that
A. the size of the nodule does not change over 2 months.
B. it contains central calcification.
C. CT attenuation values within the nodule are over 30 Hounsfield units.
D. it is semisolid on CT.
Radiologic Findings

4-11. Frontal chest radiograph (Figure 4-31 A) shows a nodule in the left mid-lung that appears solid but is slightly lobulated. CT (Figure 4-31 B) of the chest demonstrates a popcorn pattern of calcification (arrow) (B is the correct answer to Question 4-11).

Discussion

In attempting to determine whether or not a nodule is benign, the characteristics to consider are the age of the patient, any history of previous malignancy, and the nodule’s growth rate, density, shape, and edge characteristics. The most important of these are the growth rate and density. If a solid nodule has had no growth over a 2-year period and has calcification of the types associated with benign causes, then the nodule is almost certainly benign. Because of the importance of time in assessing growth, comparison with old images is the most important test and the least expensive method of determining whether a nodule is benign.

Doubling times of lung cancers are variable, but an increase in diameter of the tumor would be expected in a 2-year period. The absence of growth of a solid nodule over a 2-year period is evidence that the nodule is stable in size and must, therefore, be benign. If radiographs demonstrate growth over this 2-year interval, then the nodule should be assumed to be malignant.

If a solid nodule is diffusely and completely calcified (Figure 4-32 A), if it is calcified centrally (Figure 4-32 B), or if it has a laminated pattern (Figure 4-32 C), then the nodule may be assumed to be benign. A popcorn pattern of calcification, also benign (Figures 4-31 B, 4-32 D), can be seen in a hamartoma. Calcification may not be apparent on the initial radiograph because the most commonly used technique for chest radiography obscures subtle calcification. Demonstration of calcification may require fluoroscopy or repeated chest radiography with a lower kVp technique to enhance its depiction. When it is not clear from these studies whether calcification is present, CT should be used to identify it. CT has an extended range of tissue discrimination.
Figure 4-29. Cylindrical (A), fusiform (B), and saccular (C) bronchiectasis (arrow) on axial CT.
compared to conventional radiographs. The presence of calcification within a pulmonary nodule can be determined by evaluating the attenuation values within a region of interest (ROI) centered over the nodule (Figure 4-33 A–C). Air within the lung measures –800 Hounsfield units, non-calcified nodules measure 30 to 100 HU, and calcified nodules measure over 200 HU. Nodules with attenuation values between 0 and 200 are not necessarily malignant; they just do not have enough calcification to be categorized unequivocally as benign.

If a nodule is not calcified or if it has shown growth over a 2-year period, it should be considered as a possible malignancy, and further assessment should be dictated by the clinical circumstances. Most patients will need evaluation for possible tissue biopsy and surgical resection to determine the cause.

Nodules that are larger than 1 cm in diameter are generally evaluated with PET-CT. Smaller nodules are generally considered below the threshold of resolution for this technique. Nodules considered hypermetabolic on PET-CT (increased radiotracer uptake relative to background) are considered potentially malignant. Generally, these nodules then undergo percutaneous or surgical biopsy. However, whereas most cancers are hypermetabolic, bronchoalveolar cell carcinoma (BAC) and carcinoid may not be hypermetabolic (Figure 4-34). If these cancers are suspected on CT, a negative PET-CT examination could be a false-negative and should not preclude biopsy.

Figure 4-30. Axial CT image demonstrates the “signet ring” sign (arrow) of bronchiectasis created by the dilated bronchus (the ring) and adjacent artery.

Figure 4-31. Case 4-11: Preoperative chest radiograph (A) with subsequent CT of the chest (B) of a 53-year-old man who is scheduled for coronary artery bypass grafting.
Nodules can also be ground glass in appearance (Figure 4-35). However, this appearance is nonspecific and can be seen in multiple etiologies including infection as well as bronchoalveolar cell carcinoma. BAC can present as a ground-glass nodule that may not demonstrate any significant growth over a 2-year period. Therefore, ground-glass nodules require more extended monitoring than solid nodules do.

Nodules that are part solid and part ground glass can also be seen. These semisolid nodules behave more like solid nodules. Although they can be seen in an infectious or inflammatory process, semisolid nodules are more concerning for neoplasm. Semisolid nodules are particularly worrisome for bronchoalveolar cell carcinoma and warrant close follow-up with a low threshold for biopsy.

Bronchogenic carcinoma, particularly adenocarcinoma, frequently presents as a solitary pulmonary nodule in the periphery of the lung. A new solitary pulmonary nodule or nodule of indeterminate age, therefore, should be considered a possible malignancy. The most common cause of a solitary pulmonary nodule is a granuloma, typically the result of prior granulomatous infection, such as histoplasmosis or tuberculosis. These can frequently be identified as granulomata because of characteristic patterns of calcification.

Note that the margins of the lesion, whether smooth or spiculated, are of no value in determining the benignity or malignant potential of a lesion. Only uniform or central calcification, absence of growth over a 2-year period, or CT attenuation values over 200 HU throughout the nodule are reliable noninvasive indicators of benignity.

**EXERCISE 4-7. PULMONARY NEOPLASM**

4-12. The best description of the chest radiograph in Figure 4-36 A,B is
A. mass in the left upper lobe.
B. left upper lobe collapse.
C. mediastinal mass.
D. consolidation of the left upper lobe.
E. enlargement of the left pulmonary artery.

**Radiologic Findings**

4-12. In this case, the chest radiographs show a smoothly marginated opacity projecting over the left upper lobe. Both hila are normal in size. The opacity seen on the PA view is smaller than the volume of the left upper lobe, and no air bronchograms are present; this excludes consolidation of the lung as an answer. The posterior margin of the opacity is not a long straight or gently curving line, as is the major fissure, and therefore left upper lobe atelectasis is not the correct answer. The one best description of the radiographic findings is mass in the left upper lobe (A is the correct answer to Question 4-12). In a patient with cough, weight loss, and a history of tobacco use, bronchogenic carcinoma should be the primary consideration. A CT examination in this patient (Figure 4-37 A) shows the mass in the left upper lobe, completely surrounded by aerated lung. PET-CT fusion imaging (Figure 4-37 B) demonstrates the expected hypermetabolic activity in the left upper lobe mass. A CT-guided percutaneous biopsy of this mass yielded a diagnosis of adenocarcinoma.

**Discussion**

There are more than 220,000 new cases of lung cancer, or bronchogenic carcinoma, and 160,000 deaths from lung cancer in the United States each year. Bronchogenic carcinoma is the more appropriate term, as most of them arise from the epithelium of the airways and not the lung per se. Because early recognition and surgical resection offer the patient the best chance for cure, it is important to be familiar with the variety of radiographic appearances of lung cancer. Four major cell types account for almost 90% of all lung cancers. The major cell types are squamous cell, adenocarcinoma,
For therapeutic purposes, lung cancer is divided into small-cell and non-small-cell lung cancer (NSCLC). This distinction is necessary because small-cell bronchogenic carcinoma is almost always widespread at the time of diagnosis and is best treated by chemotherapy and radiation therapy. Non-small-cell bronchogenic carcinoma, on the other hand, is best treated by surgical resection when the tumor is confined to one lung and regional lymph nodes. The typical radiographic appearance of small-cell carcinoma is bulky hilar and/or mediastinal lymph nodes; the primary tumor sometimes is visible as a nodule within the lung (Figure 4-38).

Non-small-cell bronchogenic carcinoma includes adenocarcinoma, squamous-cell carcinoma, and large-cell carcinoma. Adenocarcinoma, the most common cell type, typically appears as a solitary pulmonary nodule in the periphery of the lung. Bronchioalveolar cell carcinoma is a subtype of adenocarcinoma that may present either as lobar

**Figure 4-33.** (A) CT scan just above the aortic arch shows a nodule in the right upper lobe (arrow) with at least two eccentric regions of calcification. (B) A region of interest has been drawn on the nodule (arrow).
Figure 4-33. (Continued) (C) The Hounsfield units in each pixel in the region of interest are demonstrated. Note the very high numbers in the central portion of the lesion, indicating calcification within those pixels.

Figure 4-34. Axial PET-CT fusion image demonstrates an endobronchial lesion with minimal hypermetabolic activity above the background level. This was biopsy-proven carcinoid, which may not be hypermetabolic on PET imaging.

Figure 4-35. CT scan of the chest demonstrates a ground-glass nodule in the left upper lobe. This was biopsy-proven bronchoalveolar cell carcinoma.
**Figure 4-36.** (A,B) Case 4-12: 64-year-old man with cough and weight loss and a 50-pack-year history of tobacco use.

**Figure 4-37.** (A) Axial CT image demonstrates a mass in the left upper lobe surrounded by aerated lung. This mass results in the opacity seen on chest radiograph. (B) PET-CT fusion image demonstrating hypermetabolic activity within the mass, consistent with malignancy in this case.
airspace disease (Figure 4-39 A) or as diffuse, ill-defined pulmonary nodules (Figure 4-39 B). Bronchioalveolar cell carcinoma may also present as a solitary pulmonary nodule, usually a ground-glass nodule (see Figure 4-35). The second most common cell type, squamous-cell carcinoma, is associated with cigarette smoking and most often is found as an endobronchial tumor resulting in lobar collapse (Figures 4-13 and 4-18). The endobronchial tumor is visible bronchoscopically, and sputum cytology may be diagnostic in this tumor. Squamous-cell carcinoma can also appear radiographically as a solitary cavitary mass (Figure 4-39 C) or noncavitary mass. Large-cell carcinoma is the least frequent cell type. Its appearance is that of a bulky lesion within the lung.

When non-small-cell lung cancer is diagnosed, the patient undergoes a series of clinical and radiologic studies to determine the stage of the tumor. In the TNM staging system (Table 4-6), the categories of disease are stage I A, IB, IIA, IIB, IIIA, IIIB, or IV (Table 4-7). Stages I, II, and IIIA are surgically resectable. Patients with either stage IIIB or stage IV disease are not surgical candidates, but are treated with chemotherapy, radiation therapy, or both. In addition to helping define which treatment the patient should receive, the stage of the tumor helps provide prognosis. Patients with stage I disease have a 56% 5-year relative survival rate. Patients with stage IV disease have a 2% 5-year survival rate.

EXERCISE 4-8. MULTIPLE PULMONARY NODULES

4-13. The most likely cause of the multiple pulmonary nodules in Case 4-13 (Figure 4-40) is
A. metastasis.
B. herpes simplex pneumonia.

<table>
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<tr>
<th>Table 4-6. Lung Cancer TNM Staging System</th>
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<tbody>
<tr>
<td>Tumor</td>
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<tr>
<td>Tis Carcinoma in situ</td>
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<tr>
<td>T1 A tumor 3 cm or less in greatest diameter, limited to the lung, and without invasion proximal to a lobar bronchus</td>
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<tr>
<td>T1a Tumor 2 cm in greatest dimension or less</td>
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<tr>
<td>T1b Tumor greater than 2 cm but less than 3 cm</td>
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<tr>
<td>T2 A tumor larger than 3 cm but less than 7 cm; a tumor that invades the visceral pleura or produces collapse or consolidation of less than an entire lung; the tumor must be more than 2 cm distal to the carina</td>
</tr>
<tr>
<td>T2a Tumor greater than 3 cm but less than 5 cm</td>
</tr>
<tr>
<td>T2b Tumor greater than 5 cm, but less than 7 cm</td>
</tr>
<tr>
<td>T3 A tumor greater than 7 cm invading parietal pleura, chest wall, diaphragm, or mediastinal pleura or pericardium; a tumor less than 2 cm from the carina; or producing collapse or consolidation of an entire lung; or with separate nodule(s) in the same lobe</td>
</tr>
<tr>
<td>T4 A tumor of any size with invasion of the mediastinum or involving heart, great vessels, trachea, recurrent laryngeal nerve, esophagus, vertebral body, or carina; or separate tumor nodule(s) in a different ipsilateral lobe</td>
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Figure 4-39. (A–C) Forms of non-small-cell carcinoma. Presentations of bronchoalveolar cell carcinoma (a subtype of adenocarcinoma) on chest radiograph includes lobar airspace disease (A) and diffuse ill-defined pulmonary nodules (B). Air-fluid levels are present within a thick-walled cavitary mass in the left lower lobe, which was biopsy-proven squamous-cell carcinoma (C).

C. histoplasmosis.
D. Wegener’s granulomatosis.
E. arteriovenous malformations.

Radiologic Findings

4-13. In this case, the chest radiograph shows multiple, smoothly marginated, solid nodules in both lungs. These nodules are distributed diffusely and have various diameters (A is the correct answer to Question 4-13). The heart is normal in size and shape.

Discussion

The radiographic pattern of multiple pulmonary nodules is frequently encountered (Table 4-8). The clinical setting has considerable influence on the differential diagnosis in such cases and should always be taken into account when assessing patients with this pattern. However, the differential diagnosis may be narrowed by assessing the absolute size of the nodules, the uniformity of their size, their marginal characteristics, whether or not they are calcified, and whether or not they are cavitary. In adults the most common causes of
Multiple nodules are metastatic neoplasm and infectious disease. Metastatic neoplasm may result from carcinoma, sarcoma, or lymphoma. Pulmonary metastases may be of any size and number. In contrast to inflammatory nodules, nodular pulmonary metastases are often of various diameters. Metastases are usually of soft-tissue density similar to muscle or blood (Figure 4-41). Metastases may rarely be calcified if the patient has a sarcoma that makes bone or cartilage (eg, osteosarcoma). Differentiation is most commonly made by the clinical setting or review of old studies, but determination of the correct diagnosis may require tissue biopsy for confirmation.

Multiple pulmonary nodules may also be due to infectious disease, most commonly fungal or mycobacterial infections. In the United States, the most common fungus is histoplasmosis (Figure 4-42), although there are regional variations. Calcified nodules that are all of similar size suggest a previous infection with either histoplasmosis or tuberculosis. Nodules seen in acute infection are often not as sharply defined as metastases. This is especially true if the nodules represent acinar shadows. In these instances, the nodule is approximately 5 to 10 mm in diameter and is ill defined or fuzzy on its margin. Acinar nodules develop in patients with viral pneumonias such as herpes pneumonia or chicken pox (varicella) pneumonia.

Multiple pulmonary nodules may also develop in a wide variety of other disorders, including Wegener’s granulomatosis and arteriovenous malformations, but would not be as numerous as in this case.

**EXERCISE 4-9. CAVITY DISEASE**

4-14. The chest radiographic findings (Figure 4-43 A, B) in Case 4-14 could be best explained as

A. multiple lung abscesses due to *Staphylococcus aureus*.

B. pneumatoceles due to *Pneumocystis jiroveci* pneumonia.

C. Wegener’s granulomatosis.

D. multiple cavities due to *Mycobacterium avium-intracellulare*.

E. metastases from Kaposi’s sarcoma.

**Table 4-7. Lung Cancer Staging Classifications**

<table>
<thead>
<tr>
<th>Stage 0</th>
<th>Stage IA</th>
<th>Stage IB</th>
<th>Stage IIA</th>
<th>Stage IIB</th>
<th>Stage IIIA</th>
<th>Stage IIIB</th>
<th>Stage IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tis N0 M0</td>
<td>T1a,b N0 M0</td>
<td>T2a N0 M0</td>
<td>T1a,b N1 M0</td>
<td>T2b N1 M0</td>
<td>T1-2 N2 M0</td>
<td>T4 N2 M0</td>
<td>Any T Any N M1a,b</td>
</tr>
</tbody>
</table>

**Table 4-8. Patterns of Multiple Pulmonary Nodules**

<table>
<thead>
<tr>
<th>Disease process</th>
<th>Nodule description</th>
<th>Nodule location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metastases</td>
<td>Various sizes</td>
<td>Peripheral, hematogenous</td>
</tr>
<tr>
<td>Granulomas</td>
<td>Similar sizes, calcified</td>
<td>Diffuse</td>
</tr>
<tr>
<td>Septic emboli</td>
<td>Varying stages of cavitation</td>
<td>Peripheral</td>
</tr>
<tr>
<td>Wegener’s granulomatosis</td>
<td>Generally larger, cavitory, hemorrhagic</td>
<td>Diffuse</td>
</tr>
<tr>
<td>Rheumatoid arthritis</td>
<td>Various sizes, cavitory, thick-walled</td>
<td>Peripheral</td>
</tr>
</tbody>
</table>

▲ Figure 4-40. Case 4-13: Chest radiograph obtained as part of a routine follow-up examination in a 43-year-old male with malignant melanoma of the right thigh treated with wide resection 3 years previously.
Figure 4-41. Axial CT image from the same patient (Figure 4-40) demonstrating multiple soft tissue attenuation nodules throughout the lungs consistent with metastatic disease.

Radiologic Findings

4-14. PA and lateral chest radiographs (Figures 4-43 A,B) and CT images (Figure 4-43 C,D) show at least two thick-walled cavitary lesions in the right lung (C is the correct answer to Question 4-14). There is no hilar or mediastinal lymph node enlargement. The heart and skeleton are normal.

Discussion

Inflammatory lesions are the most common cause of lung cavities (Table 4-9). The number of cavities may range from one to many. A wide variety of infecting organisms may result in cavitation, and the radiograph is nonspecific as to etiology. There is considerable overlap in appearances from the various organisms, so that culture or histologic evaluation is the only satisfactory means of identifying the etiology. If the lesion is single, a cavitating pneumonia should be the first
Figure 4-43. (A–D) Case 4-14: 39-year-old female with a history of renal disease.
consideration, especially if the patient is febrile. If multiple cavities are present (Figure 4-44), the infection is likely due to hematogenous dissemination, and a source for this dissemination should be sought. The source could be right-sided endocarditis or infected venous thrombi. *Staphylococcus aureus* pneumonias are frequently seen in intravenous drug users and usually appear as multiple cavities. These usually have thin walls (2 to 4 mm) that are slightly indistinct on their outer borders.

As the acquired immunodeficiency syndrome (AIDS) epidemic has progressed, it has been recognized that patients with *Pneumocystis jiroveci* may develop cavitary lesions in the lungs (Figure 4-45). These cavities may be reversible and result from pneumatoceles, or they may be due to a slowly progressive granulomatous reaction. The cavities are usually in the upper lobes and are thin walled. Pneumothorax can result when a peripheral cavity ruptures through the visceral pleura, into the pleural space.

Neoplasia, either primary or secondarily involving the lung, may also cavitate (see Figure 4-39 C). Cavities may result from pulmonary vasculitis, of which Wegener’s granulomatosis is the prototype. Demonstrating the importance of clinical history, the supplied history of renal disease points toward Wegener’s granulomatosis.

### EXERCISE 4-10. OCCUPATIONAL DISORDERS

4-15. The most likely diagnosis in Figure 4-46 A,B is
A. progressive massive fibrosis, due to silicosis.
B. pneumonia in a patient with chronic interstitial lung disease.
C. lung cancer in a patient with asbestosis.
D. rounded atelectasis in a patient with asbestosis.
E. calcified plaques in a patient with asbestos exposure.

4-16. The most likely diagnosis in Figure 4-47 A,B is
A. progressive massive fibrosis, due to silicosis.
B. pneumonia in a patient with chronic interstitial lung disease.
C. lung cancer in a patient with asbestosis.
D. rounded atelectasis in a patient with asbestosis.
E. calcified plaques in a patient with asbestos exposure.

### Radiologic Findings

4-15. The dense radiopaque lines projecting adjacent to both diaphragmatic surfaces on the PA and lateral radiographs represent calcified pleural plaques. These are better seen on the CT (Figure 4-48 A). When the pleural plaques are seen en face on the PA radiograph, they produce irregular opacities over the lung. These opacities have been described.
as having a holly leaf appearance. At the lung bases, a network of fine lines is superimposed over the normal vascular shadows. These subpleural reticular markings represent interstitial pulmonary fibrosis, which almost certainly represents asbestosis (Figure 4-48 B). (E is the correct answer to Question 4-15.)

4-16. The patient in Figures 4-47 A,B has two large opacities projecting over the upper lung zones bilaterally. Bilateral upper lobe volume loss is indicated by upward displacement of the hila. Nodular diseases that have an upper-lobe preponderance include silicosis, sarcoidosis, and eosinophilic granuloma. In this case, the nodules have coalesced into large masses, an entity known as progressive massive fibrosis. In this patient with a history of working in coal mines, the most likely of these diseases is silicosis, or coal worker’s pneumoconiosis (A is the correct answer to Question 4-16).

Discussion

The two most commonly encountered occupational lung diseases in the United States are asbestosis and silicosis. Development of these diseases is dose dependent, and there is a latent period of many years between exposure and disease. Asbestos-related diseases occur after exposure to asbestos particles, which are found in many types of insulation, fireproofing materials, concrete, and brake linings. The patient with asbestos exposure is at an increased risk of developing lung cancer. If the patient also smokes, there is an additive risk, and these patients may be as much as 100 times more likely to develop lung cancer than the nonsmoking individual with no asbestos exposure.

The term asbestosis is used to refer to the pulmonary fibrosis that may be incited by the presence of the mineral and is not used in reference to the pleural disease. The pulmonary fibrosis is predominantly distributed in the lung bases. When severe, it is detected with conventional chest radiography. When it is more subtle, CT is required for its demonstration (see Figure 4-48 B). When the abnormalities are confined to the pleura, the process is called asbestos-related pleural disease. There are five manifestations of asbestos-related pleural disease: asbestos-related pleural effusion, diffuse pleural thickening, pleural plaques, rounded atelectasis, and malignant mesothelioma. Asbestos-related pleural effusion occurs from 7 to 15 years after exposure. It is self-limited and may resolve without sequelae or result in diffuse pleural thickening. Pleural plaques are fibrous plaques that occur predominately on
Figure 4-47. (A,B) Case 4-16: 55-year-old man who worked as a coal miner for 30 years.

Figure 4-48. (A) Axial CT image with mediastinal windows shows multiple peripheral calcified pleural plaques (arrows) consistent with asbestos exposure. (B) Axial CT image with lung windows shows subpleural reticulation in the lung bases. This is consistent with asbestosis in a patient with a history of asbestos exposure.
the parietal pleural surfaces of the lower thoracic wall and diaphragmatic surfaces. Pleural plaques may be up to 8 to 10 mm thick, but are not easily visualized when seen en face. Oblique radiographs may show plaques that are projected en face on the PA chest radiograph. The plaques usually occur 10 years or more after exposure. Early in the development of pleural disease, the plaques are not calcified, but with time, the incidence of calcification increases.

CT is the most sensitive method of identifying pleural plaques (see Figure 4-48 A). Diffuse pleural thickening may result from the scarring of a previous benign asbestos-related pleural effusion, or it sometimes is due to confluent pleural plaques. Rounded atelectasis (Figures 4-49 A,B) is a piece of folded lung tissue that appears as a mass adjacent to the chest wall. The parietal pleura adheres to an area of lung, usually in the posterior lower lobes, and gradually produces a spiraling folded area of lung, which mimics lung cancer. The comet-tail appearance of bronchi and vessels spiraling into the mass may suggest the correct diagnosis, but because there is such a great increase in the risk of lung cancer in the asbestos-exposed individual, the mass should be closely followed. PET scans and biopsy may be necessary to distinguish the mass of rounded atelectasis from lung cancer. The final asbestos-related disease of the pleura is malignant mesothelioma. This is a malignant tumor of the pleura that usually presents as pleural nodules or pleural effusion (Figure 4-50 A,B).

Silicosis is another form of pulmonary fibrosis that occurs after prolonged exposure to silica. Historically, it has most often developed in coal miners. Because of improved ventilation standards and the increased automation of coal mining, silicosis is less commonly encountered today. There is an increased incidence of tuberculosis in coal miners, but no increased risk of lung cancer has been reported. Because of particle deposition, silicosis is predominantly an upper-lobe process. It first appears as small pulmonary nodules, and as the fibrosis progresses the hila are retracted upward over a period of years. The small granulomatous nodules of simple silicosis coalesce to form larger conglomerate masses. When these reach at least 1 cm in diameter, the disease is called complicated silicosis, and as they become larger still, it is designated progressive massive fibrosis. Very early disease may be seen only on CT, although in the later stages of the process, the small nodules and conglomerate masses are readily seen on either conventional radiographs or CT images (see Figure 4-47 A,B). Hilar and mediastinal lymph nodes may calcify in the periphery of the lymph node, a type of calcification known as eggshell calcification (Figure 4-51 A,B). An acute form of silicosis can occur in sandblasters who inhale a massive amount of sand. This type of silicosis radiographically resembles pulmonary edema. Coal worker’s pneumoconiosis is a similar process that results from inhalation of coal of a relatively pure carbon content. This dust is relatively more inert than silica and incites less fibrosis. The nodules are less well defined on their periphery, and there is a lesser tendency to develop progressive massive fibrosis. These distinctions are rather artificial, as rock dust is usually not...
Figure 4-50. (A) Frontal chest radiograph of a 56-year-old man with right-sided chest pain shows pleural opacity on the right. The patient was exposed to asbestos 20 years earlier. (B) CT scan through the mid thorax show loss of volume in the right hemithorax, with nodular pleural thickening encasing the lung (arrowheads), representing malignant mesothelioma. Calcified pleural plaques are also present (arrows).

Figure 4-51. Frontal (A) and lateral (B) radiographs of the chest in a 49-year-old man who shoveled sand in a glass factory with silica exposure demonstrate hilar and mediastinal adenopathy with an eggshell pattern of peripheral calcification (arrows) classically seen in silicosis or sarcoidosis.
very pure and contains a mixture of silica, carbon, and other minerals.

**EXERCISE 4-11. MEDIASTINAL MASSES AND COMPARTMENTS**

4-17. The chest radiograph in Figure 4-52 shows
A. an anterior mediastinal mass.
B. a middle mediastinal mass.
C. a posterior mediastinal mass.
D. a superior mediastinal mass.

4-18. The chest radiograph in Figure 4-53 shows
A. an anterior mediastinal mass.
B. a middle mediastinal mass.
C. a posterior mediastinal mass.
D. a superior mediastinal mass.

4-19. The chest radiograph in Figure 4-54 shows
A. an anterior mediastinal mass.
B. a middle mediastinal mass.
C. a posterior mediastinal mass.
D. a superior mediastinal mass.

**Radiologic Findings**

4-17. A spherical mass 4 cm in diameter is present in the subcarinal region on the frontal radiograph (Figure 4-52 A), and superimposed on the hilar region on the lateral radiograph (Figure 4-52 B). CT (Figure 4-55) shows that the lesion is of fluid attenuation (greater attenuation than the subcutaneous fat, but less attenuation than muscle). This mass is in the middle mediastinum. (B is the correct answer to Question 4-17.) In an asymptomatic individual, this most likely represents a congenital bronchogenic cyst. These masses can grow to sufficient size to cause symptoms such as dyspnea or dysphagia owing to compression of the trachea or esophagus. Bronchogenic cysts may also occur within the lungs and are often surgically resected because of the likelihood of pulmonary infection. The differential diagnosis of a middle mediastinal mass can be seen in Table 4-10.

4-18. The frontal radiograph (Figure 4-53) shows a lobulated mass to the right of the lower thoracic vertebrae. Note that the right heart border remains visible, suggesting that this mass is either anterior or posterior to...
the heart. On the lateral radiograph, the mass projects over the vertebral column consistent with a posterior mediastinal location. The coronal MR image in Figure 4-56 shows that the mass is paraspinal in location and associated with the neural foramen. Neurogenic tumors are the most common cause of posterior mediastinal masses. In this patient with multiple subcutaneous nodules, this mass is most likely a neurofibroma (C is the correct answer to Question 4-18).

4-19. In Figure 4-54, the frontal chest radiograph (Figures 4-54 A and 4-57 A) shows a mass projecting over the left hilum without obscuration of the interlobar pulmonary artery (arrowhead). Because the mass does not obliterate the margins of the vessel, it must be either anterior or posterior mediastinal location.

<table>
<thead>
<tr>
<th>Table 4-10. Differential Diagnosis by Mediastinal Compartment (Partial List)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superior</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>Thyroid goiter, carcinoma</td>
</tr>
<tr>
<td>Cystic hygroma</td>
</tr>
<tr>
<td>Adenopathy</td>
</tr>
<tr>
<td>Vascular abnormalities</td>
</tr>
<tr>
<td>Bronchogenic cyst</td>
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<tr>
<td></td>
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<td></td>
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</tbody>
</table>
**Figure 4-54.** (A,B) Case 4-19: 25-year-old woman with a nonproductive cough.

**Figure 4-55.** Axial CT image of the same patient in Figure 4-52 shows a round mass (arrow) of fluid attenuation in the subcarinal position. This is a typical appearance of a bronchogenic cyst.
posterior to the hilum. On the lateral view (Figure 4-57 B), the anterior clear space is somewhat opaque, and there is a suggestion of the margins of the mass. The CT scan (Figure 4-57 C) shows the mass, surrounded by fat, in the anterior mediastinum. The mass is solid and contains a few calcifications (arrow). (A is the correct answer to Question 4-19.)

Discussion

Two methods of dividing the mediastinum for radiographic purposes are in common use. The radiographic divisions are arbitrary and are intended to provide the most appropriate differential diagnosis for abnormalities that occur in these locations. Neither of the divisions follows the divisions used by anatomists. In the older system, the mediastinum is divided into three compartments. The anterior mediastinum is that portion of the mediastinum that is anterior to the anterior margin of the trachea and along the posterior margin of the pericardium and inferior vena cava. The posterior mediastinum lies behind a plane that extends the length of the thorax behind a line drawn 1 cm posteriorly to the anterior margin of the vertebral column. The middle mediastinum is the region between these two boundaries. This system has been superseded by a four-compartment model, which designates a superior mediastinal compartment as the space that lies above a plane extending from the sternomastoid to the lower border of the trachea. The anterior mediastinum is just caudad to the superior compartment and is anterior to a plane extending along the anterior aspect of the tracheal air column and along the anterior pericardium. Note that the heart shifts from the anterior to the middle mediastinum with the four-compartment system. The middle mediastinum occupies the area from the anterior pericardium backward to a plane 1 cm posterior to the anterior margin of the vertebral column. The addition of the fourth compartment occurred when CT was developed and it became easier to identify structures in each compartment.

The differential diagnosis of lesions occurring in each compartment is in part dependent on the structures that exist there (see Table 4-10). Note that there are vascular structures and lymph nodes in each of the compartments. Therefore, abnormalities of the blood vessels (eg, aneurysms) and lymph node diseases (eg, lymphoma) would have to be included in the differential diagnosis of diseases occurring there. The differential diagnosis lists include the most common disorders occurring in each region. The most common mass to occur in the superior mediastinum is an enlarged substernal thyroid, which may become large enough to extend into the anterior or middle mediastinum (Figure 4-58 A,B).

EXERCISE 4-12. PLEURAL ABNORMALITIES

4-20. The most likely diagnosis in Case 4-20 (Figure 4-59 A,B) is
A. pulmonary embolism.
B. overinflation associated with asthma.
C. pneumothorax.
D. normal chest, with a skin fold projected over the right hemithorax.
E. left lower lobe atelectasis.

Radiologic Findings

4-10. In Figure 4-59, there is increased radiolucency in the periphery of the right hemithorax. On the close-up of the right lung (Figure 4-60 A), there is a thin white line (arrows) paralleling, but displaced from, the right lateral chest wall. The thin line represents the visceral pleura. There is air-filled lung medial to this thin white line, and there is air within the pleural space lateral to this line. Note the absence of pulmonary vessels lateral to the pleural line (C is the correct answer to Question 4-20).

Discussion

Pneumothorax is the presence of air in the pleural space. The lung collapses away from the chest wall because of its normal...
elastic recoil. In some instances, a ball valve mechanism is present, and air continues to enter the pleural space and further collapses the lung and displaces the mediastinum away from the side of the pneumothorax. The relationship of the air in the pleural space to the lung and chest wall can be clearly seen on the CT scan of a patient with a right pneumothorax (Figure 4-60 B). Note that air rises to the highest point in the thorax, the anterior thorax in a supine patient and the lung apex in an upright patient. The visceral pleura covering the lung is visible as a thin white line on both chest radiographs and CT scans. No pulmonary vessels may be seen extending beyond the pleural line, and the air in the pleural space appears more radiolucent than the adjacent lung.

**Figure 4-57.** Anterior mediastinal mass (arrow) of the same patient in Figure 4-54 is demonstrated on frontal (A) and lateral (B) radiographs of the chest. A single axial CT image from the same patient (C) reveals a mass anterior to the pulmonary artery with punctuate areas of calcification (arrow) as seen in a thymoma.
The most common mimic of a pneumothorax, particularly in a supine patient, is a skin fold. The image receptor for portable AP chest radiographs is placed behind the patient’s back. Skin folds may be pressed between the patient’s back and the receptor. Radiographically, a skin fold produces an interface, or an edge of thick tissue outlined by the greater radiolucency of the superimposed lung (Figure 4-61). If you can distinguish an edge from a line, then you can distinguish a skin fold from a pneumothorax. The absence of pulmonary markings beyond the pleural line is supporting evidence for a pneumothorax. Because the vessels taper as they approach the lung periphery, the vessels in the extreme periphery of the lung may be too tiny to see.

Pneumothorax is considered spontaneous if it occurs in the absence of trauma (including barotrauma). Spontaneous pneumothorax may be primary and occur in the absence of significant other lung disease, or it may occur secondarily because of lung disease. Apical blebs are present in a high percentage of patients with primary spontaneous pneumothorax, and their rupture is thought to be the most frequent cause of spontaneous pneumothorax. For unknown reasons, it occurs most frequently in tall young men. Secondary spontaneous pneumothorax may occur in association with any cavitary lesion that lies in the periphery of the lung, as well as in emphysema, in bullous disease, and in pulmonary fibrosis of a variety of etiologies.

EXERCISE 4-13. PLEURAL EFFUSION

4-21. Which of the following radiographic signs generally does not suggest the presence of pleural effusion?
A. Meniscus-shaped opacity in a posterior costophrenic angle on the lateral projection
B. Biconvex lens-shaped opacity projecting in the midthorax on the lateral projection
**Radiologic Findings**

The frontal chest radiograph (Figure 4-62 A) shows opacity at the lower hemithorax bilaterally, which has a concave border curving upward laterally adjacent to the chest wall. The overall lung volume is low in both the right and left lungs. There is separation of the gastric bubble from the inferior margin of the lung by several centimeters. On the lateral examination (Figure 4-62 B), the opacities obscure the posterior heart margin and have a margin curving slightly upward to the posterior chest wall. Neither hemidiaphragm can be followed posteriorly to the chest wall. The findings are those of bilateral pleural effusions (C is the correct answer to Question 4-21).

**Discussion**

The visceral pleura is the outer lining of the lung, and the parietal pleura is the lining of the chest cavity. Normally, these surfaces are smooth and are separated by a minimal amount of pleural fluid. This provides a nearly friction-free environment for movement of the lung within the thorax. The pleural space, therefore, is a potential space that, in the normal individual, contains no more than 3 to 5 mL of pleural fluid. Fluid may accumulate within the pleural space as a result of conditions that (1) increase pulmonary capillary pressure, (2) alter thoracic vascular or lymphatic pathways, (3) alter pleural capillary or lymphatic permeability, or (4) affect diaphragmatic peritoneal and pleural surfaces.

Pleural effusions are usually approached clinically according to whether the effusion develops because of alterations of the Starling equation, which controls fluid flow and maintenance in body compartments, or whether the pleura is affected primarily by a disease process. Processes resulting from alterations of the Starling equation include congestive heart failure, hypoproteinemia, fluid overload, liver failure, and nephrosis. These effusions are usually...
transudates (clear or pale yellow, odorless fluid without elevation of the ratios of pleural fluid to serum protein and lactate dehydrogenase [LDH]). Processes that alter pleural capillary or lymphatic permeability include infection, inflammation, pulmonary embolism, and neoplasms. These effusions are usually exudates (clear, pale yellow or turbid, bloody, brownish fluid; pleural fluid protein: serum protein greater than 0.5; and pleural fluid LDH:serum LDH greater than 0.6). Enlarged lymph nodes or masses within the hila or mediastinum may obstruct lymphatic fluid flow and cause pleural exudates. Abdominal conditions that may produce pleural effusions include pancreatitis, subphrenic abscesses, liver abscesses, ovarian tumors, peritonitis, and ascites.

The most common radiographic sign of pleural effusion is pleural meniscus. The volume of fluid necessary to produce a pleural meniscus within a costophrenic angle varies from individual to individual. Approximately 100 mL of pleural fluid will cause appreciable blunting of the posterior costophrenic angle on the lateral view (Figure 4-63 A), and 200 mL will cause blunting of the lateral costophrenic angle on the PA projection in an upright patient (Figure 4-63 B). A lateral decubitus chest radiograph, with the side containing the pleural effusion placed down (dependent), will demonstrate even smaller amounts of free-flowing pleural effusions (Figure 4-63 C). Each millimeter of thickness of pleural fluid in the lateral decubitus projection corresponds to approximately 20 mL of pleural fluid. Large pleural effusions may usually be aspirated without guidance other than the chest radiograph. Small effusions are more difficult to aspirate and, if thoracentesis is planned, additional imaging guidance with ultrasonography or CT may be used. The effusion may simply be marked and aspirated by the clinical physician, or the effusion may be aspirated by a radiologist. If thoracentesis is attempted and fails for a large pleural effusion, it may be loculated and further imaging guidance is usually helpful.

When pleural adhesions develop, fluid in the pleural space becomes loculated (Figure 4-64 A–C) and may be trapped in nondependent areas of the thorax. The appearance of pleural 

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**Figure 4-60.** (A) Close-up frontal view of the chest of the same patient in Figure 4-59 shows a thin white line (arrows), corresponding to the visceral pleura. Lucency on either side represents air in the pleural space laterally and normally aerated lung medially. This is the hallmark of pneumothorax. (B) Axial CT image (lung window settings) shows air in the right pleural space. Note that the pneumothorax in this supine patient rises to the nondependent area of the thorax.
fluid may change and, rather than taking a meniscus shape, may assume the shape of a convex margin away from the chest wall. If air is introduced in the pleural space by penetration of the chest wall, or if fluid is trapped in the fissures, it will assume a biconvex lens shape (Figure 4-65). If a bronchopleural fistula develops, the patient will have a hydropneumothorax that may be recognized by air-fluid levels of different lengths on the PA and lateral chest radiographs (Figure 4-66). When cavities develop in the lung, the fluid levels are usually of the same length (Figure 4-67).

EXERCISE 4-14. PULMONARY VASCULAR DISEASE

4-22. The most likely cause for this patient’s dyspnea and pleuritic chest pain (Figure 4-68 A–D) is
A. multifocal pneumonia.
B. malignant pleural effusion.
C. pulmonary embolism.
D. septic emboli.
E. drug-related pneumonitis.

Radiologic Findings

4-22. The chest x-ray shows a wedge-shaped opacity in the periphery of the right lung base. There is blunting of the right lateral costophrenic angle on the PA view of

Figure 4-61. Frontal chest radiograph shows multiple skin folds visualized as edges, or interfaces, projecting over the right hemithorax.

Figure 4-62. (A,B) Case 4-21: 65-year-old man with increasing dyspnea of 1-week duration.
Figure 4-63. Frontal (A) and lateral (B) views of the chest show blunting of both lateral costophrenic angles (arrow) as well as the posterior costophrenic angles (arrow) caused by small bilateral pleural effusions. Note the batwing appearance of pulmonary edema. (C) Right lateral decubitus chest radiograph from a different patient shows displacement of the lateral margin of the right lung (arrows) from the chest wall by free-flowing pleural effusion.
Figure 4-64. (A) Posteroanterior radiograph shows an opacity (arrows) in the right lower hemithorax. The right pulmonary artery, right heart border, and right hemidiaphragm remain visible, suggesting that this opacity lies posteriorly. (B) Lateral chest radiograph demonstrates an opacity posteriorly contiguous with the pleural surface but with a well-defined anterior margin (arrows). Note the obtuse angle that the opacity makes with the posterior chest wall. (C) Axial contrasted CT image demonstrates the loculated pleural fluid seen on chest radiograph. The lung is displaced anteriorly. The pleura (arrows) is enhancing, suggesting an exudative process.
The opacity could represent a Hampton’s hump in the clinical setting of pulmonary embolus. Alternatively, pneumonia could have a similar presentation. The CT scan demonstrates filling defects within the pulmonary arteries bilaterally. At the levels shown, thromboemboli are visible within the right main pulmonary artery extending into the right upper lobe pulmonary artery (Figure 4-68 C) and within the basilar segmental arteries bilaterally (Figure 4-68 D). (C is the correct answer to Question 4-22.) The lung windows (Figure 4-68 E) show a peripheral area of increased attenuation, consistent with an area of reperfusion edema and/or pulmonary infarction.

**Discussion**

Pulmonary thromboembolism can occur as a result of deep venous thrombosis, typically from the veins of the pelvis and lower extremities. These thrombi dislodge (embolize) and travel via the inferior vena cava and right heart chambers to become trapped in the tapering branches of the pulmonary arterial system. Because pulmonary embolism often occurs without pulmonary infarction, the appearance of the chest radiograph is usually normal. The areas of lung deprived of pulmonary arterial flow are perfused by bronchial arterial collateral vessels. The chest radiograph may demonstrate subtle signs of volume loss or a small pleural effusion. Pulmonary opacities develop because of microatelectasis within the region of lung that has had an embolus, from edema as the blood flow is restored via the bronchial circulation, or from hemorrhage within a pulmonary infarction. Pulmonary infarction may occur if the pulmonary venous pressure is elevated or the bronchial arterial supply to a region is deficient for some reason. The cone-shaped area of pulmonary infarction has been called a Hampton’s hump (Figure 4-68 A) and is
Figure 4-66. Frontal (A) and lateral (B) chest radiographs demonstrate an air-fluid level in the left hemithorax. Note that the interface between the air and fluid in this patient’s hydropneumothorax is of different length on the two views. This is characteristic of an air-fluid level in the pleural space.

Figure 4-67. Close-up frontal (A) and lateral (B) chest radiographs of the left upper lobe demonstrate an air-fluid level (arrow). In this patient, the line separating the air and fluid is the same length on both views, suggesting that the cavitary lesion is spherical in shape. This is characteristic of an air-fluid level in the lung parenchyma, in this case, a lung abscess.
named after the person who originally described it. An area of radiolucency, corresponding to diminished pulmonary vascularity distal to a pulmonary embolism, is occasionally seen and is called the Westermark sign. There may also be an increase in the size of the pulmonary artery proximal to a large central pulmonary embolus (Fleischner sign).

Two imaging modalities are widely used in the evaluation of a patient with suspected pulmonary embolism: radionuclide perfusion scan and chest CTA. The radionuclide perfusion scan may be the more appropriate examination in the patient with a normal chest radiograph and no preexisting cardiac or pulmonary disease. In the patient with an abnormal chest radiograph, or preexisting...
cardiopulmonary disease, the V/Q scan is more likely to be interpreted as “indeterminate” and a chest CT becomes the preferred imaging modality. The chest CT also has the advantage of demonstrating unsuspected abnormalities, such as pericardial effusion, emphysema, esophagitis, or aortic dissection, which could be responsible for the patient’s chest pain or dyspnea.

On chest CTA, thromboemboli are visible as filling defects within the contrast-filled pulmonary arteries. These are typically several centimeters long and often are seen draped across the bifurcation of an artery (saddle emboli) (Figure 4-69). In patients with acute pulmonary embolism, the filling defects are seen within the center of the arterial lumen, although they may also completely occlude the artery. In patients with chronic pulmonary embolism, the filling defects are more likely to be found against the wall of the artery. Calcification within the thrombus also confirms the chronic nature of the thrombus.

There will be some patients in whom the diagnosis of pulmonary embolism remains uncertain after either a V/Q scan or a chest CTA. These examinations can be inadequate for a number of both technical and clinical reasons. The chest CTA can be difficult to interpret unless the patient is able to suspend respiration for the duration of the scan. Fortunately, helical CT scans are able to scan the entire thorax in under 20 seconds. Many patients with severe dyspnea, however, are unable to achieve this. Pulmonary angiography can be obtained to further evaluate the pulmonary arterial circulation when either the V/Q scan or chest CTA is nondiagnostic.

**EXERCISE 4-15. INTERSTITIAL LUNG DISEASE**

**4-23.** The most likely cause for this patient’s dyspnea and pleuritic chest pain (Figure 4-70 A–C) is

A. emphysema.
B. empyema.
C. pneumonia.
D. pulmonary fibrosis.
E. aspiration.

**Radiologic Findings**

**4-23.** The chest x-ray (Figure 4-70 A,B) shows diffuse bilateral coarse interstitial opacities with slight basilar predominance. The hemidiaphragms are flattened on the lateral radiograph. The CT scan (Figure 4-70 C) demonstrates multiple small similar-sized cysts stacked along the lung periphery with some preservation of normal lung centrally, particularly on the right. There is traction bronchiectasis present as well (D is the correct answer to Question 4-23).

**Discussion**

The list of interstitial lung diseases is long, and the differentiation can be complex. However, pulmonary fibrosis can be readily identified. Fibrosis can be subtle, with visible linear markings in the lung periphery on CT, or as obvious as the cystic change seen in this patient. End-stage pulmonary fibrosis is most readily recognized as stacks of air-filled...
Lucencies in the lung periphery in a pattern called "honeycombing" (Figure 4-70 C). This is often seen as the end stage of multiple interstitial lung diseases, most frequently in usual interstitial pneumonitis (UIP). These patients are almost certainly symptomatic, many requiring supplemental oxygen.

Lucencies in the lung can result from many causes. A lucency with a discernible wall is called a cavity. As described in previous exercises, infectious or neoplastic etiology can result in a cavity or air-filled lucency within the lung. However, these are rarely small and stacked as in this case. Empyema, or an infected pleural fluid collection, can also result in a cavity of air seen on chest radiograph. This cavity is generally larger and unilateral. Therefore, A, B, and E are incorrect.

In emphysema, the air-filled lucencies lack a discernable wall. (Figure 4-71 A). These lucencies are called bullae and, in centrilobular emphysema, have an upper lobe preponderance.
These lucencies are not cysts, because a true lung cyst is lined with epithelium. Emphysema is a common cause of dyspnea and is most often smoking-related. In these patients, the lung volumes are often larger than normal, and the lungs appear more radiolucent. The bullous lesions of centrilobular emphysema are more easily recognized on CT than on chest radiographs. Unlike other cystic lung diseases, a vessel can generally be seen coursing through the bulla rather than around the lucency. Another form of emphysema is paraseptal emphysema, in which the bullae occur along the lung periphery (Figure 4-71 B).

GLOSSARY OF TERMS IN CHEST ROENTGENOLOGY

**Acinar pattern** (synonyms: alveolar pattern, airspace disease, consolidation): A collection of round or elliptic, ill-defined, discrete or partly confluent opacities in the lung, each measuring 4 to 8 mm in diameter and together producing an extended, inhomogeneous shadow.

**Air bronchogram**: A branching lucency that represents the roentgenographic shadow of an air-containing bronchus peripheral to the hilum and surrounded by airless lung (whether by virtue of absorption of air, replacement of air, or both), a finding generally regarded as evidence of the patency of the more proximal airway.

**Air-fluid level**: A local collection of gas and liquid that, when traversed by a horizontal x-ray beam, creates a shadow characterized by a sharp horizontal interface between a gas density above and liquid density below.

**Air space**: The gas-containing portion of lung parenchyma, including the acini and excluding the interstitium and purely conductive portions of the lung.

**Anterior junction line**: A vertically oriented linear opacity approximately 1 to 2 mm wide, produced by the shadows of the right and left pleural surfaces in intimate contact between the aerated lungs anterior to the great vessels. It is usually obliquely oriented, projected over the tracheal air column, below the level of the clavicles.

**Aortopulmonary window**: A zone of relative lucency seen on both the PA and lateral chest radiographs bounded medially by the left side of the trachea, superiorly by the inferior surface of the aortic arch, and inferiorly by the left pulmonary artery. The pleural surface of the aortopulmonary (AP) window is normally concave; convexity of the AP window suggests lymphadenopathy.

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Atelectasis: Less than normal inflation of all or a portion of lung with corresponding diminution in volume. Qualifiers are often used to indicate extent and distribution (linear or pleatlike, subsegmental, segmental, lobar), as well as mechanism (resorption, relaxation, compressive, passive, cicatricial, adhesive).

Azygoesophageal recess: On the frontal chest radiograph, a vertically oriented interface between air in the right lower lobe, and the adjacent mediastinum containing the azygos vein and esophagus. It projects in the middle of the heart and spine on the frontal view.

Bleb: A thin-walled lucency within or contiguous to the visceral pleura.

Bulla: A sharply demarcated area of avascularity (lucency) within the lung measuring 1 cm or more in diameter and possessing a wall less than 1 mm in thickness.

Carina: The bifurcation of the trachea into right and left main bronchi.

Cavity: A gas-containing space within the lung surrounded by a wall whose thickness is greater than 1 mm and often irregular in contour.

Fissure: The infolding of visceral pleura that separates one lobe, or a portion of a lobe, from another. Radiographically visible as a linear opacity normally 1 mm or less in width. Qualifiers: minor (horizontal), major, accessory, azygos, anomalous.

Ground-glass pattern: A finely granular pattern of pulmonary opacity such that pulmonary vessels remain visible. The degree of opacity is not sufficient to result in air bronchograms.

Hilum (plural: hila): Anatomically, the depression or pit in the lung measuring 1 cm or more in diameter and spinal on the frontal view.

Bull: A linear opacity no greater than 2 mm in width.

Lobe: One of the principal divisions of the lungs (usually three on the right, two on the left) enveloped by the visceral pleura except at the hilum. The lobes are separated in whole or in part by pleural fissures.

Lucency (synonym: radiolucency): The shadow of tissue that attenuates the x-ray beam less effectively than surrounding tissue. On a radiograph, the area that appears more nearly black, usually applied to areas of air density or fat density.

Lymphadenopathy (synonym: adenopathy): Enlargement or abnormality of lymph nodes.

Mass: Any pulmonary or pleural lesion greater than 3 cm in diameter.

Miliary pattern: A collection of tiny (1 to 2 mm in diameter) discrete opacities in the lungs, generally uniform in size and widespread in distribution.

Nodular pattern: A collection of innumerable small, discrete opacities (2 to 10 mm in diameter), generally widespread in distribution.

Nodule: A sharply defined, discrete, circular opacity up to 3 cm in diameter within the lung.

Opacity: The shadow of tissue that attenuates the x-ray beam more than surrounding tissue. On a radiograph, areas that are more white than the surrounding area are said to be more opaque.

Posterior junction line: A vertically oriented, linear opacity approximately 2 mm wide, produced by the shadows of the right and left pleurae in intimate contact between the aerated lungs, representing the plane of contact between the lungs posterior to the trachea and esophagus, and anterior to the spine; the line may project above and below the suprasternal notch.

Posterior tracheal stripe: A vertically oriented linear opacity 2 to 5 mm wide, extending from the thoracic inlet to the bifurcation of the trachea, visible on the lateral radiograph, representing the posterior tracheal wall and contiguous mediastinal tissue (anterior, and often posterior, walls of the esophagus).

Primary complex: The combination of a focus of pneumonia due to a primary infection (eg, tuberculosis or histoplasmosis), with granulomas in the draining hilar or mediastinal lymph nodes. (Synonym: Ranke complex. The term Ghon focus describes the pulmonary lesion that has calcified. Ranke complex is the term to describe the combination of the Ghon focus and calcified hilar lymph nodes.)

Reticular pattern: A collection of innumerable small, linear opacities that together produce the appearance of a net.

Reticulonodular pattern: A collection of innumerable small, linear and nodular opacities that together produce the appearance of a net and superimposed small nodules.

Right tracheal stripe: A vertically oriented linear opacity 2 to 3 mm wide, extending from the thoracic inlet to the right tracheobronchial angle. It represents the right tracheal wall and contiguous mediastinal tissue (visceral and parietal pleurae of the right lung).

Septal line (synonym: Kerley line): A linear opacity, usually 1 to 2 mm in width, produced by thickening of the
interlobular septa and often due to either edema or cellular infiltration.

**Silhouette sign:** The effacement of an anatomic soft-tissue border by either a normal anatomic structure or a pathologic state, such as airlessness of adjacent lung or accumulation of fluid in the contiguous pleural space.

**Stripe:** A longitudinal opacity 2 to 5 mm in width.

**Tramline shadow:** Parallel or slightly convergent linear opacities that suggest the projection of tubular structures, generally representing thickened bronchial walls.

**SUGGESTED READING**


Imaging of the breast is undertaken as part of a comprehensive evaluation of this organ, integrating the patient's history, clinical signs, and symptoms. Radiography of the breast is known as mammography, or radiomammography. When used periodically in asymptomatic patients, this is called screening mammography. When imaging is targeted to patients with signs or symptoms of breast cancer, it is referred to as diagnostic breast imaging and usually is a tailored evaluation consisting of some combination of mammography and other techniques described later. Using the integrated approach, it is often possible to make an accurate diagnosis nonoperatively, and treatment may be individualized according to each patient's needs. The primary purpose of breast imaging is to detect breast carcinoma. A secondary purpose is to evaluate benign disease, such as cyst formation, infection, implant complication, and trauma.

Before the 1980s, when breast imaging was much less widely used, the proportion of surgery for benign breast disease was higher, and treatment for breast carcinoma was initiated at later stages of the disease than at present. Breast imaging has increased the detection of tumors smaller than those found on clinical breast examination and has enabled patients to avoid unnecessary surgery.

The outcome of earlier diagnosis and treatment, however, is yet to be proven. Mortality from breast cancer has remained fairly stable for several decades in spite of the introduction and popularization of screening mammography. Debate continues as to the efficacy of routine breast screening in certain age groups. It is almost universally acknowledged that women over 50 years of age benefit from periodic screening mammography. Several large population studies have shown a decrease in mortality of around 30% in this group. However, controversy continues concerning the value of screening mammography for women under the age of 50 years. Because breast cancer has a lower prevalence in this age group, the impediment to mass screening is largely economic; that is, the number of lives saved relative to dollars spent must be justified. Another difference is that in younger
women the breast parenchyma is more often dense and nodular. This condition decreases the sensitivity for detection for carcinoma and leads to more false-negative and false-positive results.

Besides a decrease in mortality, a second benefit of earlier diagnosis is that patients with breast carcinoma are afforded more treatment options; lumpectomy with radiation therapy is an option to mastectomy in many patients.

Mammography has been in common use since about 1980, and breast ultrasonography has been the most often used adjunctive technique during this time. The major contribution of ultrasonography has been its effectiveness in distinguishing cystic lesions from solid masses. Sonography has, therefore, helped to avoid unnecessary surgery, because asymptomatic simple cysts do not require intervention. Ultrasonography, together with mammography, is also used to help characterize solid lesions as benign, indeterminate, or suspicious.

Magnetic resonance (MR) imaging of the breast can be used in selected patients. Image-guided needle biopsy of the breast has become the first-line procedure for diagnosis of indeterminate lesions of the breast, with surgical biopsy being reserved for special cases. Nuclear medicine and contrast injection studies (ductography) are occasionally used under special circumstances with specific indications.

**TECHNIQUE AND NORMAL ANATOMY**

**Film-screen and Digital Radiography (Radiomammography)**

The film-screen mammogram is created with x-rays, radiographic film, and intensifying screens adjacent to the film within the cassette; hence the term *film-screen mammography*. The digital mammogram is created using a similar system, but replacing the film and screen with a digital detector.

The routine examination consists of two views of each breast, the craniocaudal (C-C) view and the mediolateral oblique (MLO) view, with a total of four films. The C-C view can be considered the “top-down” view, and the MLO an angled view from the side (Figures 5-1, 5-2). The patient undresses from the waist up and stands for the examination, leaning slightly against the mammography unit. The technologist must mobilize, elevate, and pull the breast to place as much breast tissue as possible on the surface of the film cassette holder. A flat, plastic compression paddle is then gently
but firmly lowered onto the breast surface to compress the breast into as thin a layer as possible. This compression achieves both immobilization during exposure and dispersion of breast tissue shadows over a larger area, thereby permitting better visual separation of imaged structures. Compression may be uncomfortable, and may even be painful in a small proportion of patients. However, most patients accept this level of discomfort for the few seconds required for each exposure, particularly if they understand the need for compression and know what to expect during the examination. Mammography has proved to be more cost-effective, while maintaining resolution high enough to
demonstrate early malignant lesions, than any other breast imaging technique. In its present state of evolution, however, the sensitivity of radiomammography ranges from 85% to 95%.

**Limitations**

Sensitivity is limited by three factors: (1) the nature of breast parenchyma, (2) the difficulty in positioning the organ for imaging, and (3) the nature of breast carcinoma.

**The Nature of Breast Parenchyma**

Very dense breast tissue may obscure masses lying within adjacent tissue. Masses are more easily detected in a fatty breast.

**Positioning**

A technologist performing mammography must include as much breast tissue as possible in the field of view for each image. The x-ray beam must pass through the breast tangentially to the thorax, and no other part of the body should intrude into the field of view, so as to not obscure any part of the breast. This requires both a cooperative patient and a skilled technologist. If a breast mass is located in a portion of the breast that is difficult to include in the image, mammography may fail to demonstrate the lesion. Also, because of these practical considerations, routine mammography is not performed in markedly debilitated patients.

**The Nature of Breast Carcinoma**

Some breast carcinomas are seen as well-defined rounded masses or as tiny, but bright, calcifications, and are easily detected. Others, however, may be poorly defined and irregular, mimicking normal breast tissue. Rarely, still others may have no radiographic signs at all.

For these reasons, it must be remembered that mammography has significant limitations in detection of carcinoma. It cannot be overemphasized that any suspicious finding on breast physical examination should be evaluated further, even if the mammogram shows no abnormality. Occasionally, additional imaging may reveal an abnormality, but if not, short-term close clinical follow-up or biopsy is warranted.

**Normal Structures**

Normal breast is composed mainly of parenchyma (lobules and ducts), connective tissue, and fat. Lobules are drained by ducts, which arborize within lobes. There are about 15 to 20 lobes in the breast. The lobar ducts converge upon the nipple.

**Parenchyma**

The lobules are glandular units and are seen as ill-defined, splotchy opacities of medium density. Their size varies from 1 to several millimeters, and larger opacities result from conglomerates of lobules with little interspersed fat. The breast lobes are intertwined and are therefore not discretely identifiable. This parenchymal tissue is contained between the pre-mammary and retromammary fascia.

The amount and distribution of glandular tissue are highly variable. Younger women tend to have more glandular tissue than do older women. Glandular atrophy begins inferomedially, and residual glandular density persists longer in the upper outer breast quadrants. However, any pattern can be seen at any adult age (Figure 5-3).
Along with glandular elements, the parenchyma consists of ductal tissue. Only major ducts are visualized mammographically, and these are seen in the subareolar region as thickened linear structures of medium density converging on the nipple.

**Connective Tissue**
Trabecular structures, which are condensations of connective tissue, appear as thin (≤1 mm) linear opacities of medium to high density. Cooper’s ligaments are the supporting trabeculae over the breast that give the organ its characteristic shape, and are thus seen as curved lines around fat lobules along the skin-parenchyma interface within any one breast (Figure 5-4).

**Fat**
The breast is composed of a large amount of fat, which is lucent, or almost black, on mammograms. Fat is distributed in the subcutaneous layer, in among the parenchymal elements centrally, and in the retromammary layer anterior to the pectoral muscle (Figure 5-4).

**Lymph Nodes**
Lymph nodes are seen in the axillae and occasionally in the breast itself (Figure 5-4).

**Veins**
Veins are seen traversing the breast as uniform, linear opacities, about 1 to 5 mm in diameter (Figure 5-4).

**Arteries**
Arteries appear as slightly thinner, uniform, linear densities and are best seen when calcified, as in patients with atherosclerosis, diabetes, or renal disease.

**Skin**
Skin lines are normally thin and are not easily seen without the aid of a bright light for film-screen mammograms. Various processing algorithms with digital mammography allow better visualization of the skin.

**Screening Mammography**
The standard mammogram (along with appropriate history-taking) makes up the entire screening mammogram. The indication for this examination is the search for occult carcinoma in an asymptomatic patient. Physical examination by the patient’s physician, known as the clinical breast examination (CBE), is an indispensable element in complete breast screening. Although the American Cancer Society no longer recommends routine breast self-examination (BSE), particular attention should be paid to lumps identified by the patient as new or enlarging. Such patients should be referred for diagnostic mammography. Table 5-1 includes guidelines for frequency.

**Diagnostic Mammography**
The diagnostic mammogram begins with the two-view standard mammogram. Additional maneuvers are then used as...
appropriate in each case, dictated by history, physical examination, and findings on initial mammography. Indications for diagnostic mammography are (1) a palpable mass or other symptom or sign (eg, skin dimpling, nipple retraction, or nipple discharge that is clear or bloody), and (2) a radiographic abnormality on a screening mammogram. Additionally, patients with a personal history of breast cancer may be considered in the diagnostic category.

Other projections, magnification, and spot compression may be used to further evaluate abnormalities. These techniques provide better detail and disperse overlapping breast tissue so that lesions are less obscured.

### Implant Views

Patients with breast implants require specialized views to best image residual breast tissue because the implants obscure large areas of the breast tissue with routine mammography. These specialized views (Eklund, “push-back,” or implant displacement view) displace the implants posteriorly while the breast tissue is pulled anteriorly as much as possible.

### Computer-Aided Detection

Growing availability and affordability of computing power has led to the development of computer-aided detection (CAD). CAD utilizes complex algorithms to analyze the data from a mammogram for suspicious calcifications, masses, and architecture distortion. It then flags these areas so that the interpreting radiologist can give these areas special attention. Several studies show increased cancer detection when CAD is applied, and sensitivity and specificity continue to improve as these algorithms are refined.

### Ultrasonography

The indications for ultrasonography are (1) a mammographically detected mass, the nature of which is indeterminate, (2) a palpable mass that is not seen on mammography, (3) a palpable mass in a patient below the age recommended for routine mammography, and (4) guidance for intervention. Ultrasonography is a highly reliable technique for differentiating cystic from solid masses. If criteria for a simple cyst are met, the diagnosis is over 99% accurate. Although certain features have been described as indicative of benign or malignant solid masses, this determination is more difficult to make and less accurate than the determination of the cystic nature of a mass.

A limitation of ultrasonography is that it is very operator-dependent. Also, it images only a small part of the breast at any one moment. Therefore, an overall inclusive survey is not possible in one image, and lesions may easily be missed.

### Normal Structures

The skin, premammary and retromammary fasciae, trabeculae, walls of ducts and vessels, and pectoral fasciae are well seen as linear structures. The glandular and fat lobules are oval, of varying sizes, and hypoechoic relative to the surrounding connective tissue (Figure 5-5).

Simple cysts are anechoic (echo-free) and have thin, smooth walls. Increased echogenicity is seen deep to cysts (enhanced through-transmission). Most solid masses are hypoechoic relative to surrounding breast tissue.

### Magnetic Resonance Imaging

The role of MRI in mammography continues to expand, with common applications including (1) staging of and surgical planning for breast tumors, (2) searching for a primary tumor in patients who present with cancerous axillary lymph nodes, (3) evaluating tumor response to neoadjuvant chemotherapy, (4) differentiating tumor recurrence from posttreatment changes in patients with previous breast-conserving surgery and radiation, (5) screening of high-risk patients, (6) evaluating...
implants, and (7) evaluating difficult (dense or fibrous) breasts. In addition, the technology for MR-guided breast biopsies is increasingly available.

The patient lies prone on the scanner table, and a specialized coil surrounds the breasts. Depending on the clinical question, a varying number of pulse sequences are performed to evaluate the breasts or the composition of a suspicious lesion. Scan times can range from 30 minutes to over an hour.

MRI can show whether a lesion is solid or contains fat or fluid. Dynamic scanning after administration of intravenous contrast shows whether structures enhance and at what rate. Cancers classically enhance rapidly with subsequent “washout.” For instance, a lesion that enhances relatively rapidly on dynamic exam (think neovascularity) is more concerning for malignancy. If more than one suspicious lesion is identified, the relative proximity of these lesions can determine whether a patient would be a good candidate for lumpectomy rather than mastectomy. The wide field of view allows staging by evaluating the axillary and internal mammary nodes. Figure 5-6 shows an enhancing cancerous tumor.

Although MRI is quite sensitive (good for detecting disease), it is relatively nonspecific. This is due to the overlapping imaging characteristics of both benign and malignant processes. Like cancer, some benign breast structures show enhancement, although usually with a slower rate.

Because of the relatively low specificity, screening with MRI is best used in patients with a higher probability of disease. The 2007 American Cancer Society recommendations include annual MRI breast screening of patients with a lifetime risk of 20% or greater.

**Normal Structures**

Tissues are differentiated by their pattern of change on different pulse sequences. The skin, nipple and areola, mammary fat, breast parenchyma, and connective tissue are normally seen, in addition to the anterior chest wall, including musculature, ribs and their cartilaginous portions, and portions of internal organs. Small calcifications are not visible, and small solid nodules may not be detected. Cystic structures are well seen. Normal implants appear as cystic structures with well-defined walls. Their location is deep to the breast parenchyma or subpectoral, depending on the surgical technique that was used to place the implants. Internal signal varies and depends on implant contents, either silicone or saline.

**Ductography**

Ductography, or galactography, uses mammographic imaging with contrast injection into the breast ducts. The indication for use is a profuse, spontaneous, nonmilky nipple discharge from a single duct orifice. If these conditions are not present, the ductogram is likely to be of little help. The
purpose is to reveal the location of the ductal system involved. The cause of the discharge is frequently not identified. Occasionally, an intraluminal abnormality is seen, but findings have low specificity.

The patient lies in supine position while the discharging duct is cannulated with a blunt-tipped needle or catheter under visual inspection and with the aid of a magnifying glass. A small amount of contrast material (usually not more than 1 mL) is injected gently by hand into the duct. Several mammographic images are then made. The procedure requires about 30 minutes and is not normally painful.

**Normal Structures**

Just deep to the opening of the duct on the nipple, the duct expands into the lactiferous sinus. After a few millimeters, the duct narrows again and then branches as it enters the lobe containing the glands drained by this ductal system. The normal caliber of the duct and its branches is highly variable, but normal duct walls should be smooth, without truncation or abrupt narrowing. With high-pressure injection, the lobules, as well as cystically dilated portions of ducts and lobules, may opacify.

**Image-Guided Needle Aspiration and Biopsy**

The indications for needle aspiration and biopsy of breast lesions are varied and are variably interpreted by radiologists and referring physicians. Two categories are discussed here.

The first indication is aspiration of cystic lesions to confirm diagnosis, to relieve pain, or both. Nonpalpable cysts require either ultrasound or mammography to be seen. A fine needle (20- to 25-gauge) usually suffices to extract the fluid. The cystic fluid is not routinely sent for cytology unless it is bloody.

The second indication concerns solid lesions. Needle biopsy is used in this case (1) to confirm benignity of a lesion carrying a low suspicion of malignancy mammographically, (2) to confirm malignancy in a highly suspicious lesion prior to initiating further surgical planning and treatment, and (3) to evaluate any other relevant mammographic lesion for which either follow-up imaging or surgical excision is a less desirable option for further evaluation.

Guidance for needle biopsy can be accomplished with stereotactic mammography, ultrasound, and MR. Imaging

**Figure 5-6.** (A) Mammogram showing dense breast tissue. (B) MRI of same breast showing enhancing cancer in otherwise minimally enhancing breast.
modality for needle guidance is selected on the basis of lesion characteristics, availability of technology, and personal preference of the radiologist. Ultrasound and mammography are the most commonly used techniques.

Large core biopsy (typically 14-, 11-, or 8-gauge) has been shown to be more accurate for nonpalpable lesions than fine needle aspiration (20-gauge or smaller) and is often combined with vacuum assistance to further increase tissue yield.

Mammographic guidance is most easily and accurately performed with a stereotactic table unit. Lesions of only a few millimeters can be successfully biopsied. With stereotactic tables, the patient lies prone with the breast protruding through an opening in the table surface. A needle is mechanically guided to the proper location in the breast with computer assistance. The entire procedure requires 30 minutes to 1 hour.

Image-Guided Needle Localization

When a nonpalpable breast lesion must be excised, imaging is used to guide placement of a needle into the breast, with the needle tip traversing or flanking the lesion. Either ultrasonographic or mammographic guidance can be used, and the choice again depends on lesion characteristics and personal preference. Once the needle is in the appropriate position, a hook wire is inserted through the needle to anchor the device in place. This prevents migration during patient transport and surgery. After needle placement, the patient is taken to the operating theater for excision of the lesion by the surgeon.

Biopsy Specimen Radiography

When a lesion is excised from the breast, a surgical specimen can be radiographed to document that the mammographic abnormality was removed. This practice is routinely followed with needle-localized lesions, but palpable lesions excised may also be radiographed to confirm that the specimen contains an abnormality that may have been present on the mammogram.

Patient Preparation

For the mammogram, two-piece clothing is most convenient as the patient will need to undress from the waist up. Patients should not apply antiperspirant to the breast or axilla because it may cause artifacts.

Mammography is generally limited to ambulatory, cooperative patients because of the difficulties in proper positioning and because mammography units are not portable. If a debilitated patient has a palpable mass, then ultrasound would be a reasonable first step, followed by bedside needle aspiration or biopsy if the mass is solid. Screening mammography in markedly debilitated patients rarely has clinical utility.

Patients for whom stereotactic biopsy is being considered should be able to lie in prone position without moving for about 1 hour.

Conflict with Other Procedures

Coordinating with other techniques is an infrequent problem with breast imaging. One situation that does occasionally cause difficulty occurs in the patient with a palpable mass.
that is aspirated with a needle prior to imaging. Aspiration of a simple cyst may cause bleeding into the lesion. Subsequent ultrasonography then shows a complex lesion with debris or some apparently solid elements, rather than a simple cyst. A complex lesion requires more aggressive management than does a simple cyst. Therefore, imaging is best performed prior to aspiration.

THE SYMPTOMATIC PATIENT

EXERCISE 5-1. THE PALPABLE MASS

(Please answer questions for this exercise before looking at the images, which are presented with the discussion.)

5-1. In Case 5-1, a 34-year-old woman who noticed a new lump in her breast, which test should be ordered first?
   A. Screening mammography
   B. Excisional biopsy
   C. Ultrasonography
   D. Diagnostic mammography
   E. Needle aspiration

5-2. Case 5-2 is a 60-year-old woman who, on the insistence of her children, went for her first routine physical examination in many years. Her doctor found a mass in her breast. Which test should be ordered first?
   A. Screening mammography
   B. Excisional biopsy
   C. Ultrasonography
   D. Diagnostic mammography

5-3. In Case 5-3, a 53-year-old woman thinks she feels a hard nodule deep in her breast. Her breasts have always been difficult to examine because of their dense nodular texture. What test should be ordered first?
   A. Screening mammography
   B. Excisional biopsy
   C. Ultrasonography
   D. Diagnostic mammography
   E. Needle aspiration

5-4. In Case 5-4, a 78-year-old woman with a soft, rounded mass discovered during physical examination, which one of the following statements is true?
   A. A 78-year-old will not likely benefit from mammography.
   B. Soft, rounded masses are benign and do not require biopsy.
   C. This mass should initially be aspirated with a needle.
   D. If this mass is carcinoma, the patient will probably die of this disease.
   E. Her physical findings could easily be caused by a lipoma.

Radiologic Findings

5-1. Ultrasonographic image of the patient in Figure 5-7. The anechoic, uniformly black area represents a simple cyst.

▲ Figure 5-7. Case 5-1. Ultrasonographic image of the patient. The anechoic, uniformly black area represents a simple cyst. Note that the walls of the cyst are sharp, and there is a brighter echo pattern deep to the cyst (enhanced through-transmission).
cyst. Note that the walls of the cyst are sharp, and there is a brighter echo pattern deep to the cyst (enhanced through-transmission) (C is the correct answer to Question 5-1). Figure 5-8 illustrates the mammographic features of a cyst. The shape is round or oval, and the margins are smooth and sharply delineated.

5-2. Detail of a mammogram (Figure 5-9) of the patient in Case 5-2. Note the spiculated mass in the upper outer quadrant of this otherwise fatty breast. Diagnosis: invasive ductal carcinoma (D is the correct answer to Question 5-2).

5-3. Detail of a mammogram (Figure 5-10 A) of the patient in Case 5-3. There is a dense nodular breast pattern with a vague, small, rounded opacity (arrow). Spot compression view (Figure 5-10 B) of the region of suspected abnormality in Figure 5-10 A. Note how much easier it is to see the lesion and the spiculation (around it) with spot compression. Note also the difficulty in detecting and evaluating this tumor within dense glandular tissue, compared with the fatty breast in Case 5-2 (D is the correct answer to Question 5-3).

5-4. The 78-year-old patient in Case 5-4 (Figure 5-11) has a soft mass in her breast and clearly needs a diagnostic mammogram because of her age and the palpable findings (E is the correct answer to Question 5-4).

Approach to the Palpable Lump

When a breast lump is found, several questions must be answered before proceeding with breast imaging. First, given that lumpy breasts are a normal variant, when is a lump significant? Experts in CBE advise palpation with the flat surface of two to three fingers, and not with the fingertips. With this technique, nonsignificant lumps will disperse into background breast density, but a significant lump will stand out as a dominant mass.

Second, is the lump new or enlarged? A new lump is more suspicious than a lump that has not changed over a few years.

Third, how big is the lump? Tiny pea-sized or smaller lumps, particularly in young women, are often observed closely with repeated CBE, because small breast nodules are extremely common, frequently resolve spontaneously, and...
Factors should be weighed, including age, family history of breast carcinoma, reproductive history, and findings at CBE. If the primary care physician is uncertain of the significance of the findings of CBE, evaluation by a breast specialist may be helpful prior to requesting radiologic tests.

Discussion

The 34-year-old woman in Case 5-1 indeed has a dominant mass, 2 cm in diameter on CBE. She says it was definitely not present until recently. She has no risk factors for breast cancer. The mass most likely is a fibroadenoma or a cyst, but carcinoma cannot be excluded. The patient now needs breast ultrasonography.

Ultrasonography is best ordered before attempted needle aspiration because aspiration can alter the appearance of simple cysts, giving a misleading suspicious appearance. Therefore, answer E, needle aspiration, is incorrect.

Figure 5-10 shows an image from the ultrasound study that represents the area precisely in the location of the palpable mass. This area is echo-free, with sharply delineated walls and posterior acoustic enhancement (increased echogenicity deep to the anechoic area) consistent with a fibroadenoma or simple cyst.

Fourth, how old is the patient? If the patient is less than 35 years of age, then radiation is avoided unless specifically indicated, because the younger breast is more sensitive to radiation. For patients over the age of 35 years, breast imaging begins with a diagnostic mammogram at the time a lump is deemed to be significant. The mammogram provides a view of the lump, as well as of the remainder of the involved breast and the opposite breast, where associated findings may aid in diagnosis and treatment planning.

If the patient is below 35 years of age, a significant lump is usually first examined with ultrasonography to determine whether a simple cyst is present. If there is no cyst, and the patient is below 30 years of age, the radiologist may choose to obtain a mammogram, but the density of the breast in such a young patient may limit the usefulness of radiomammography, so the mammogram may be limited to one breast or to a single view.

For women between the ages of 30 and 40 years, judgment is needed as to whether other imaging is indicated. Several factors should be weighed, including age, family history of breast carcinoma, reproductive history, and findings at CBE. If the primary care physician is uncertain of the significance of the findings of CBE, evaluation by a breast specialist may be helpful prior to requesting radiologic tests.
simple cyst. If these three features are seen, the probability of a simple cyst is greater than 99% and no further treatment is indicated unless the patient has pain and needs cyst drainage for symptomatic relief. Therefore, option B, excisional biopsy, is inappropriate, because biopsy can be avoided by showing a simple cyst. No further imaging is needed. The patient is under the age of 40 years, not yet of screening age, and radiation should be avoided in young patients. Therefore, answers A and D, screening and diagnostic mammography, are not viable options until ultrasound is performed.

Simple cysts are very common in the premenopausal patient and in patients who are being treated with hormone replacement therapy. A complex cyst is one that has internal debris—blood, pus, or tumor. A complex cyst requires further evaluation, and a short-term follow-up (6 to 8 weeks) ultrasound may be sufficient. If the debris is due to attempted aspiration, it may clear on follow-up ultrasonography. Otherwise, excision or needle biopsy is indicated.

The 60-year-old woman in Case 5-2 has a 1.5-cm dominant mass on CBE. It is irregular and not freely mobile. The patient has never had a mammogram. Because she has a palpable mass, however, a screening mammogram is inappropriate, and option A is incorrect. Although the mass feels suspicious, she still needs a diagnostic mammogram prior to biopsy (option B, excisional biopsy, is incorrect), to exclude other lesions such as multifocal carcinoma. The need for ultrasonography in a patient of this age is dictated by the mammographic appearance; therefore, option C, ultrasonography, is incorrect.

Her mammogram (Figure 5-9) shows a very fatty breast, making any abnormal findings readily apparent. There is a mass measuring 1 cm in the upper outer quadrant that corresponds to the area of the palpated mass. The mass is of high density, being white on the mammogram. There is abundant spiculation and stranding around the mass that is represented by the radiating linear densities around the periphery of the mass. There is also retraction of the linear patterns of the normal breast tissue; this retraction is known as architectural distortion. These findings represent the classical features of a malignant lesion on mammography, and this mass must be biopsied. A spiculated mass such as this is the most common appearance of invasive breast carcinoma. Less common signs are a circumscribed mass, asymmetric density, and architectural distortion alone. Intraductal (noninvasive) carcinoma is more commonly associated with calcifications.

Spiculation around an invasive carcinoma corresponds to fingers of tumor, as well as to a desmoplastic reaction of adjacent normal breast tissue; this retraction is known as architectural distortion. These findings represent the classical features of a malignant lesion on mammography, and this mass must be biopsied. A spiculated mass such as this is the most common appearance of invasive breast carcinoma. About 90% of primary breast carcinomas are ductal carcinomas, and the other 10% are lobular carcinomas.

Besides carcinoma, the primary differential diagnosis for a spiculated mass includes postsurgical change, other trauma with hematoma, fat necrosis, infection, and radial scar (a complex, spontaneous benign lesion involving ductal proliferation, elastosis, and fibrosis).

There are no other lesions in our patient’s breast, and the other breast appears normal. By mammographic criteria, then, the patient is a good candidate for treatment with lumpectomy and radiation therapy rather than mastectomy. Her tumor is solitary, localized to one quadrant, and her breast tissue is otherwise easy to evaluate mammographically. Recurrent tumor or additional lesions should, therefore, be readily seen on posttreatment follow-up mammograms.

For a mass that feels malignant and appears suspicious on a mammogram, fine-needle aspiration (FNA) at the bedside may provide a rapid cytological diagnosis of carcinoma. Because FNA best follows mammography, option E, needle aspiration, is incorrect. FNA may then be followed by definitive surgical treatment at a later date, after the patient has had time to consider the treatment options available. If FNA fails to disclose carcinoma, then excisional biopsy is required because of the suspicious findings on mammography and CBE. The occasional false-negative FNA occurs with tumors that do not shed cellular material readily.

Cytology of this palpable mass revealed ductal carcinoma, and this patient chose to have a lumpectomy.
The 53-year-old patient in Case 5-3 has an ill-defined 1.5-cm hardened nodular area in her breast. Results of screening mammography less than 1 year ago were normal. Her breast tissue is not fatty, as in Case 5-2, but she has quite dense, nodular, fibroglandular tissue, which may obscure small masses. The average doubling time of breast carcinoma makes it unlikely that she has a palpable carcinoma that is entirely new since her last mammogram. It is quite possible, however, that she has had a smaller cancer for a few years and that it has now grown large enough to be palpated. Breast tumors are typically not palpable unless they are at least 1 cm in diameter. Before this stage, in the preclinical phase, the tumor may be visible up to 2 or 3 years earlier on the mammogram if the breast is fatty. In dense breasts, as discussed previously, tumors may not be seen on the mammogram until later stages. For this reason, regular CBE is important. Mammography will miss some cancers, regardless of the situation, at a rate variably reported to be between 5% and 15%.

With a new area of abnormality on physical examination, being in a high-risk age group (over 50 years old), and having a dense parenchymal pattern, the patient needs another mammogram, this time a diagnostic mammogram of the involved breast only. Option A, screening mammogram, is incorrect, because it is too soon to repeat screening mammography at this time and the patient does have a palpable finding—a contraindication for a screening study.

Figure 5-10 A shows a vague, rounded opacity within dense fibroglandular tissue. This is in the area of the palpable mass, as indicated by a small BB placed on the skin over the abnormality. Detail is not adequate to make a judgment as to the possibility of malignancy here, or even to confirm that a real lesion is present. The appearance may merely be due to superimposed normal breast shadows. Compression spot films are needed to confirm the presence of a mass and to better define its borders.

Figure 5-10 B shows spot compression of the questioned opacity seen on initial images. This localized compression with a smaller paddle placed directly over the abnormality achieves two things. First, it separates the opacity from adjacent breast tissue, demonstrating this to be a discrete mass with high density and not merely superimposition of normal shadows. Second, it elicits clear spiculation and architectural distortion around the mass. These features are classic for breast carcinoma, and biopsy is therefore required. Biopsy of this lesion showed invasive ductal carcinoma.

The 78-year-old patient in Case 5-4 has a soft mass in her breast and clearly needs a diagnostic mammogram because of her age and the palpable findings. Soft, rounded masses on physical examination are often benign fibroadenomata or cysts, but carcinoma may also present this way (Statement B is false). Other benign causes of these physical findings include hematoma, abscess, and lipoma (Statement E is true). Therefore, a mammogram may be beneficial for two reasons: (1) if a benign finding is revealed, biopsy may be avoided; and (2) if findings suggest malignancy, optimal treatment can be planned on the basis of extent of the lesion and presence or absence of additional lesions (Statement A is false).

Her mammogram (Figure 5-11) shows two findings. There is a rounded mass with multiple lobulations and circumscribed borders. The fact that the borders are not sharply outlined on all sides raises the suspicion level for this finding. Masses that are sharply delineated may be followed with serial mammograms at 6-month intervals if they are known not to be new, are nonpalpable, and show no other features of malignancy. This is not the case with the patient in Case 5-4. Note the fading margin along portions of the mass. This mass corresponds to the palpable finding. Ultrasound would be useful to exclude a multiloculated cyst and show the lesion to be solid. Biopsy is indicated, but needle aspiration without imaging would have been inappropriate (Statement C is false).

A circumscribed mass representing carcinoma is seen less often than a spiculated mass. About 10% of invasive ductal carcinomas represent the better-differentiated subtypes, including medullary carcinoma, mucinous (colloid) carcinoma, and papillary carcinoma, all of which are frequently seen as circumscribed masses. They tend to have a better prognosis than the less well-differentiated garden-variety ductal carcinomas.

The differential diagnosis for the circumscribed mass on mammography includes carcinoma (primary as well as metastatic), fibroadenoma, and cysts; hematoma, abscess, and miscellaneous benign lesions are seen much less often. Correlation with clinical history and physical examination can help to narrow the differential diagnosis. When carcinoma cannot be excluded, either needle aspiration or excisional biopsy is required.

This patient had a needle biopsy. Because palpation alone could not reliably localize this lesion for needle biopsy because of its soft nature and the difficulty in fixing its position, stereotactic mammographic guidance was used in localizing the lesion for this procedure. The diagnosis of mucinous carcinoma was made by microscopic inspection of the specimen.

Now, were you astute enough to perceive the second lesion? Above and to the left of large mass is a smaller, dense spiculated mass. This was also biopsied and proved to be a carcinoma of the very well-differentiated tubular type. Even though the patient has two lesions now, both carry an excellent prognosis and they are unlikely to cause her death (Statement D is false). In fact, although mastectomy is certainly a reasonable treatment for her, local excision would also be an option with these nonaggressive lesions.
EXERCISE 5-2. LUMPINESS, NIPPLE DISCHARGE, AND PAIN

5-5. The most likely explanation for the patient’s symptoms and mammographic change in Case 5-5 (Figure 5-12) is
A. hormone effect.
B. infectious mastitis.
C. carcinoma.
D. congestive heart failure.
E. cystic disease.

5-6. With respect to ductography and the condition of the patient in Case 5-6 (Figure 5-13), which of the following statements is true?
A. Ductography should be performed in all patients with nipple discharge.
B. The cause for this patient’s discharge is more likely to be malignant than benign.
C. This ductogram shows an extraluminal filling defect.
D. Ductography has a high specificity for malignant lesions.
E. Ductography is helpful in guiding the surgeon’s approach.

5-7. With respect to Case 5-7, which of the following statements is false (Figure 5-14)?
A. There is diffuse abnormality on the left.
B. Inflammatory carcinoma is high on the differential diagnostic list.

▲ Figure 5-12. (A, B) Case 5-5. The mammogram (A was taken 1 year before B) in a 82-year-old woman who complains of newly lumpy, painful breasts.

▲ Figure 5-13. Case 5-6. Ductography in a 45-year-old woman with a serous nipple discharge.
C. Infectious mastitis is unlikely to be the cause in this nonlactating patient.
D. The mammographic appearance is nonspecific.
E. Follow-up imaging after a course of antibiotics would be appropriate.

5-8. With respect to Case 5-8, which one of the following statements is true (Figure 5-15)?
A. The soreness indicates a benign process.
B. The appearance is malignant, and biopsy is necessary.
C. Findings on physical examination and history may radically alter our management decision.
D. Bleeding, such as that due to anticoagulation therapy, would not have this appearance.
E. The most likely diagnosis is fibrocystic change.

**Radiologic Findings**

5-5. These mammograms show a diffuse marked increase in mammographic density with a nodular character (A is the correct answer to Question 5-5).

5-6. In this ductogram, contrast has been injected into a portion of a single ductal system with opacification of the lactiferous sinus and larger branching ducts. Most of the walls are smooth, as they should be. However, there is a filling defect in one of the major branches, as exhibited by the lucency outlined by contrast on all sides and indicated by the arrow (E is the correct answer to Question 5-6; Statement C is false).

5-7. Mammograms of the right and left breast show that the entire left breast (B) is abnormally dense (C is the correct answer to Question 5-7).

5-8. Mammogram shows a large band of high density with markedly spiculated margins in the upper part of the breast (C is the correct answer to Question 5-8).
Discussion

Lumpy breasts are a variant of normal and, as such, require careful physical examination and mammography to avoid unnecessary surgery, as well as not to miss a carcinoma. Diffuse lumpiness is not a contraindication to screening mammography, but when a particular lump becomes dominant, a diagnostic study is indicated.

The two mammograms of the patient in Figure 5-12 were obtained 1 year apart. Between these two examinations, the patient began to exhibit menopause symptoms and was started on hormonal replacement therapy. The breasts, which were previously largely fatty (A), have become moderately dense and very lumpy on palpation 1 year later (B). This change can also be seen, although not usually as dramatically, in the perimenopausal time of estrogen flare.

Such changes can be seen asymmetrically or unilaterally, and it is useful to remember the estrogen effect when evaluating mammograms with interval changes. Correlation with clinical history is then needed.

Answer B, infectious mastitis, and Answer C, carcinoma, are incorrect as both of these entities are usually unilateral and focal. Option D, congestive heart failure (CHF), is incorrect because CHF causes bilateral changes that have a more linear pattern of trabecular thickening on mammography, rather than the patchy, ill-defined nodular pattern characteristic of glandular and cystic densities seen here. Answer E, cystic disease, is incorrect. Cysts are seen as a component of hormone-related breast changes, but spontaneous cystic disease alone is rare at this age.

In the patient in Case 5-6, there is a single intraluminal filling defect on ductography. However, we cannot determine from these findings alone whether the defect is due to a benign or a malignant nodule (Statement D is false), although approximately 90% of nipple discharges are due to benign causes (Statement B is false). The filling defect in this woman was a benign papilloma, the most common cause of bloody or serous discharge. Mammograms usually do not show these small, intraductal nodules.

Whether or not a filling defect is seen on a ductogram, biopsy is needed to rule out carcinoma, and the ductogram may be helpful in showing the surgeon which area of the breast harbors the cause of discharge (Statement E is true). However, many surgeons are able to identify the lobe(s) involved in the pathology by inspecting the nipple, noting the location of the discharging duct, and by palpation, observing which portion of the breast produces discharge when compressed. Usually, ductography is not easily performed and is of limited usefulness when discharge is not spontaneous, profuse, and confined to a single duct. Therefore, statement A is false; ductograms should not be performed on all patients with nipple discharge. Furthermore, only bloody or serous discharges are of concern. A large portion of patients with discharge have secretions typical of fibrocystic change (ie, a dark brownish or greenish fluid rather than a truly bloody or serous discharge). Milky discharge is normal.

In Case 5-7, the patient's entire left breast is abnormally dense (Statement A is true). There is skin thickening as well. This is a nonspecific appearance (Statement D is true); infection and inflammatory carcinoma are both high on the differential diagnosis list (B is true; C is false). Breast carcinoma may incite an inflammatory response in the breast, mimicking a benign infectious process both clinically and radiographically. The patient turns out to have an elevated white blood cell count and fever with marked pain. This information now makes infection more likely than tumor, and a course of antibiotics with follow-up imaging to monitor resolution is appropriate (Statement E is true).

Figure 5-16 shows the follow-up mammogram after significant clinical resolution. The mammographic findings have resolved, and the left breast now appears very similar to the right one.
Infectious mastitis occurs more frequently in lactating women but is not uncommon in nonlactating women, particularly in diabetic patients. Imaging (mammography or ultrasound) is useful to exclude a drainable abscess collection and to provide a baseline for monitoring resolution to exclude carcinoma.

Case 5-8 illustrates the importance of correlation with history and physical examination. This patient has pain, as in the last case, but her mammographic abnormality is much more localized and appears more like a malignant mass, being a high-density opacity with excessive spiculation. However, this, too, is a benign process. The patient was in a motor vehicle accident 2 months earlier and sustained a severe injury to the right side of her chest. Physical examination shows a resolving laceration and contusion that extends in a linear fashion over the right breast (no wonder she is sore!). A CT scan performed at the time of trauma showed the acute injury precisely in the area shown on the mammogram. These mammographic features are consistent with a resolving hematoma from acute trauma. Therefore, no further action is warranted at this time, other than follow-up (Statement C is true). Although pain is not a prominent feature of carcinoma, patients with cancer may be symptomatic. Therefore, pain does not always indicate benignancy (Statement A is false).

The mammographic appearance would certainly be highly suspicious for invasive carcinoma in the absence of clinical information, but with careful correlation we are able to avoid biopsy in this case (Statement B is false).

Anticoagulation therapy with resultant bleeding could also have this appearance (Statement D is false).

Fibrocystic change, although very common, is an unlikely diagnosis. Fibrocystic change appears as increased cloudy densities, nodular densities, and occasionally some thickened linear densities, but rarely as a spiculated mass (Statement E is false).

THE ASYMPTOMATIC PATIENT

EXERCISE 5-3. THE FIRST MAMMOGRAM

5-9. According to the American Cancer Society, the best program of breast screening for this woman in Case 5-9 (Figure 5-17) includes all of the following except
A. yearly MRI.
B. yearly mammograms.
C. cessation of routine mammograms at age 65.
D. annual clinical breast examination.

5-10. The most likely diagnosis in Case 5-10 (Figure 5-18) is
A. complex cyst.
B. fibroadenolipoma.
C. galactocele.
D. ductal carcinoma.
E. oil cyst.
5-11. The differential diagnosis in Case 5-11 (Figure 5-19) includes all of the following except
A. invasive ductal carcinoma.
B. cyst.
C. intraductal comedocarcinoma.
D. fibroadenoma.
E. mucinous carcinoma.

Radiologic Findings

5-9. Detail of mammogram of the patient in this case shows a smoothly margined small mass with a lucent center (arrow) (C is the correct answer to Question 5-9).
5-10. The mammogram in this case shows a circumscribed mass (arrows) with internal lucency as well as opacity (B is the correct answer to Question 5-10).
5-11. Mammogram of patient in this case shows a nodular density (arrow), with indistinct margins (C is the correct answer to Question 5-11).

Discussion

In Case 5-9, the 40-year-old woman has a strong family history of breast cancer, which puts her at high risk for developing the disease. As was stated in the introduction to this chapter, controversy exists concerning when mammographic screening should be initiated and the appropriate frequency of examinations in different groups. Most experts agree, however, that patients with a strong family history will benefit from screening beginning at age 40. The American Cancer Society (ACS) recommends annual screening from age 40 in all female patients; therefore, B is not the correct answer.

Although the upper age limit for mammographic screening has not been defined, we certainly cannot recommend cessation over age 65, because the prevalence of breast cancer is greatest in women in their 50s and 60s. Current ACS guidelines recommend yearly mammograms for all women over the age of 40 years. Appropriate age for termination of screening is best judged by the patient's physician, weighing life expectancy against potential benefits from screening.

ACS recommends annual screening MRI in women at high risk for breast cancer. ACS also recommends yearly physical examination by the physician to detect tumors missed by mammography, as well as those that become detectable between routine mammograms (interval cancers). Therefore, A and D are not correct answers to Question 5-9.

This patient's mammogram is normal and demonstrates a typical normal lymph node. The node is smoothly margined and has a fatty hilum, indicated by the darker center.

In Case 5-10, there is a circumscribed mass in the axillary tail of this breast. The key to diagnosis is the mixture of densities within the lesion. There are medium-density opacities interspersed with lucencies within a smoothly margined mass. This appearance is pathognomonic for a fibroadenolipoma, sometimes called by the misnomer hamartoma. Being composed of elements of normal breast (fatty, glandular, and fibrous tissues) organized within a thin capsule, a fibroadenolipoma forms a "breast within a breast." As such, it is benign and needs no further evaluation. It may be palpable as a soft mass.

The point to remember here is that fat-containing masses are always benign. Answer D, ductal carcinoma, is incorrect. The differential diagnosis of a fatty mass, besides fibroadenolipoma, includes lymph node, as in Case 5-9, galactocele, lipoma, and oil cyst. Galactoceles are usually smaller and are most commonly seen in lactating women (Answer C is incorrect).

Oil cysts result from fat necrosis and are usually smaller. Typically, they are entirely lucent, as they are filled with oil, except for a thin wall (Answer E is incorrect).

Option A, complex cyst, is incorrect because this entity would not contain fat. A cyst, whether it contains serous fluid, blood, or pus, is always opaque and of low to high density, not lucent.

In Case 5-11, an asymptomatic 45-year-old woman's first mammogram shows a 1-cm nodule centrally located in this breast. The differential diagnosis remains broad without further studies to help characterize this nodule. All choices except option C, intraductal comedocarcinoma, may have this
appearance. Intraductal carcinoma, when not mammographically occult, usually appears as microcalcifications. Because the margins are indistinct, however, the patient must be recalled for additional imaging to rule out carcinoma.

The sonographic image shows a solid lesion, ruling out a simple cyst. Spot compression is then used to evaluate the borders. If all margins were to appear smooth, one acceptable course of action would be serial 6-month follow-up mammograms for a period of 2 years to demonstrate stability. If any change occurs during this time, biopsy is indicated.

Spot compression (Figure 5-20 A) reveals that portions of the border are not smooth, raising the level of suspicion for malignancy. To exclude carcinoma, biopsy is needed.

Biopsy may be accomplished with excision or with needle biopsy. Excision would require needle localization of the nodule for the surgeon, because this is a nonpalpable lesion. Core needle biopsy, either stereotactic or ultrasound-guided, is preferable because it is minimally invasive, causes less morbidity to the patient, leaves no distortion in the breast or on the skin, and is often less expensive than surgical excision. Accurate needle biopsy devices, however, are expensive and are not universally available.

This nodule was diagnosed as a fibroadenoma with stereotactic core needle biopsy (Figure 5-20 B). Fibroadenomas are very common and are frequently the cause of benign breast biopsy. They occur in very young women (teenagers and women under 30 years of age) and persist undiscovered through the age at which the first mammogram is obtained, then, upon discovery, become a concern of both physician and patient. They may also become palpable or mammographically visible in older women after previously normal mammograms. They continue to be a management problem, because fibroadenoma and carcinoma have overlapping mammographic features and both are common lesions in middle-aged women. With age, fibroadenomas become involuted and heavily calcified, thereby revealing their true identity (Figure 5-21). Without this appearance, however, biopsy is often necessary.

A high index of suspicion and careful evaluation, together with either close follow-up or liberal use of needle biopsy, are needed to minimize both false-negative impressions and excessive breast surgery.

**EXERCISE 5-4. ARCHITECTURAL DISTORTION AND ASYMMETRIC DENSITY**

5-12. Concerning the architectural distortion in the right breast in Case 5-12 (Figure 5-22), which statement is false?
A. Without history of biopsy, scarring is unlikely.
B. Previous mammograms could be very helpful.
C. It is probably nonmalignant because the patient does not complain of a mass.
D. Invasive lobular carcinoma commonly has this appearance.
E. This is probably not an asymmetric response to hormone therapy.

5-13. The mammographic appearance in Case 5-13 (Figure 5-23) is least likely to be caused by
A. normal breasts.
B. postsurgical change.
C. trauma.
D. cystic disease.
E. tumor.

**Radiologic Findings**

5-12. Bilateral craniocaudal views show architecture distortion in the right breast without a discrete dominant mass (C is the correct answer to Question 5-12).
5-13. Bilateral mediolateral oblique views of patient in this case show areas of asymmetric density in the left upper and right lower breast. The densities are interspersed with fat. Margins are generally concave, and there is no architectural distortion (D is the correct answer to Question 5-13).

▲ Figure 5-21. Characteristic appearance of heavily calcified involuting fibroadenoma.

▲ Figure 5-22. Case 5-12. A 51-year-old woman evaluated with screening mammography.
Discussion

Although normal breast tissue is remarkably symmetric, it is never exactly the same on both sides. The challenge in mammography is to recognize normal variation and to be able to distinguish nonpathologic asymmetry from disease. This is not always possible, particularly in the asymptomatic group. A high index of suspicion is needed in evaluating the screening mammogram, just as in the baseline clinical breast examination. Once asymmetry is noted mammographically, a careful, focused breast examination is needed. If no suspicious areas are detected and if the radiographic features suggest fibroglandular tissue, then follow-up alone is adequate. Radiographically, we look for a homogeneous, nondistorted pattern of fat interspersed with lobular densities. Any dominant mass or architectural distortion should cause concern.

In Case 5-12, one area shows a different architectural pattern. The lines of tension appear to pull to a central focus. This is a classic appearance of invasive lobular carcinoma. Remember that 90% of the breast cancers are ductal in origin, and the other 10% are lobular, as in this case. This type of carcinoma shows a subtle infiltrating pattern much more often than does ductal carcinoma (Statement D is true).

One of the problems with this disease is that it is difficult to describe the extent of tumor mammographically. There is a large area of asymmetric architecture in this patient, but where the tumor ends is unclear. This patient had a carcinoma that measured 4 cm.

A correlated clinical examination often reveals abnormalities not detected without the guidance of mammographic findings (Statement C is false). Biopsy of any suspicious-feeling area is strongly recommended. Studies have shown that a high percentage of carcinomas “missed” at mammography appear as architecture distortion or asymmetric density. This patient did have a large area of thickening in the upper aspect of this breast, confirming the suspicious nature of the mammographic findings.

Previous mammograms are definitely useful in evaluating architecture distortion and asymmetric density. If the finding is unchanged over time, no further action may be needed. If the finding is new or is increasing, it is more easy to recognize (Statement B is true). Hormonal therapy may indeed have an asymmetric effect (Statement E is true), but it does not take the form of architecture distortion.

Surgical biopsy may result in such distortion of the architecture, but precise correlation with location and timing of the surgery is needed (Statement A is true).

Unlike the previous patient, the woman in Case 5-13 has multiple areas of breast asymmetric density. There is a large area in the upper part of the left breast and a smaller area in the lower part of the right breast. Both areas show fat interspersed with fibroglandular densities. There is no architectural distortion. Margins of the larger opacities are generally concave—a sign of benignity. There are no dominant or circumscribed masses, and cystic disease therefore would not be part of the differential diagnosis, because cysts are rounded.
masses. Having learned from the previous case that missed carcinoma often presents as asymmetric density, tumor must remain in the differential diagnosis, and answer E is incorrect.

Both trauma and postoperative change can lead to ill-defined asymmetric density. With trauma there may be bleeding, contusion, or actual deformity, if severe. With surgery, asymmetry results both from removal of normal tissues, leaving less density on the operated side, and from surgical trauma (hematoma and distortion), which causes increased localized densities. Therefore, options B and C are both incorrect. The most likely cause of this woman’s mammographic appearance is normal breast tissue, and answer A is incorrect. The multiplicity and bilaterality of areas of asymmetry, the lack of signs or symptoms of breast cancer, and the fibroglandular characteristics of the densities all support this diagnosis.

**EXERCISE 5-5. THE FOLLOW-UP MAMMOGRAM**

5-14. Which of the following statements about Case 5-14 is false (Figure 5-24)?
A. The abnormal finding is a spiculated mass.
B. The rate of change is too slow for a breast cancer.
C. A malpractice claim should not be encouraged.
D. The lesion is probably not palpable.
E. This change warrants biopsy.

5-15. With respect to the calcifications in Case 5-15 (Figure 5-25), which statement is false?
A. They may be described as pleomorphic.
B. The coarse nature of some of the calcifications suggests this is a benign process.
C. They signal an aggressive malignancy.
D. They are most likely due to necrosis in duct walls.
E. Magnification should be performed to assess the extent of disease.

5-16. With respect to the calcifications in Case 5-16 (Figure 5-26), which statement is true?
A. They may be described as granular.
B. The regional distribution makes them highly suspicious.
C. Follow-up alone would be inadequate.
D. The new onset indicates a high probability of malignancy.
E. They have a less than 20% chance of being malignant.

**Radiologic Findings**

5-14. This case shows back-to-back craniocaudal views of the right breast obtained 1 year apart. In the interval, a small spiculated mass has enlarged so as to become more apparent (arrow) (B is the correct answer to Question 5-14).

5-15. The mammogram of the patient in this case shows a cluster of microcalcifications posteriorly in the central aspect of the breast. Previous mammograms have been normal (B is the correct answer to Question 5-15).

5-16. Magnification view of a portion of the breast of the patient in this case shows coarse calcifications, some of which are rounded or ringlike (E is the correct answer to Question 5-16).

**Discussion**

Case 5-14 illustrates the concept of developing density. A developing density is any opacity that increases in size or density.
over time. All such opacities should be evaluated critically, as they can be signs of carcinoma. This concept is based on the natural behavior of breast cancer, which generally grows slowly. With periodic screening, the early tumor will be imaged but unrecognized on early images and may not be detected until 1, 2, 3, or more years later. Tumors 5 mm or smaller are very difficult to differentiate from normal breast tissue, but masses larger than 1 cm are more easily detected. The typical breast cancer has been present for several years by the time it is 1 cm in size. Therefore, breast cancers are routinely visible in retrospect on previous mammograms if the patient has had frequent screening. This does not mean, however, that malpractice has occurred. If the cancer is still small, no harm has been done and more harm could potentially be done by biopsying all such tiny densities, because most of them would be normal breast (Statement C is true). Being suspicious but judicious with any developing density, therefore, is necessary to detect breast cancer early without unnecessary biopsy.

This patient has a small (about 1 cm) spiculated mass in the central part of the breast (Statement A is true). It has increased slightly in size over 1 year, with a growth rate typical for breast carcinoma (Statement B is false and is the correct answer to Question 5-14). Being so small in a medium-sized breast, it is unlikely to be palpable (Statement D is true) and, therefore, would require imaging guidance for any biopsy. The spiculated margins, the rate of growth, and the patient’s age group all make this a very suspicious lesion, and biopsy is warranted (Statement E is true). This lesion was an infiltrating ductal carcinoma.

Case 5-15 illustrates a new finding after a previous normal screening. There is a cluster of microcalcifications in the central area. Note that the calcifications are small and irregular, but we do not see their configuration exquisitely; nor can we be confident of the extent of disease, because there may be other smaller calcifications that we do not see. The patient, therefore, requires recall for magnification mammography (Figure 5-27) (Statement E is true). On magnification, we can appreciate that the calcifications are of many different sizes and shapes (ie, pleomorphic) (Statement A is true). Malignant microcalcifications are usually less than 0.5 mm in size, and the very coarse calcifications are classically benign. However, there is significant overlap, and configuration is generally a more helpful sign. Malignant calcifications are usually either granular or linear and branching.

These granular, linear, and branching calcifications are typical of intraductal carcinoma. The aggressive type of intraductal carcinoma, comedo or high-nuclear-grade carcinoma, causes necrosis in the cancerous mammary duct walls. Calcifications form in areas of necrosis, forming a “cast” of the duct. This process results in the linear and branching forms of calcification (Statements C and D are true). Pathologic analysis of this tissue showed intraductal carcinoma of the comedo type.
Lesser degrees of necrosis result in smaller, more granular calcifications, whereas extensive necrosis yields rather large rod-shaped or branched calcifications. Option B is false because, although large calcifications alone are usually benign, the mixture of tiny irregular calcifications with the coarse casting calcifications remains very suspicious for malignancy.

In Case 5-16, the mammogram detail shows typical benign calcifications. Benign calcifications take many forms, but if we see rings with lucent centers, as in this case, we can rest assured that they are benign. These rings are calcifying microcystic areas of fat necrosis. This is a very common benign finding. Punctate, or dotlike, calcifications are also usually benign if uniform and smooth. Granular calcifications are more angular, like broken needle tips, and would be more suspicious (Statement A is false).

Benign calcifying processes such as fibroadenoma, sclerosing adenosis, and fat necrosis can all be unifocal, or regional, as well as multifocal or diffuse; therefore, distribution alone does not make calcifications suspicious (Statement B is false).

Benign processes of many types do present in adulthood and therefore may appear de novo after a previously normal screening examination. Again, the configuration of calcifications is more helpful (Statement D is false).

For obviously benign calcifications such as these, routine follow-up alone is adequate (Statement C is false). Some calcifications are obviously malignant as in Case 5-15. A third group of calcifications is classified as indeterminate, and these require further evaluation, either close mammographic follow-up or some type of biopsy. Taken as a group, biopsied microcalcifications historically have had a rate of malignancy of only 20%. Therefore, Option E is true, because these ringlike calcifications have a better-than-average chance of being benign.

**SUGGESTED READING**

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Musculoskeletal Imaging

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**Techniques**
- Conventional Radiography
- Mammographic Techniques
- Fluoroscopy
- Computed Tomography
- Magnetic Resonance Imaging
- Nuclear Medicine
- Biopsy

**Technique Selection**
- Trauma
- Bone or Soft-Tissue Tumors

**Exercises**
- 6-1 Trauma
- 6-2 Local Disease
- 6-3 Systemic Disease

When Wilhelm Conrad Roentgen discovered the x-ray in November 1895, he investigated it thoroughly, testing its ability to penetrate various inanimate objects and observing its effects on fluorescent screens and photographic film. He gazed in amazement at the image of the bones of his own hand as he allowed the new rays to penetrate his flesh. He made a photographic x-ray image of a hand (reportedly his wife’s) and sent prints of it together with his paper describing the new phenomenon to a carefully selected list of scientific colleagues.

By mid-February 1896, Roentgen's paper had not only been published but also reprinted in other scientific journals including the American journal *Science*. Scientists everywhere repeated Roentgen's simple experiments and confirmed the truth of his discovery. Within a year, x-rays were in widespread use for medical purposes—chiefly for imaging of the skeleton.

Since Roentgen's time, many new imaging techniques have been developed that allow radiologists to see the muscles and other soft tissues of the musculoskeletal system as well as the bones and to evaluate the amount of metabolic activity in the bones and soft tissues. These techniques make skeletal imaging an exciting area of radiology that can enhance patients' quality of life. The techniques can also be very expensive, however. This chapter is intended to introduce you to musculoskeletal imaging techniques and to suggest efficient ways to use them that will help you to make correct diagnoses without excessive cost. Naturally, the suggestions made in these pages must be tailored to the needs of individual patients.

**TECHNIQUES**

**Conventional Radiography**

Conventional radiographs are the most frequently obtained imaging studies. They are chiefly useful for evaluation of the bones, but useful information about the adjacent soft tissues may also be obtained. Gas in the soft tissues may be a clue to an open wound, ulcer, or infection with a gas-producing organism. Calcifications in the soft tissues can indicate a tumor, myositis ossificans, or systemic disorders such as scleroderma or hyperparathyroidism.
To get the most information possible from conventional radiographs, you should carefully choose the study to be ordered. At most hospitals and clinics, standardized sets of views have been developed that are routinely obtained together for evaluation of specific body areas in certain clinical settings. It is useful to know what will routinely be obtained when a certain set of films is ordered. Radiographs of the ankle, for example, usually include a straight frontal view of the ankle, a frontal view obtained with approximately 15 degrees internal rotation of the ankle (the mortise view), and a lateral view. There will be some variation among institutions, however. At a minimum, two views at right angles to one another should be obtained when a fracture or dislocation is suspected, because such injuries are notorious for being very subtle or even invisible in one projection, even when they are glaringly obvious in another view (Figure 6-1). Radiographs should be focused on the anatomic area being evaluated, free of overlapping, extraneous anatomy (Figure 6-2). If the knee

\[\text{Figure 6-1. (A,B) Slipped capital femoral epiphysis.} \]
\[\text{(A) Anteroposterior (AP) radiograph of the pelvis. There are signs of a fracture through the physis of the left proximal femur: that femoral epiphysis is less well mineralized than the one on the right, the lucent line demarcating the physis is slightly widened, and the alignment of the edges of the epiphysis and metaphysis is abnormal. These signs are relatively subtle and could be easily missed. (B) Frog-leg lateral view of the left hip. This view, a lateral of the proximal femur, is much more obviously abnormal. Along the posterior edge of the femur, the cortices of the epiphysis and metaphysis should be flush but are instead offset by approximately 5 mm (arrow).}\]
is the site of trouble, do not order views of the entire tibia and fibula; you will be disappointed with the visualization of the knee. This principle must be abandoned more or less in young children and mentally impaired individuals who may not be able to localize their symptoms well, and also in trauma victims with so many injuries that the relatively minor ones may be overlooked.

In addition, when the radiographs will be studied by a consulting radiologist, it is helpful to provide a succinct yet accurate history pinpointing your clinical concerns. Simply indicating the site of injury will improve the likelihood that a subtle fracture will be discovered.

A conventional radiograph of a normal bone will show a smooth, homogenous cortex surrounding the medullary space. The cortex will be thicker along the shaft (diaphysis) of long bones and thinner in small, irregular bones such as the carpal and tarsal bones and at the ends of long bones (Figure 6-3). Exceptions are the normal roughening of the cortex at tendon and ligament insertion sites and the normal interruption of the cortex at the site of the nutrient arteries. Naturally these occur at predictable places that differ from bone to bone. Within the medullary space of normal bone are trabeculae. These are visible in radiographs as thin, crisp white lines that are arranged not randomly but in predictable patterns that enhance the stress-bearing capability of the bone. It is beyond the scope of this chapter to address the appearance of each bone.

When questions arise concerning whether a particular appearance is normal or abnormal, several solutions are possible. Two books, Keats’s *Normal Variants* and Kohler’s *Borderlands*, are very useful in helping to distinguish the normal from the abnormal (see suggested reading). Correlation with the results of the history and physical examination may also be helpful. Finally, comparison with the patient’s prior radiographs or with a radiograph of the opposite extremity may also help (Figure 6-4). Comparison views of the opposite extremity are especially helpful in children, in whom the open physes and accessory centers of ossification may vary considerably from individual to individual but tend to vary less from side to side than among different people.
Mammographic Techniques

Any soft-tissue area that can be pulled away from the skeleton and placed between the compression paddle and detector may be imaged with mammographic technique. In extremity imaging, mammographic technique is occasionally used to search for small calcifications or foreign bodies in the soft tissues.

Fluoroscopy

Fluoroscopy plays an important role in evaluation of joint motion. It is often used by orthopedic surgeons to monitor placement of hardware. It may be of assistance in positioning patients for unusual or difficult conventional radiographic views.

Computed Tomography

Tomography (either conventional complex-motion tomography or computed tomography [CT]) has two major uses in skeletal imaging. The first is evaluation of fracture fragment position. CT provides excellent delineation of fractures (Figure 6-5). Multislice scanners, which have become commonplace since about 2005, acquire data in blocks and can depict anatomy in any plane with the same resolution and accuracy that previously was possible only in the axial plane. In this way, a fracture may be evaluated in multiple planes of section, usually sagittal and coronal as well as axial. The decision to use CT for fracture evaluation should be based on whether the study will change treatment or will be of sufficient help in operative planning to justify the additional radiation and expense. Scapular fractures, for example, are often treated conservatively, but orthopedic surgeons differ on treatment of fractures that extend into the glenoid or involve the scapular spine. Some believe these benefit from internal fixation; others do not. Tomographic evaluation of these structures will be more useful to a surgeon who would use internal fixation selectively than to one who would use conservative therapy on all scapular fractures.

Three-dimensional reconstruction is available with many CT scanners. There is usually an extra charge. This may be justified if it helps the orthopedic surgeon to plan operative intervention and thus decrease the time required for surgery. Three-dimensional images are also useful for teaching.

Figure 6-2. (Continued) (C,D) AP and lateral radiographs of the finger. The patient returned 2½ months later, complaining that his finger still hurt. This time radiographs were coned more closely to the finger and care was taken on the lateral view to image the ring finger separately from the others. In that view the intra-articular fracture of the proximal aspect of the middle phalanx is quite obvious (arrow). It is far more subtle on the frontal view.