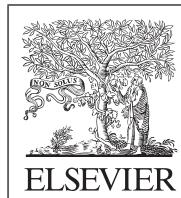


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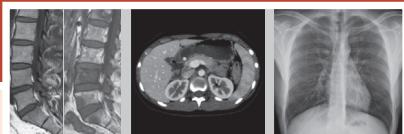
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Respiratory System

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p0040

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LEARNING OBJECTIVES

- p0010 *On completion of Chapter 3, the reader should be able to do the following:*
- o0010 1. Describe the anatomic components of the respiratory system.
- o0015 2. Describe the various types of tubes, vascular access lines, and catheters used in relation to the respiratory system.
3. Characterize a given condition as congenital, hereditary, inflammatory, infectious, or neoplastic.
4. Identify the pathogenesis of the chest pathologies cited and the typical treatments for them.
5. Describe, in general, the radiographic appearance of each of the given pathologies.

o0020

o0025

o0030

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Aspiration pneumonia

Aspergillosis

Asthma

Bronchial carcinoid tumors

Bronchiectasis

Chronic obstructive bronchitis

Chronic obstructive pulmonary disease

Coin lesion

COVID-19

Cystic fibrosis

Diffusion

Emphysema

Exudates

Hemothorax

Hypercapnia
Hypoxemia
Legionella pneumonia
Lung carcinoma
Mediastinal emphysema
Miliary tuberculosis
Mycoplasma pneumonia
Pleural effusion

Pleurisy
Pneumococcal pneumonia
Pneumoconioses
Pneumonia
Progressive disseminated histoplasmosis
Pulmonary tuberculosis
Respiratory distress syndrome

Respiratory failure
Sinusitis
Subcutaneous emphysema
Transudates
Tuberculosis
Ventilation
Viral pneumonia

s0010 ANATOMY AND PHYSIOLOGY

[AU3] The respiratory system is responsible for two major functions. **Ventilation** involves the movement of air in and out of the lungs, and **diffusion** relates to the exchange of carbon dioxide and oxygen between the lungs and the circulatory system. This system is subdivided into the upper respiratory tract—the nose, mouth, pharynx, and larynx—and the lower respiratory tract—the trachea, bronchi, alveoli, and lungs (Fig. 3.1). The thoracic cavity consists of the right and left pleural cavities and the mediastinum. The thoracic cavity is lined with a serous membrane termed parietal pleura. This membrane continues over the lungs where it is termed visceral pleura.

Anatomically, the mediastinum is divided into the anterior, middle, and posterior portions. The anterior mediastinum contains the thyroid and thymus glands. The middle mediastinum contains the heart and great vessels, esophagus, and trachea. The posterior mediastinum contains the descending aorta and the spine.

The anatomic bony structures of the thorax provide support and protection, and assist in both inspiration and expiration. These bony structures include the ribs, sternum, and thoracic vertebrae.

The paranasal sinuses are lined with respiratory epithelium and communicate with the nasal cavities, hence their inclusion in this chapter. The maxillary and ethmoid sinuses are the only paranasal sinuses present at

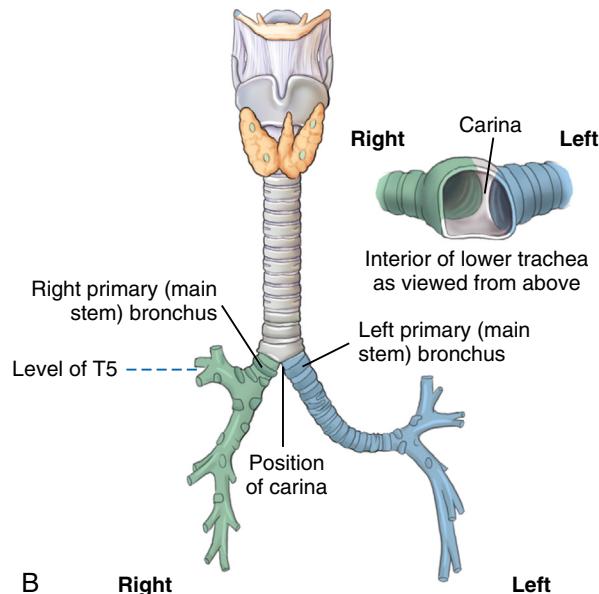
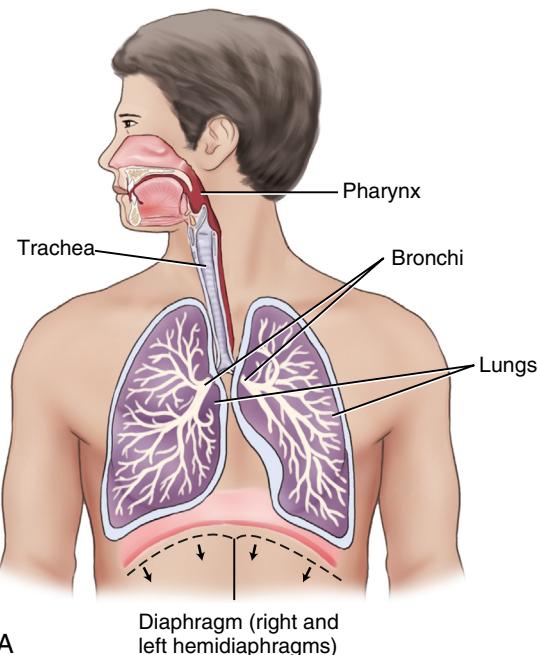


Fig. 3.1 (A) The respiratory system. (B) The trachea and its bifurcation at the carina. (From Bontrager, K. L., & Lampignano, J. P. (2014). *Textbook of radiographic positioning and related anatomy* (8th ed.). Mosby.)

birth. The frontal sinuses generally develop shortly after birth and are fully developed by the age of 10 years. The sphenoid sinus begins to develop around the age of 2 or 3 years and is fully developed by late adolescence.

s0015 IMAGING CONSIDERATIONS

p0065 When imaging patients with suspected respiratory conditions it is imperative to consider transmission-based precautions. These precautions are the second tier of basic infection control and are used in addition to standard precautions. Certain diseases such as measles, varicella, tuberculosis, pneumonia, respiratory syncytial virus (RSV), and pertussis require respiratory precautions. Droplet precautions are for diseases that are transmitted by respiratory droplets and can be spread by coughing, sneezing, or talking, and the technologist should don a mask when entering the patient care area. Airborne precautions are warranted with pathogens, such as tuberculosis, measles, varicella, and COVID-19, which spread using the airborne route. A fit-tested NIOSH-approved N95 mask or higher-level respirator should be used.

s0020 Radiography

p0070 The most frequently performed examination in any radiology department is conventional radiography of the chest. Although this examination may seem routine, chest radiography provides important information about soft tissues, bones, the pleura, the mediastinum, and lung tissue.

s0025 Exposure Factor Conditions

p0075 Correct exposure factor selection is critical because an incorrect exposure factor may obscure or appear to create pathologic findings. This is particularly true for serial mobile radiographs because the interpreting physician relies heavily on consistent exposure conditions to analyze the change in pathology after treatment. Institutions may record exposure techniques for mobile chest images so that different technologists can use similar exposure factors to maintain consistency among the radiographs. Digital mobile units, using direct capture (DR) image receptors are most often used for portable imaging. Accurate technical selection is important when using digital radiography systems to ensure that an appropriate exposure indicator is obtained, and that consistency is maintained between subsequent images.

In the respiratory system, any condition that adds p0080 fluid or tissue to the normally aerated chest (e.g., pneumonia) requires an increase in technical factors to afford proper penetration and exposure. Similarly, any condition that increases the aeration of the chest (e.g., emphysema) reduces the amount of radiation required for proper exposure to be achieved and may require a decrease in technical factors. Most experts agree that when chest radiography is performed using a digital imaging system, the technologist must use his or her knowledge of pathologic conditions and specific image receptor characteristics to assess whether a change in milliamperere second (mAs) or kilovoltage peak (kVp) is required to adjust the radiographic exposure. The kilovoltage range should be chosen based on the energy level necessary to penetrate the part of interest, keeping in mind the presence of additive or subtractive pathologies.

The use of automatic exposure control (AEC) in chest p0085 radiography facilitates consistent radiographic exposures but requires careful analysis of the clinical history and conscious thought about the type of disease present and its location to ensure truly optimal diagnostic-quality radiographs. Activation of the sensor, for example, over an area of significant aeration or consolidation (tissue or fluid accumulation) may result in excessive or insufficient exposure, respectively. Although the image may look fine during the initial visual examination, care must be taken to always utilize an exposure indicator to assess proper technique selection. Experience with AEC, combined with careful thought in selecting the proper sensor, eliminates these mistakes.

Position and Projection

Patient position and projection are also critical exposure conditions that may distort the final image. Position refers to the arrangement of the patient's body (e.g., erect, supine, recumbent), and projection refers to the path of the X-ray beam (e.g., anteroposterior [AP], i.e., the X-rays entering through the body's anterior surface and exiting the posterior surface). The standard projections for chest radiography are the erect posteroanterior (PA) and left lateral (Fig. 3.2). Each of these serves to place the heart closer to the image receptor because the heart lies in the anterior part of the chest and mostly to the left side. When combined with a standard 72-in source-to-image distance (SID), magnification of the heart is minimized, consolidation of the major vessels is reduced, and air–fluid levels are more accurate.

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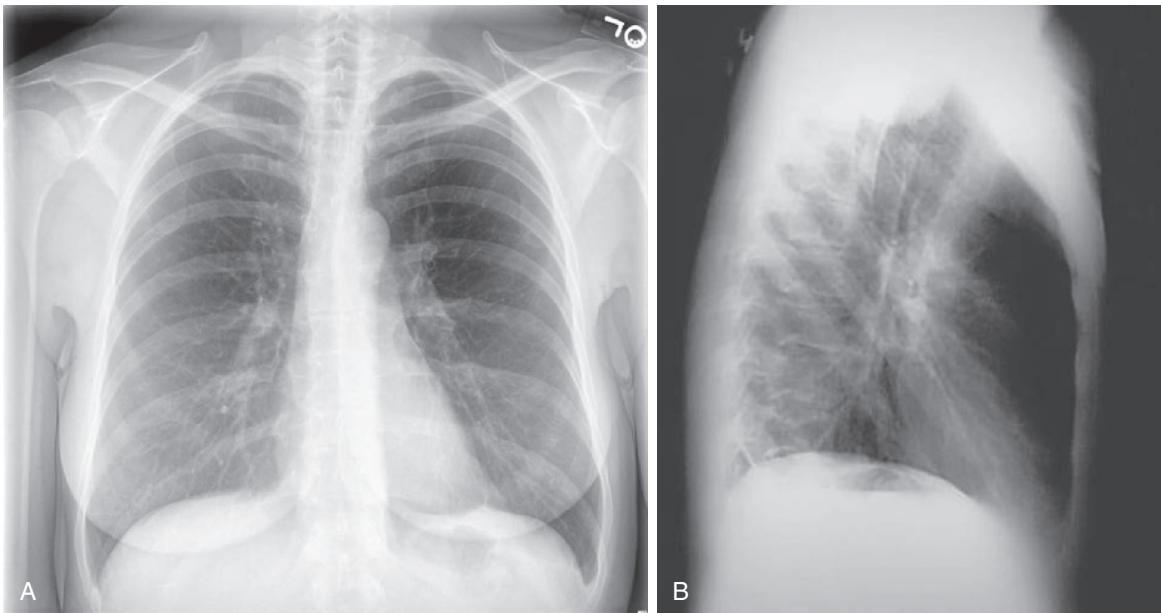


Fig. 3.2 (A) Normal erect posteroanterior chest radiograph. (B) Normal erect lateral chest radiograph. (From Northcentral Technical College, Wausau, Wisconsin.)

s0035 Chest Radiography

p0095 On a normal erect PA chest image, the costophrenic and cardiophrenic angles are demonstrated, with the right hemidiaphragm appearing 1 to 2 cm higher than the left because of the position of the liver. When a patient is radiographed in the recumbent position, the lower lung fields may be obscured because of abdominal pressure raising the level of the diaphragm (Fig. 3.3).

p0100 Other projections of the thorax are used less frequently than the erect PA and left lateral projections. The AP projection is the method of choice for mobile radiography when the patient is too ill to tolerate a visit to the department and assume an erect position. As much as possible, it is important that mobile chest radiographs be taken upright or semi-upright to demonstrate any air-fluid levels present. Maintenance of the beam perpendicular to the plane of the image receptor is essential to avoid any foreshortening of the heart. Furthermore, use of the 72-in SID is very important for mobile radiography to minimize magnification of the heart, which is located farther from the image receptor in the AP projection.

p0105 The AP and PA projections in the lateral decubitus position are useful under specific conditions such as diagnosing free air in the pleural space or pleural fluid. For example, for a right lateral decubitus chest radiograph,

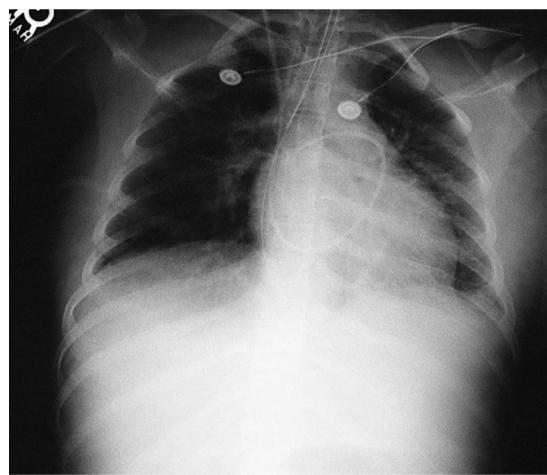


Fig. 3.3 Recumbent anteroposterior chest radiograph demonstrating obscuring of the lower lung fields. (From The Ohio State University Wexner Medical Center, Columbus, Ohio.)

the patient is requested to lay on their right side. In this position, any fluid present tends to layer out along the edge of the lung field on the dependent side which enhances its visibility, whereas the free air rises toward the left side. Lateral decubitus views of the chest have been widely replaced by computed tomography (CT).

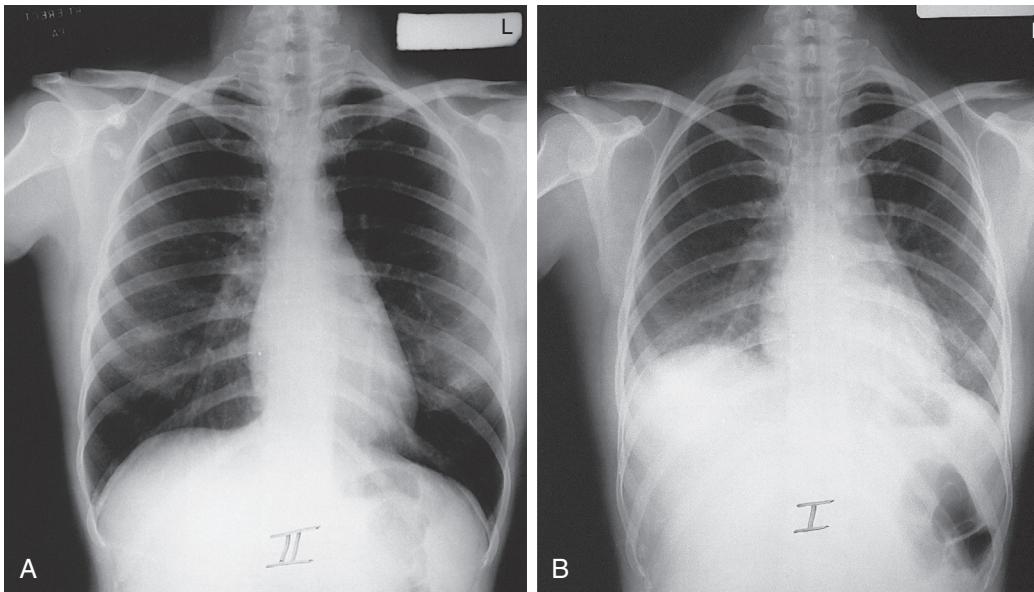


Fig. 3.4 (A) Normal appearance of the chest during inspiration. (B) Chest imaging during expiration on the same patient demonstrates elevation of the diaphragm and a heart that is more transverse and appears larger. (From Riverside Methodist Hospital, Columbus, Ohio.)

p0110 For evaluation of the standard PA chest radiograph, the size and radiolucency of both lungs should be compared. Criteria for adequate inspiration and penetration of chest radiographs vary from institution to institution; however, a rule of thumb is that adequate inspiration should provide visualization of 10 posterior ribs within the lung field. In addition, all thoracic vertebrae and intervertebral disk spaces should be faintly visible through the mediastinum on an adequately penetrated chest radiograph. The average movement of the lungs and diaphragm between inspiration and expiration is approximately 3 cm (Fig. 3.4).

p0115 Oblique projections of the thorax are useful in separating superimposed structures such as the sternum, esophagus, and thoracic spine. A lordotic chest radiograph is useful in demonstrating the apical regions of the lung, which are normally obscured by bony structures on the standard PA projection (Fig. 3.5). Certain diseases such as tuberculosis (TB) have a predilection for the apices.

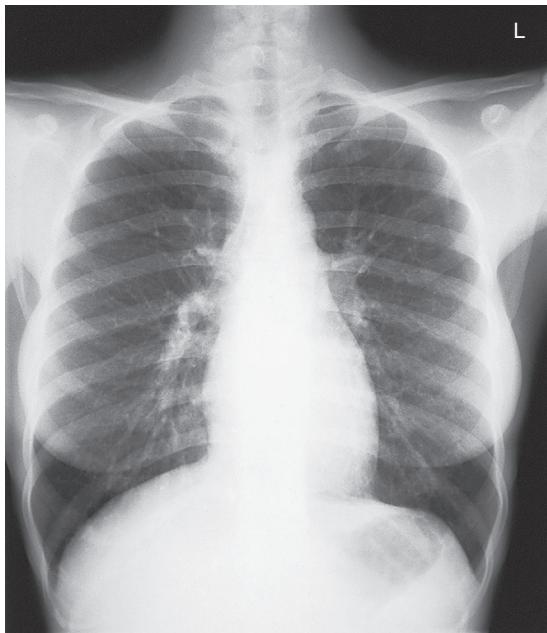
s0040 Soft Tissues of the Chest

p0120 Various soft-tissue densities are present on chest radiographs that may vary with age, sex, and pathologic condition. The pectoral muscles are normally demonstrated overlying and extending beyond the lung fields.



Fig. 3.5 Lordotic chest radiograph taken during expiration to demonstrate a possible pneumothorax. (From The Ohio State University Wexner Medical Center, Columbus, Ohio.)

Radiographs often demonstrate breast shadows in the mid-chest region (Fig. 3.6). These shadows are normally homogeneous in appearance, and larger breasts may obscure the costophrenic angles. Elevation of the breasts may be necessary to better demonstrate the bases of the lungs. Surgical removal of one or both breasts is also evident on chest radiographs; breast prostheses, which



f0035

Fig. 3.6 Breast shadows are readily recognizable on the normal posteroanterior chest radiograph. (From Riverside Methodist Hospital, Columbus, Ohio.)

appear as well-defined, circular, radiopaque densities, are also evident. Nipple shadows may be visible at the level of the fourth or fifth anterior rib spaces and may occasionally mimic nodules or masses in the chest. These soft-tissue structures may be differentiated with nipple markers or oblique projections of the chest.

s0045 **Bony Structures of the Chest**

p0125 The ribs, sternum, and thoracic spine enclose the thoracic cavity. These structures assist the technologist in the assessment of the technical adequacy of chest radiographs. Congenital anomalies of the ribs may be demonstrated (Fig. 3.7), as well as calcified costal cartilages. This calcification generally occurs in people in their late 20s and beyond. Rib fractures may be seen (Fig. 3.8), sometimes with an accompanying pneumothorax. A depressed sternum (pectus excavatum) may also be demonstrated, possibly displacing the heart (Fig. 3.9). The thoracic spine may be assessed for scoliosis, which may affect the chest cavity, and kyphosis or compression fractures of the vertebrae.

s0050 **Mediastinum**

p0130 The mediastinum contains all thoracic organs except the lungs. The heart occupies a large portion of the

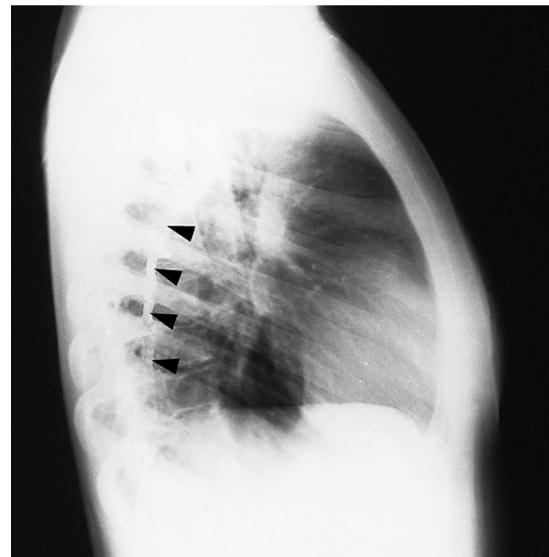


Fig. 3.7 Congenital intrathoracic rib seen as a curving, tubular density in the posterior thorax (arrowheads). Usually, these ribs are attached at one or both ends of a posterior rib and lie extrapleurally inside the thoracic cage. (From American College of Radiology, Reston, Virginia.)

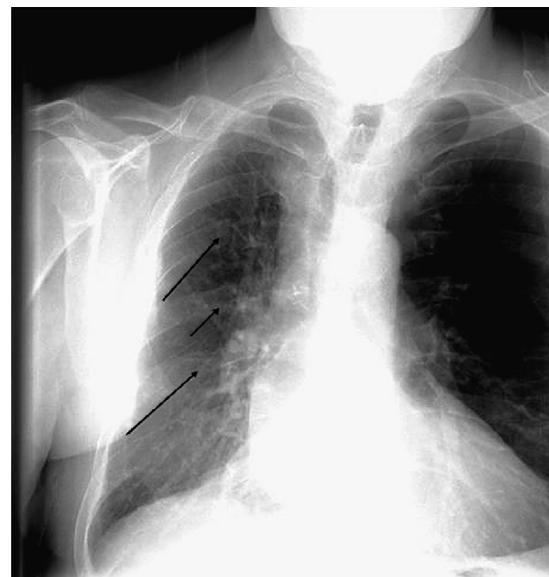


Fig. 3.8 Right-sided rib fractures (arrows) in combination with a right clavicular fracture. (From The Ohio State University Wexner Medical Center, Columbus, Ohio.)

mediastinum, and the shape of the heart varies with age, degree of respiration, and patient position. Other organs contained within the mediastinum include the



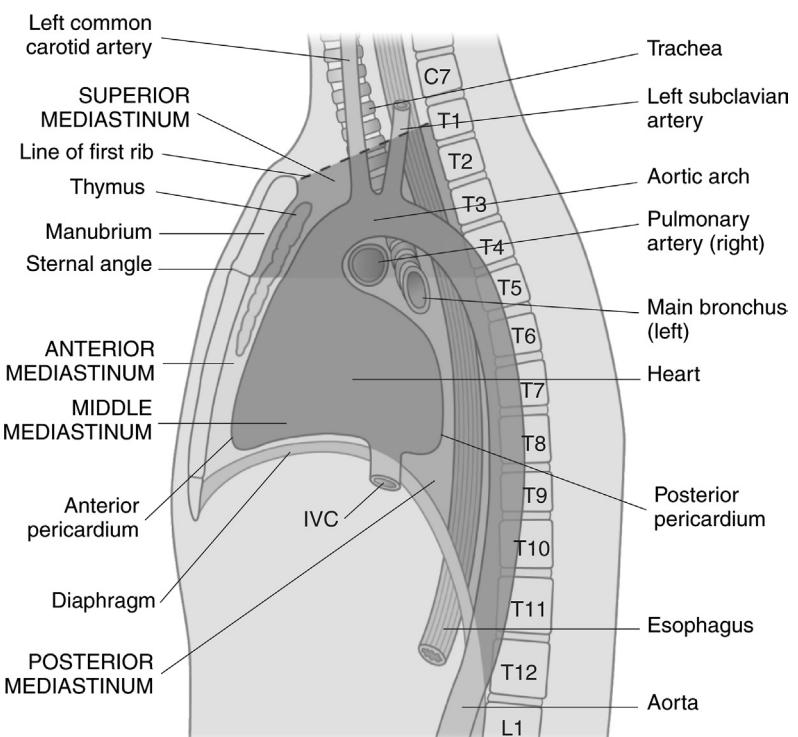
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Fig. 3.9 Lateral projection of the chest demonstrating pectus excavatum, including compression of the heart toward the spine. (From The Ohio State University Wexner Medical Center, Columbus, Ohio.)

thyroid and thymus glands, and nervous and lymphatic tissues (Fig. 3.10).

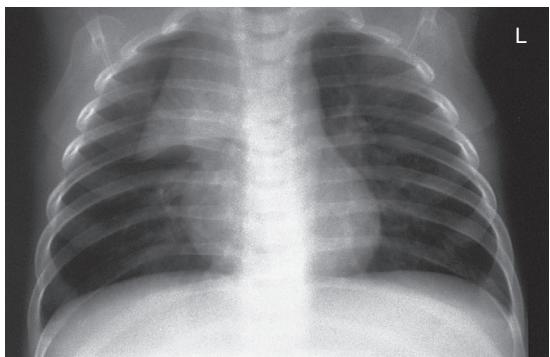
The mediastinum is divided compartmentally into the *superior mediastinum*, which contains the thymus, trachea, esophagus, and aortic arch; the *anterior mediastinum*, which contains the thymus; the *middle mediastinum*, which contains the heart and great vessels, trachea, and main bronchi; and the *posterior mediastinum*, which contains the esophagus and descending aorta.

In infants, the mediastinum appears wide because of the normally large thymus. In frontal projections, it may extend beyond the heart borders and caudally to the diaphragm, and in a lateral projection, it may fill the anterior portion of the mediastinum, which is normally radiolucent later in life. This radiographic appearance is readily visible in both PA and lateral views and is referred to as the “thymic sail sign” because of its characteristic appearance (Fig. 3.11). Diagnosis is difficult because the width of the upper mediastinum varies greatly with the



f0055

Fig. 3.10 Sagittal view of the mediastinum. (From Standring, S. (2009). *Gray's anatomy* (4th ed.). Churchill Livingstone.)

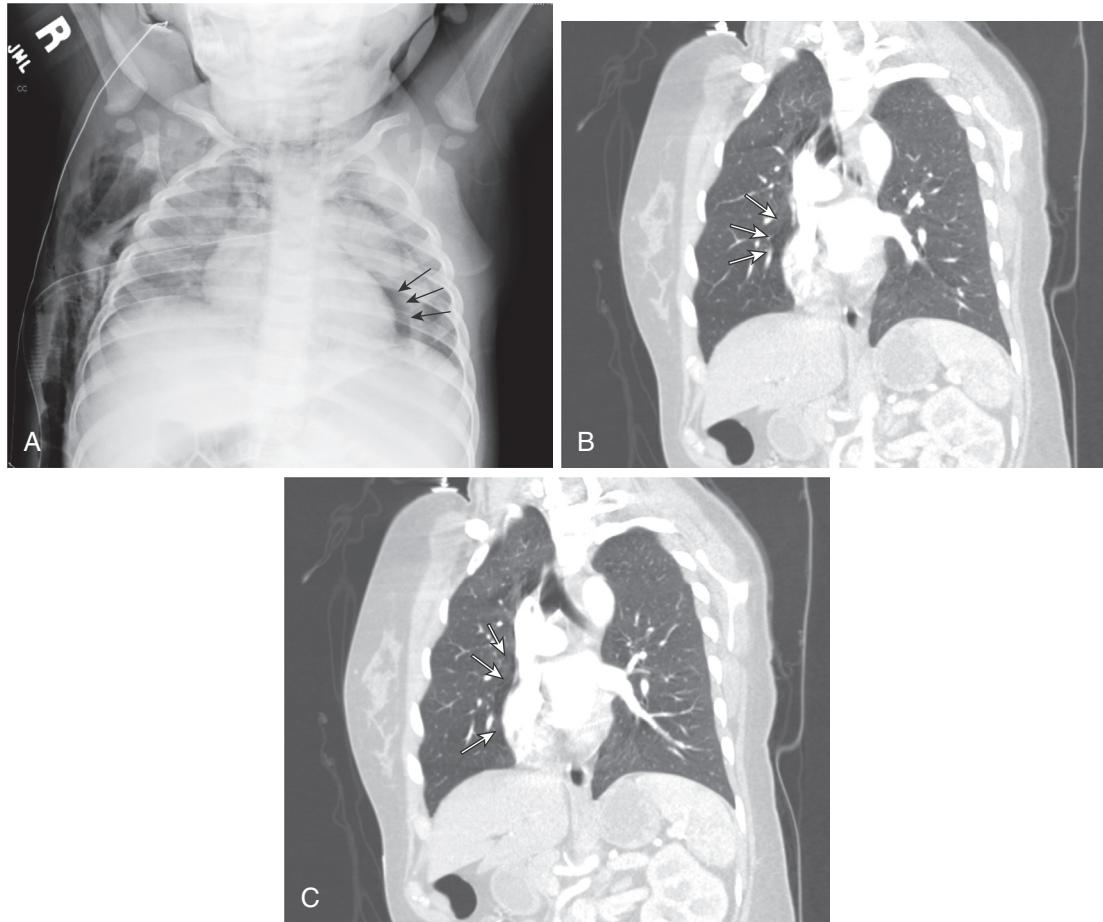


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Fig. 3.11 Normal enlargement of the thymus in a 3-month-old infant demonstrates the "thymic sail sign," evidenced by the uniform-density increase in the right upper lung area. (From American College of Radiology, Reston, Virginia.)

phase of respiration. Crying may present an opportune moment for the technologist to make an exposure, but the resultant Valsalva maneuver adds to the distortion of the thymus. The Valsalva maneuver increases both the intrathoracic pressure and the intraabdominal pressure by asking the patient to inhale deeply and hold their breath to force the diaphragm and chest muscles against a closed glottis. True mediastinal masses are rare in infants and generally represent congenital malformations or neoplasms. In the mediastinum of older adults, the aorta dilates, and the aortic knob becomes much more visible.

Mediastinal emphysema (pneumomediastinum) p0145 occurs when there has been a disruption in the esophagus or airway and air is trapped in the mediastinum (Fig. 3.12). It may result from chest trauma, endoscopy,



f0065

Fig. 3.12 (A) Portable pediatric anteroposterior chest radiograph demonstrating a pneumomediastinum (arrows). (B and C) Oblique coronal CT demonstrating a pneumomediastinum around the heart. (From The Ohio State University Wexner Medical Center, Columbus, Ohio.)

or violent vomiting. When unaccompanied by a pneumothorax, spontaneous mediastinal emphysema is usually self-limiting, subsiding in a few days without complication. Air in the mediastinum from rupture of the esophagus (usually from vomiting) or a major bronchus (usually from trauma) is more serious and requires prompt diagnosis and surgical intervention. CT is the imaging of choice, however an esophagram may be performed to verify the presence of a perforation if CT is inconclusive.

p0150 When the pneumomediastinum is extensive, air may pass from the mediastinum into the subcutaneous tissues of the chest or neck, resulting in **subcutaneous emphysema** (Fig. 3.13). Diagnosis of this may be made by feeling air bubbles in the skin of the chest or neck.

p0155 Glandular enlargements of the thyroid gland are demonstrated by a displacement or narrowing of the trachea. The thyroid gland is usually located superior to the lung apices, but an ectopic thyroid gland may also displace the trachea. Clinical manifestations of an ectopic thyroid gland are often absent, and the mass may be discovered accidentally when chest radiography is performed for some other purpose.

p0160 In some instances, a routine chest radiograph may be requested upon admission to the hospital, but for stable patients, this must be based on specific clinical indications such as a need for cardiac monitoring or the presence of extrathoracic disease. Although many institutions routinely obtain mobile chest radiographs for all patients in the intensive care unit, recent research indicates that



f0070

Fig. 3.13 Significant subcutaneous emphysema seen throughout the thorax, especially extending along the right border of the chest. (From The Ohio State University Wexner Medical Center, Columbus, Ohio.)

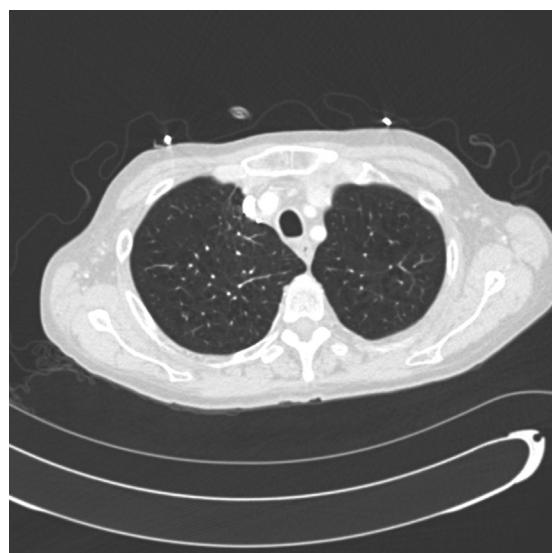
the diagnostic and therapeutic value of routine chest radiography is low in this population. Based on current evidence, the American College of Radiology (ACR) suggests that routine mobile chest radiography indications include, but are not limited to, people with acute cardiopulmonary conditions, monitoring and/or life-support devices, those who are critically or medically unstable, the elderly, or those with a clinical condition preventing transport to the imaging department. In cases involving the placement of an endotracheal (ET) tube, central venous line, arterial line, and chest tubes, radiographs should only routinely be obtained upon placement of the device. Follow-up chest radiography should not be routine for these patients and should be performed based on appropriate clinical indications.

Computed Tomography

s0055

Volumetric computed tomography (CT) offers the advantage of imaging the entire chest with one breath hold, which allows for better evaluation of the chest, especially the diaphragm area. Advances in CT software allowing for high-resolution, thin-slice thicknesses ranging from 1 to 1.5 mm (Fig. 3.14) and faster scanning times, in combination with dynamic scanning (Fig. 3.15), have greatly enhanced the role of CT in chest imaging. CT is the method of choice for the evaluation of pulmonary adenopathy. Standard radiography is only

p0165



f0075

Fig. 3.14 High-resolution CT of a normal chest. (From The Ohio State University Wexner Medical Center, Columbus, Ohio.)

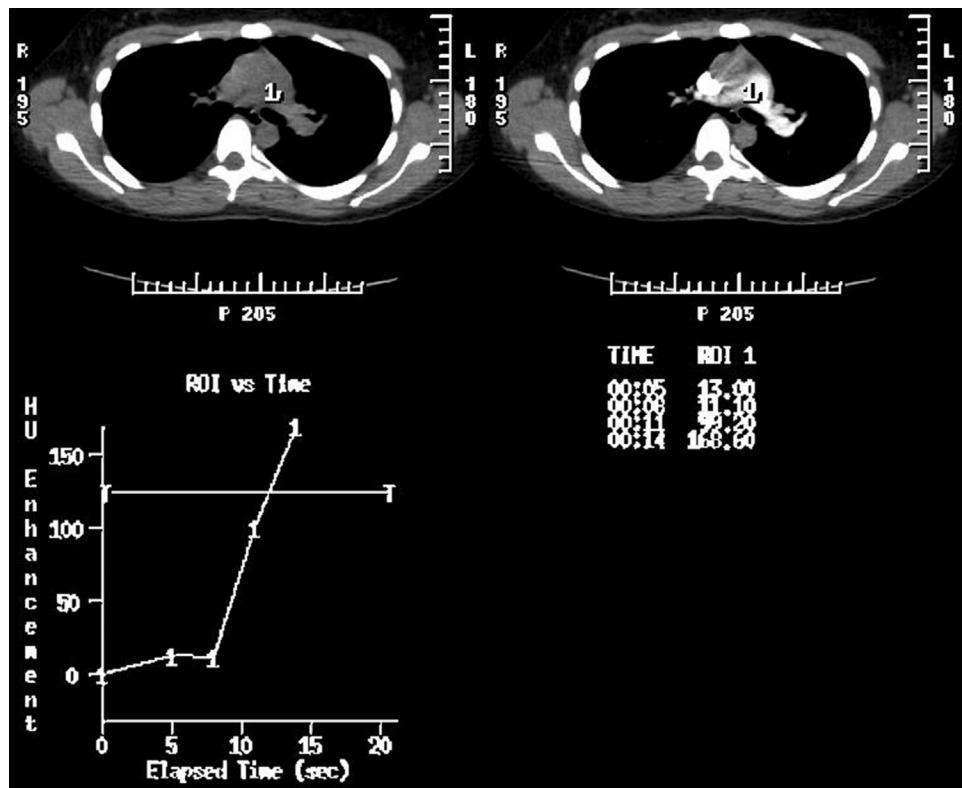


Fig. 3.15 Contrast-enhanced CT of the chest using CT software to track the bolus of intravenous contrast media. (From The Ohio State University Wexner Medical Center, Columbus, Ohio.)

about 50% sensitive to chest disease, typically displaying advanced pathologic conditions. The excellent specificity of CT, however, may be a problem because most people have granulomatous disease, which is often benign. A rule of thumb for evaluating the character of a visualized nodule relates to its size: those less than 1 cm in size are usually benign, and those larger than 1 cm may be malignant. Also, the presence of calcium within a nodule is a reasonable indication of benignity, particularly in the middle of the lesion or diffusely within the nodule, but eccentric calcification may indicate malignancy.

CT is also sensitive in detecting emboli within the thoracic vessels (Fig. 3.16). When a pulmonary embolus is suspected, a computed tomographic angiogram (CTA) of the chest with contrast is performed. Chest CT is also indicated in the clinical staging of small-cell lung carcinomas and in the detection of metastatic disease of the chest. Percutaneous transthoracic needle aspiration is commonly performed under CT guidance. Needle aspirations are performed to obtain cytologic specimens from lesions within

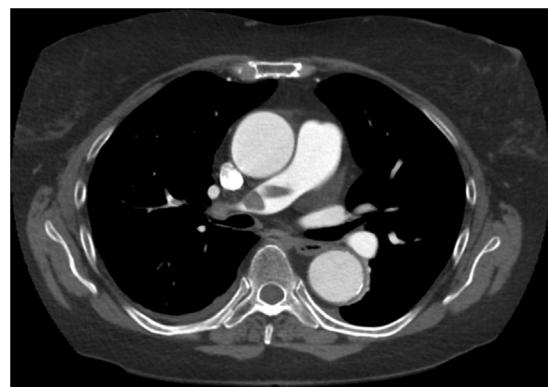
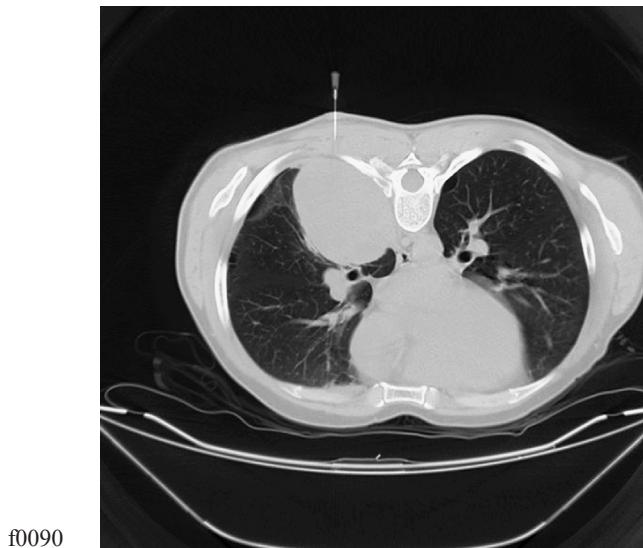


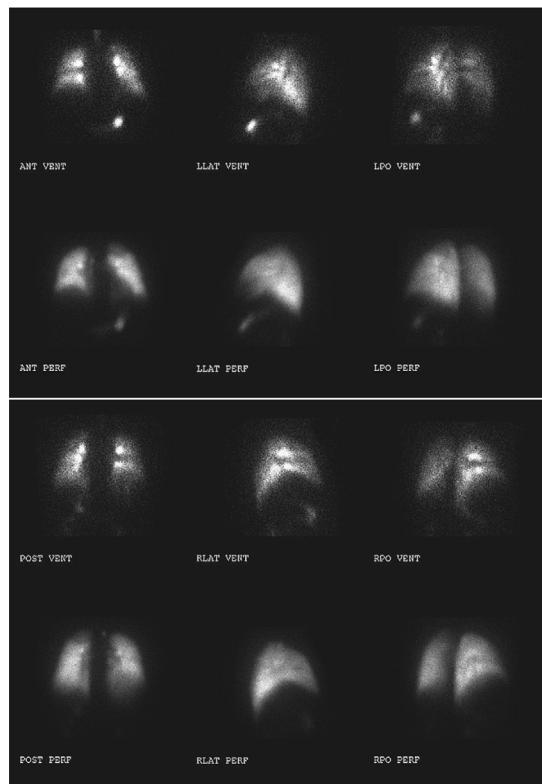
Fig. 3.16 CT of the lung demonstrating a massive embolism within the main pulmonary artery branches and smaller bronchial vessels. (From Northcentral Technical College, Wausau, Wisconsin.)

the lungs (Fig. 3.17), pleural space, and mediastinum. Following the biopsy, chest radiographs may be obtained to check for a possible pneumothorax or hemorrhage.



f0090

Fig. 3.17 CT-assisted core biopsy of a large right lung mass. (From The Ohio State University Wexner Medical Center, Columbus, Ohio.)



f0095

Fig. 3.18 Example of an NM perfusion and ventilation scan performed to evaluate a possible PE. (From The Ohio State University Wexner Medical Center, Columbus, Ohio.)

s0060 Nuclear Medicine

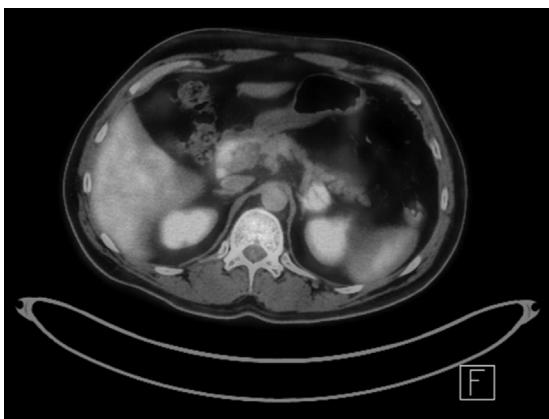
- p0175 Perfusion and ventilation scans, as performed in nuclear medicine (NM), are useful in evaluating chest disease, particularly in the case of obstructive disease and in cases of suspected pulmonary emboli (PE) when a CTA is contraindicated. Planar ventilation/perfusion (VQ) scans are the standard method for diagnosing PE. However, some studies have shown that single-photon emission computed tomography (SPECT) may increase specificity and sensitivity.
- p0180 Injection of a radionuclide, technetium-99m macroaggregated albumin (Tc-99m MAA), into the venous system for a perfusion causes it to become trapped in the pulmonary circulation, allowing for gamma-camera visualization of its distribution. In a ventilation scan, the patient inhales a radioactive gas (such as xenon or Tc-99m diethylenetriaminepentaacetic acid [DTPA]) and holds their breath while an image is taken of the gas distribution throughout the lungs (Fig. 3.18).
- p0185 Positron emission tomography (PET) captures information regarding metabolic activity. The primary imaging agent used in PET of the lungs is fluorodeoxyglucose (FDG), making it useful in distinguishing benign from malignant lesions within the chest because it has the capability of imaging an increase in glucose uptake from

neoplastic cells. FDG whole-body PET is useful in the evaluation of solitary pulmonary nodules and in the staging of bronchogenic carcinoma (Fig. 3.19).

SPECT is also used to analyze the function of internal organs. This NM imaging test, which is like a PET scan, requires a radiotracer to be introduced into the body. SPECT is not only helpful in the diagnosis of PE, but also in the evaluation of patients with chronic obstructive pulmonary disease (COPD). Traditionally, the best option for diagnosing the severity of COPD in NM is through the use of a lung quantification study. This study is performed by administration of the perfusion radionuclide (Tc-99m MAA) with a posterior image acquired. Regions of interest are drawn over varying areas of the lungs (right upper quadrant, right lower quadrant, left upper quadrant, and left lower quadrant) to determine how well these regions of the lungs are perfused comparatively to each other.

s0065 **CHEST TUBES, VASCULAR ACCESS LINES, AND CATHETERS**

p0195 A variety of tubes, lines, and catheters can be placed in relation to parts of the respiratory system. It is important for the technologist to be familiar with each of these and exercise great caution in attempting patient movement with any in place. It is best to have assistance from



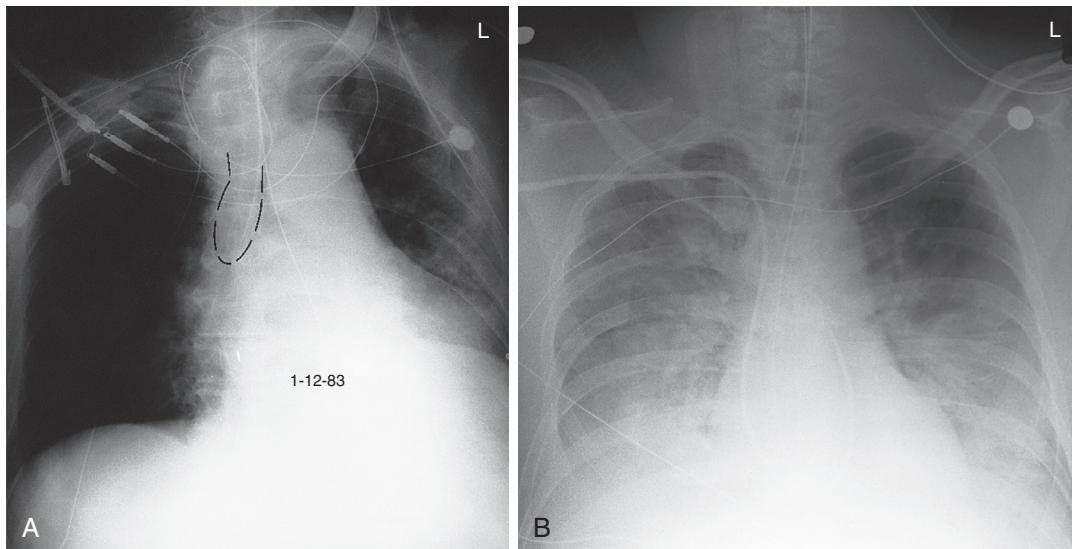
f0100

Fig. 3.19 Axial PET and CT of the abdomen used for staging bronchogenic carcinoma (same as Fig. 3.55A). (From The Ohio State University Wexner Medical Center, Columbus, Ohio.)

another technologist or nursing personnel to ensure that the lines and tubes are free of any obstructions before patient movement occurs. Furthermore, the technologist who is unsure whether a patient can sit erect should always ask the nurse. Due to the instability of critical care patients, the X-ray tube, image receptor, and exposure technique should be established before the patient is moved. Critical care patients can often only be erect for a short period because of the instability of their blood pressure. Finally, it is necessary to cover the image receptor with a plastic bag to limit infection transfer and keep the cold image receptor surface from touching the patient's back.

An **endotracheal (ET) tube** is a large plastic tube p0200 inserted through a patient's nose or mouth into the trachea. It helps to manage the airway, allows for frequent suctioning, and allows for mechanical ventilation. A properly placed ET tube is visualized on chest radiography, 5 to 7 cm above the carina with neutral position of the neck (Fig. 3.20). Movement of a patient with an ET tube should be done with great caution because unintentional displacement or accidental extubation may leave the patient without a patent airway.

A **chest tube**, also known as a *thoracostomy tube*, is p0205 a flexible plastic tube inserted between the ribs and into

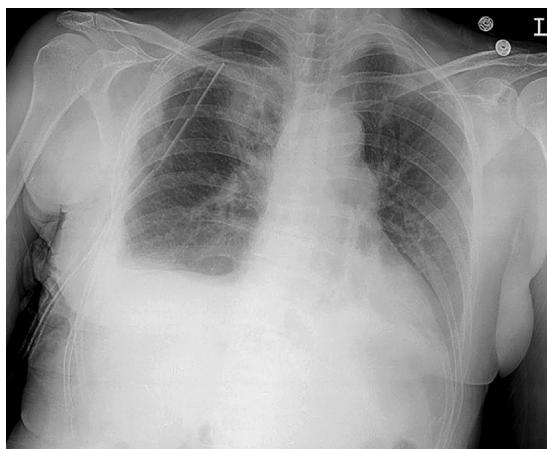


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Fig. 3.20 (A) Incorrect endotracheal (ET) tube placement creates a shift of the heart and mediastinum to the left with loss of air volume in the left lung. The ET tube tip lies in the proximal right main stem bronchus, inferior to the carina. (B) Correct placement of the ET tube demonstrating balanced lung ventilation. (From The Ohio State University Wexner Medical Center, Columbus, Ohio.)

the pleural space. The chest tube creates negative pressure in the chest cavity and allows for reexpansion of the lung to allow the patient to breathe normally. Chest tubes allow for the removal of air (e.g., pneumothorax) or fluid (e.g., pleural effusion or hemothorax) from the thoracic cavity (Fig. 3.21). Chest tubes placed lower on the chest wall are usually for fluid drainage; those placed higher are usually for air removal. After open heart surgery, a chest tube may be placed in the mediastinum for proper fluid drainage. Its location is midline, just below the sternum. The collection device attached to the chest tube must be kept below the level of the chest to allow for proper drainage. The amount of time a chest tube remains in the thorax is dependent on the amount of deflation of the lung.

Central venous catheters (CVCs) are used to measure the pressure in the vena cava (central venous pressure). The silicone rubber tube is inserted into the internal jugular, subclavian, or femoral vein and advanced into the superior vena cava (SVC) just above the right atrium (Fig. 3.22). This catheter provides an alternative injection site to compensate for loss of peripheral infusion sites or to allow for infusion of massive volumes of fluids. In addition, it allows for measurement of central venous pressure, which indicates a patient's fluid status and provides information about the function of the heart's right side. Chest radiographs are generally requested following the insertion of a CVC to check for proper placement and the presence of a pneumothorax



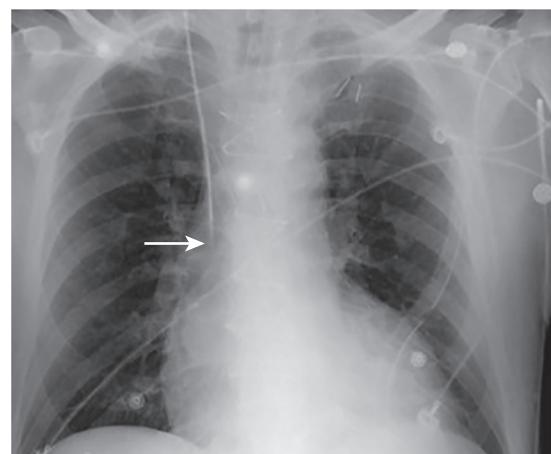
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Fig. 3.21 Portable chest radiograph demonstrating proper chest tube placement in the right lung near the apex. (From The Ohio State University Wexner Medical Center, Columbus, Ohio.)

or hemothorax. Improperly placed catheters may result in cardiac arrhythmias.

A pulmonary artery catheter (Swan-Ganz catheter) is usually inserted via the subclavian vein, but other insertion sites include the antecubital vein, jugular vein, and femoral vein. It is a multi-lumen catheter that serves to evaluate cardiac function. The pulmonary artery catheter measures pulmonary wedge pressure, reflecting left atrial pressure. It does not enter the heart's left side but is positioned in the pulmonary artery (Fig. 3.23). Inflation of the balloon at the tip of the catheter allows the tube to float into a smaller pulmonary artery capillary. Diagnosis and management of heart failure resulting from myocardial infarction and cardiogenic shock represent the most common use of the catheter.

Other central venous catheters such as a Hickman catheter or a Port-a-Cath are usually inserted via the subclavian vein. Hickman catheters are open to the outside of the body with the tip of the catheter placed in the SVC. Port access devices are placed under the skin, just below the clavicle (Fig. 3.24). Because these devices are not open to the outside, a port access device is less likely to become infected and requires little maintenance. These catheters allow multiple tapping for injection of various agents, typically chemotherapeutics. Location in the subclavian vein provides ready access to the venous circulation and its blood flow return to the heart.



f0115

Fig. 3.22 Chest radiograph showing a properly positioned central venous catheter. The white arrow shows the tip of the catheter within the superior vena cava. (From Frank, P. (2024). *Anesthesiology and critical care morning report: Beyond the pearls*. Elsevier.)

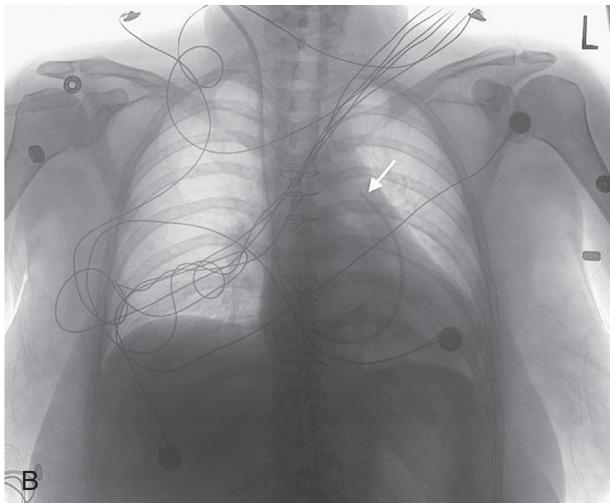
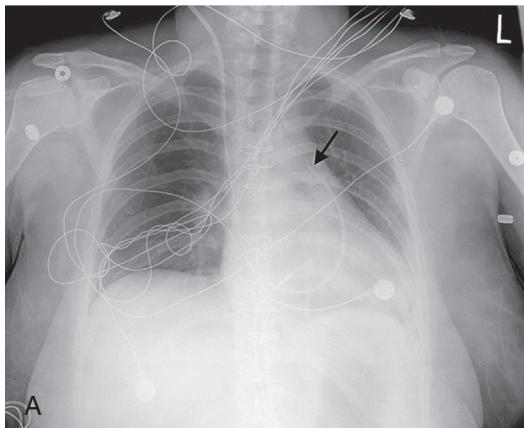


Fig. 3.23 (A) Swan-Ganz catheter placement from the right intrajugular vein with the tip in the proximal right pulmonary artery (arrow). (B) Inverted image of the same patient (arrow). (From The Ohio State University Wexner Medical Center, Columbus, Ohio.)

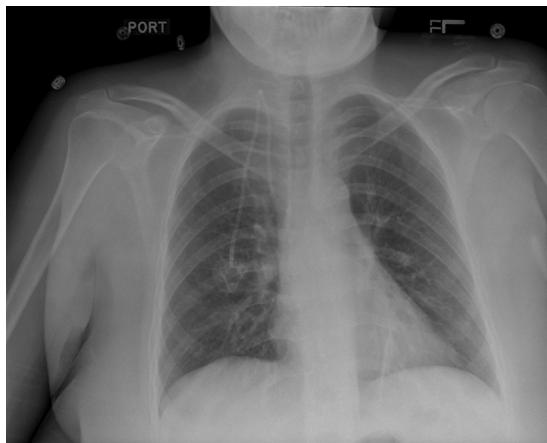


Fig. 3.24 Portable anteroposterior chest radiograph demonstrating the placement of a double Port-a-Cath. (From North-central Technical College, Wausau, Wisconsin.)

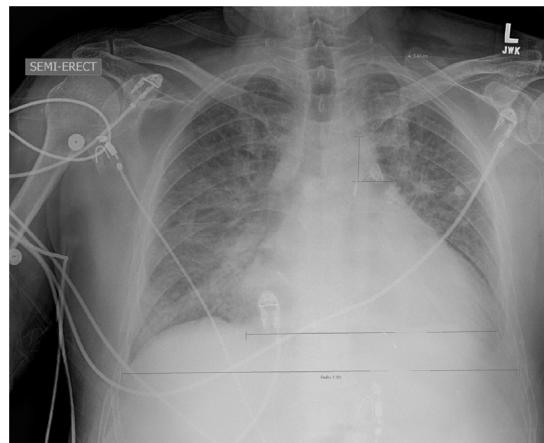


Fig. 3.25 Portable anteroposterior chest radiograph demonstrating intraaortic balloon pump (IABP) placement. (From The Ohio State University Wexner Medical Center, Columbus, Ohio.)

p0225 An intraaortic balloon pump (IABP) catheter is a specialized device typically inserted during surgery or percutaneously at the bedside in critical care units or in the cardiac catheterization laboratory. A 40-mL balloon at the distal end of the catheter allows for inflation and deflation by a pump that is synchronized to the patient's cardiac cycle to provide mechanical support of the left ventricle. These devices reduce the workload of the heart and help improve systemic blood flow, including increased blood supply to the cardiac muscle. The

balloon is placed in the descending aorta below the subclavian artery and above the renal arteries (Fig. 3.25). Caution should be used in moving affected patients because movement may cause the balloon to float downward, possibly blocking the lower circulation.

Ventricular pacing electrodes may be placed for **p0230** temporary or permanent purposes. Temporary pacing electrodes are inserted via the antecubital vein into the right ventricle. They provide electrical pacing of the

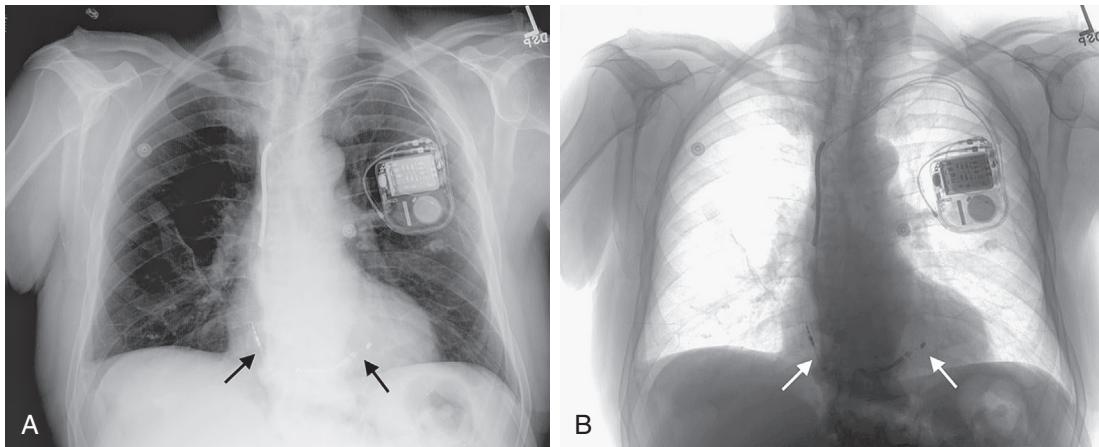


Fig. 3.26 (A) Portable chest radiograph taken after pacemaker insertion demonstrating proper placement of lead wires (arrows). (B) Inverted image of the same patient. (From The Ohio State University Wexner Medical Center, Columbus, Ohio.)

heart in people experiencing a very slow heart rate (i.e., bradycardia) as a result of misfiring of the heart's electrical system. Also, patients who have had open heart surgery may have these electrodes placed directly on the heart's surface and brought externally beneath the sternum at midline as a temporary precaution against heart arrhythmia problems. Permanent electrodes are used for permanent heart pacing needs. The pacemaker generator is inserted under the skin, below the right clavicle, with the electrodes placed into the right ventricle (Fig. 3.26).

s0070 **RESPIRATORY FAILURE**

p0235 **Respiratory failure** is a term used to describe a lack of respiratory function or a lack of oxygen and carbon dioxide exchange. This may occur at two levels: (1) within the lungs (intrapulmonary gas exchange) or (2) as a result of impaired breathing (inability to move air into and out of the lungs). This may occur following acute trauma to the chest or as a result of an acute or chronic lung disease. When ventilation is normal, carbon dioxide (CO_2) is removed from the lungs to maintain metabolic homeostasis at the cellular level, thus ensuring that the partial pressure of CO_2 (pCO_2) in arterial blood is approximately 40 mm Hg. When pCO_2 levels are above 40 mm Hg, this signals that the CO_2 is not being removed properly, which denotes hypoventilation that can cause hypoxemia and hypercapnia. **Hypoxemia** signifies low oxygen levels within arterial blood and results

from a failure of the gas exchange function. Common causes include toxic gas or smoke inhalation, COPD, atelectasis, severe pneumonia, high altitudes, hypoventilation, or impaired diffusion (a physical separation of gas and blood) resulting from pulmonary edema or an acute lung injury. In cases of congenital heart defects, hypoxemia may also be caused by shunting of blood from the right side to the left side of the heart without passing through the lungs. The term **hypercapnia** refers to failure of ventilation resulting in the inability to move air into and out of the lungs, with consequent increased blood CO_2 content. Hypercapnic or hypoxic respiratory failure may be caused by upper airway obstruction, insufficient respiratory drive, respiratory muscle fatigue or paralysis, or a dysfunction of the CNS resulting in a defective ventilatory pump. Patients in respiratory failure usually exhibit tachypnea, tachycardia, irregular or gasping breathing patterns, and paradoxical abdominal motion. If hypoxemia is acute, it may cause cardiac arrhythmias and alteration of consciousness ranging from confusion to coma.

Arterial blood gas (ABG) measurement is the primary method for diagnosing respiratory failure and for determining the severity of the failure. An arterial oxygen level (pO_2) less than 60 mm Hg, an arterial pCO_2 greater than 45 mm Hg, or both are indicative of respiratory failure. Chest radiographs are often obtained to help identify the cause of respiratory failure. The treatment of respiratory failure includes establishing a patent airway, administration of bronchodilator drugs, and controlled

p0240

oxygen therapy with the use of specialized, nonventilator masks termed continuous positive airway pressure (CPAP) and bilevel positive airway pressure (BiPAP) devices. Patients may also be intubated and placed on a mechanical positive-pressure ventilator (PPV). Care must also be taken to maintain cardiac output and to assist the failing circulation secondary to cardiac dysfunction.

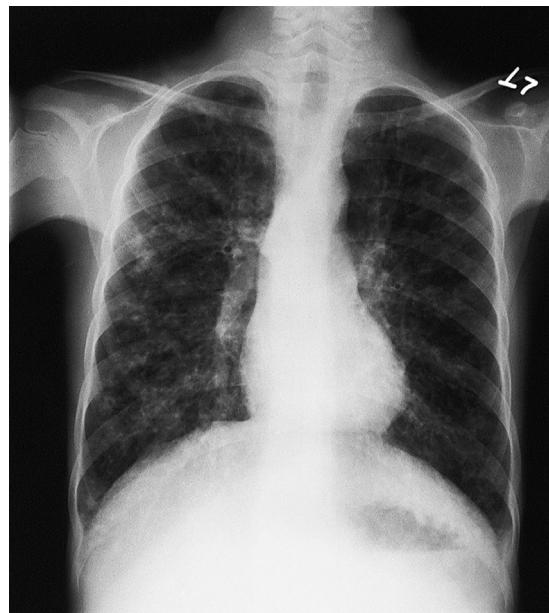
s0075 **CONGENITAL AND HEREDITARY DISEASES**

s0080 **Cystic Fibrosis**

p0245 **Cystic fibrosis** is an autosomal recessive condition caused by mutations in the cystic fibrosis transmembrane conductance regulator (*CFTR*) gene that leads to severe pulmonary manifestations and often leads to significant morbidity and mortality. Cystic fibrosis involves many organs in addition to the respiratory system, and nearly all exocrine glands are affected in varying distributions and degrees of severity. These glands and other organs affected include the salivary glands, small bowel, pancreas, biliary tract, female cervix, and male genital system. In the respiratory system, evidence suggests that the lungs are histologically normal at birth. Pulmonary damage is initiated by gradually increasing secretions as a result of hypertrophy of the bronchial glands, leading to obstruction of the bronchial system. The resultant plugging promotes staphylococcal infection, followed by more tissue damage, and atelectasis (collapse of lung tissue) and emphysema. Once the cycle is in motion, it is difficult to stop.

p0250 The signs and symptoms of cystic fibrosis usually include a chronic cough and wheezing associated with recurrent or chronic pulmonary infections. The cough is often accompanied by sputum, gagging, vomiting, and disturbed sleep. Barrel-chest deformity, clubbing of fingers, and cyanosis occur as the disease progresses. In adolescents and adults, pulmonary complications associated with cystic fibrosis include pneumothorax, hemoptysis, and right-sided heart failure secondary to pulmonary hypertension.

p0255 Due to progress in medical and surgical treatments, patients in the United States are expected to survive into their 40s or longer with cystic fibrosis. However, it remains the most common lethal genetic disease in White children. Its diagnosis rests largely on a medical history of a sibling with cystic fibrosis, laboratory



f0140

Fig. 3.27 Increased lung volume resulting from generalized obstructive disease and air trapping, which is characteristic of cystic fibrosis, as seen in this 9-year-old male. Also seen are areas of irregular aeration with cystic and nodular densities. (From American College of Radiology, Reston, Virginia.)

findings indicating elevated sodium and chloride levels in sweat, and genetic testing for *CFTR* gene mutations. Chest radiography aids in the diagnosis of cystic fibrosis. Radiographs taken over a period of years demonstrate gradually worsening structural abnormalities. Early changes of bronchial thickening and hyperinflation (Fig. 3.27) progress to extensive bronchiectasis, cyst formation, lobar atelectasis, scarring, pulmonary artery and right ventricular enlargement, and overinflation of the lung and chest wall. Conventional sinus radiography and CT studies of the paranasal sinuses demonstrate persistent opacification of the paranasal sinuses.

The prognosis associated with cystic fibrosis is determined by the degree of pulmonary involvement and varies greatly. However, respiratory failure resulting from deterioration of the lungs is inevitable and eventually leads to death, even for patients who survive well into their 40s. Treatment methods include antimicrobial drugs to combat infection, bronchodilators administered through inhalers, respiratory physical therapy, and, in some cases, a lung transplant may be performed in patients with end-stage lung disease. Although *CFTR* modulator therapy is available, symptomatic therapy

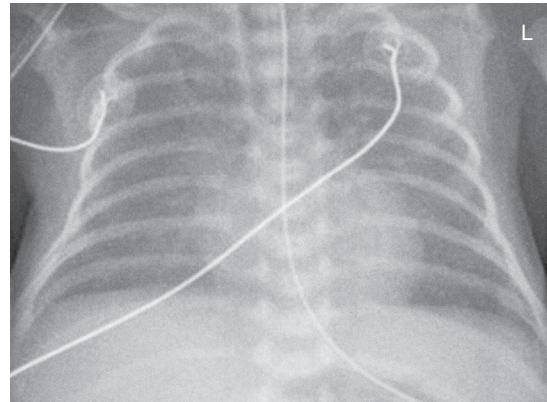
continues to play a key role in the treatment of cystic fibrosis patients.

s0085 **Respiratory Distress Syndrome**

p0265 Also known as hyaline membrane disease, **respiratory distress syndrome (RDS)** is a disorder affecting premature infants or those born at less than a 37-week gestation resulting from insufficient production of surfactant (an agent that lowers surface tension). Incomplete maturation of the type II alveolar cells within the surfactant-producing system causes unstable alveoli, the structures in which gas exchanges occur in the lungs. Infants are particularly in need of a low surface tension in the alveoli, and surfactant provides this. Its deficiency results in alveolar collapse with widespread adhesive atelectasis. RDS occurs more frequently in premature White, male infants. It also occurs in premature infants of mothers with diabetes mellitus because insulin may inhibit the production of surfactant. When an increased risk is apparent before birth, corticosteroid drugs may be administered before delivery.

p0270 The signs of RDS include rapid and labored breathing within the first 24 hours after delivery with the atelectasis and respiratory failure progressively worsening. Because of the rigid lung structure, resistance develops in the pulmonary circulatory system. This may result in the development of patent ductus arteriosus, a medical condition where the temporary blood vessel of the ductus arteriosus fails to close after birth, allowing blood to be shunted between the ventricles of the heart. In severe cases, respiratory and metabolic acidosis may develop because blood passing through the lungs is not adequately oxygenated and its CO_2 is inadequately eliminated.

p0275 Chest radiography demonstrates severe atelectasis with an air-bronchogram sign, characterized by bronchi surrounded by nonaerated alveoli (Fig. 3.28). This is a life-threatening condition, but if the infant's ventilation is adequately supported, surfactant production should begin within a few days. Continuous positive airway pressure (CPAP) is the first line of therapy for infants with RDS. Other treatment consists of maintenance of a proper thermal environment and satisfactory levels of tissue oxygenation, which is monitored frequently via ABG measurements. In some instances, pulmonary surfactant may be introduced intratracheally to reduce the severity of the disease. Once the surfactant is present, RDS will resolve in 4 or 5 days.



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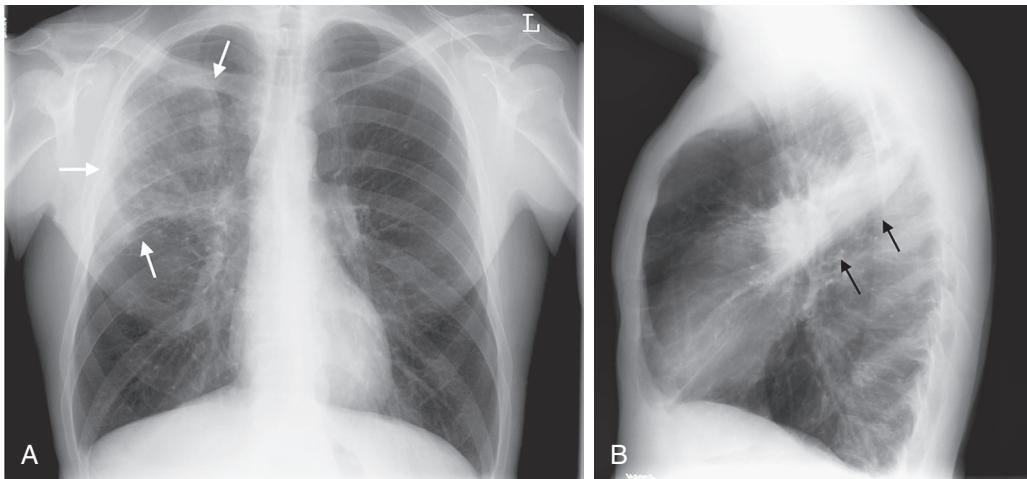
Fig. 3.28 Respiratory distress syndrome in a preterm infant. Note the "ground-glass" appearance of the lungs, especially in the right perihilar area. (From The Ohio State University Wexner Medical Center, Columbus, Ohio.)

INFLAMMATORY DISEASES

Pneumonias

Pneumonia is the acute inflammation of lung parenchyma and is the most frequent type of lung infection, resulting in an inflammation of the lung (pneumonitis) and compromised pulmonary function. According to the CDC, pneumonia is the leading cause of hospitalization among adults and children in the United States and is the most common lethal nosocomial infection. The main causes of pneumoniae are bacteria, viruses, and mycoplasmas. In adults, bacteria such as *Streptococcus pneumoniae* (*Pneumococcus*), *Staphylococcus aureus*, *Haemophilus influenzae*, and *Legionella pneumophila* are the most common causes of typical pneumonia. *Chlamydia pneumoniae* and *Mycoplasma pneumoniae* are common causes of atypical pneumonias in adolescents and young adults. Atypical pneumonias present less obvious radiographic signs compared with typical bacterial pneumonias. Viral pathogens such as the influenza virus, SARS-CoV-2 (COVID-19), parainfluenza virus, adenovirus, and respiratory syncytial virus (RSV) may cause pneumonias. In addition, fungal pneumonias may result from *Pneumocystis carinii*, especially in patients with compromised immune systems.

Pneumonitis may affect the entire lobe of a lung (lobar pneumonia), a segment of a lung (segmental pneumonia), the bronchi and associated alveoli (bronchopneumonia), or interstitial lung tissue (interstitial pneumonia). Conventional chest radiography is



f0150

Fig. 3.29 Posteroanterior (A) and lateral (B) chest radiographs demonstrating pneumococcal pneumonia infiltrates in the upper lobe of the right lung (arrows). Note that the lateral projection clearly demonstrates the segment of the lobe affected, and the posteroanterior projection shows a faint outline of the air-filled bronchi. (From The Ohio State University Wexner Medical Center, Columbus, Ohio.)

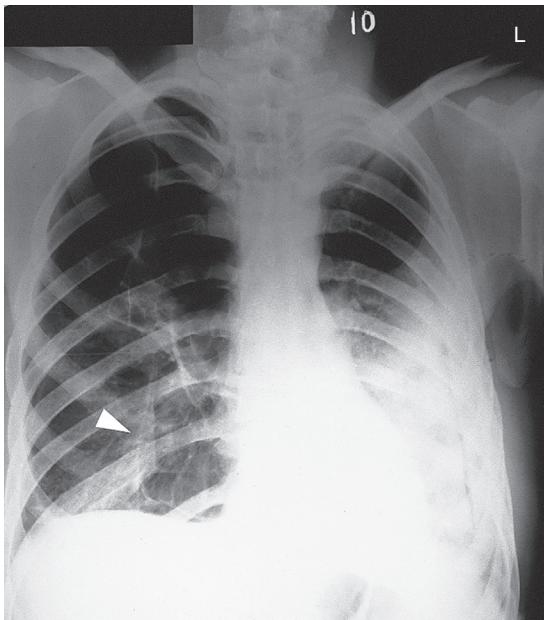
important in determining the location of the inflammation, with the pneumonias appearing as soft, patchy, ill-defined alveolar infiltrates or pulmonary densities. Alveolar infiltration results when the alveolar air spaces are filled with fluid or cells. Symptoms associated with pneumonia include a cough, fever, and purulent sputum production, usually developing over days. Patients with pneumonia often exhibit tachypnea, a decrease in oxygen saturation, and during physical evaluation crackles may be heard in conjunction with bronchial breath sounds.

Pneumococcal (lobar) pneumonia is the most common bacterial pneumonia caused by *Streptococcus pneumoniae*. This type of bacteria is often present in healthy throats, and the pneumonia is generally preceded by an upper respiratory infection. When the body defenses are weakened, the bacteria multiply, work their way into the lungs, and inflame the alveoli. This disease is usually accompanied by chills, cough, and fever. Pneumococcal pneumonia generally affects the alveoli of an entire lobe of a lung, without affecting the bronchi themselves (Fig. 3.29). Chest radiography demonstrates collection of fluid in one or more lobes (consolidation), with the lateral view serving to identify the degree of segmental involvement. Air-filled bronchi are made visible due to the surrounding fluid-filled alveoli resulting in a radiographic sign termed air-bronchogram. Pleural fluid may often be seen in lateral decubitus projections of the chest.

Antibiotics—based on Gram stain laboratory results, patient age, and epidemiology—and bed rest are the treatment for pneumococcal pneumonia, which usually resolves in approximately 1 week. Thirty percent of all *Streptococcus pneumoniae* strains are resistant to antibiotics. Immunization with the polysaccharide pneumococcal vaccine is recommended in children under 2 years of age and in older adults, especially residents of nursing homes and extended care facilities.

Staphylococcal pneumonia is the most common hospital-acquired pneumonia and can also occur during epidemics of influenza when secondary infection with staphylococci is common. Patients present with a productive cough, dyspnea, fever, and pleuritic pain. Staphylococcal pneumonia is severe and may be fatal, especially in infants. A pneumatocele (a thin-walled, air-containing cyst) is the characteristic radiographic lesion and is more typically seen in children. These may enlarge and form abscesses in the later stages of the disease. Another characteristic sign is the spread of patchy consolidation localized in and around the bronchi (Fig. 3.30). Drug therapy with antibiotic agents is the treatment of choice.

Legionella pneumonia is a severe bacterial pneumonia caused by *Legionella pneumophila* that is spread through inhaling the bacteria from water or soil. According to the Centers for Disease Control and Prevention (CDC), approximately 8000 to 18,000 people in

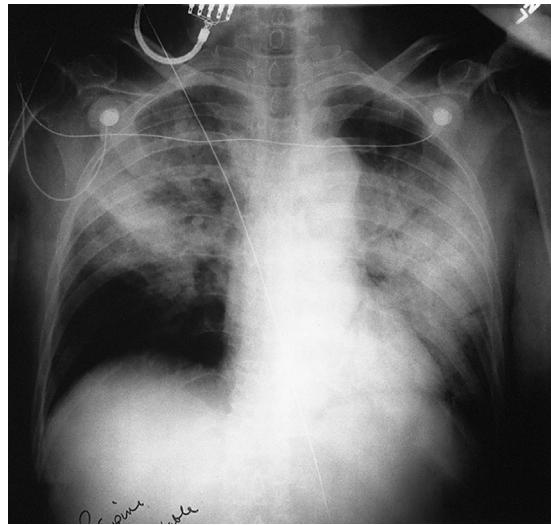


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Fig. 3.30 Staphylococcal pneumonia in a 20-year-old male, indicated by multiple large pneumatoceles in the right lung and consolidation of the left lower lobe of the lung (arrow). An empyema in the lower left lung was later drained surgically. (From American College of Radiology, Reston, Virginia.)

the United States are hospitalized and treated annually and about one in 10 people who get the disease will die from the infection. However, most people make a full recovery. Clinically, patients complain of malaise, muscular aches, chest pain with a nonproductive cough, and occasional vomiting and diarrhea. In human-made water systems, the *Legionella* can grow and outbreaks of this disease occur in large buildings such as hotels and hospitals, most frequently in late summer to early fall. *Legionella* pneumonia most commonly affects middle-aged males. Risk factors include smoking, alcohol abuse, and immunosuppression from corticosteroids. Its radiographic appearance is like that of other bacterial pneumonias, with patchy infiltrates throughout the lungs (Fig. 3.31). Diagnosis is made by culturing the *L. pneumophila* organism from sputum or bronchoscopy brushings and performing urinary antigen assays. Chest radiography will show pleural effusion. Treatment consists primarily of antibiotic administration (erythromycin or azithromycin) and oxygen therapy.

Mycoplasma pneumonia is a type of community-acquired atypical bacterial pneumonia. *Mycoplasma* pneumonia is most common among pediatric and



f0160

Fig. 3.31 *Legionella* pneumonia in a 55-year-old female, showing rounded opacities in the upper half of the right lung and lower two-thirds of the left lung. (From American College of Radiology, Reston, Virginia.)

adolescent patients. Spread of this pneumonia occurs by airborne droplets in close contact. Radiographically, this disease appears as a fine, reticular pattern in a segmental distribution, followed by patchy areas of air space consolidation. In severe cases, the radiographic appearance may mimic TB. *Mycoplasma* pneumonia is resistant to penicillin; however most cases are self-limiting and don't require treatment.

Aspiration pneumonia occurs when something other than air is inhaled (aspirated) into the respiratory tract. It may follow anesthesia, alcoholic intoxication, or stroke that causes dysphasia or a loss of the cough reflex. Chest radiography reveals edema produced by irritation of air passages (Fig. 3.32), appearing as densities radiating from one or both hila into the dependent segments. The treatment of aspiration pneumonia is strictly supportive and includes correction of hypoxia, control of secretions, and replacement of fluids. Further infection is treated by antimicrobial drugs based on laboratory results.

Viral pneumonia is caused by various viruses, most commonly influenza virus, rhinovirus, and adenovirus. Severe acute respiratory syndrome (SARS), RSV, and COVID-19 are also contributing causes. Viral pneumonia is common among patients younger than 5 years and older than 50 years. This disease is spread by an infected patient shedding the virus, which is transmitted to a

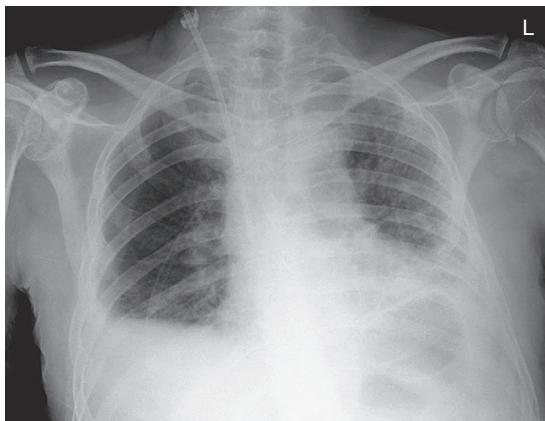


Fig. 3.32 Aspiration pneumonia caused by aspiration of gastric contents. (From The Ohio State University Wexner Medical Center, Columbus, Ohio.)

nonimmune individual. Most cases of viral pneumonia are mild, and radiographic findings are often minimal. The diagnosis of this disease is based on clinical findings, serologic tests, and polymerase chain reaction (PCR)-based tests, and often requires exclusion of bacterial agents first. Symptoms include a dry, nonproductive cough, fever, shortness of breath, and dyspnea. Loss of smell (*anosmia*) and loss of taste (*ageusia*) in the presence of the other symptoms is a red flag for COVID-19 pneumonia. Complications include secondary bacterial infections, termed superinfections, which result from a lowered resistance brought on by the inflammatory response to the virus. Patients with COVID-19 pneumonia can have varying degrees of involvement with as little as 10% of the lung involved, to complete “white lung” appearance on CT indicative of acute respiratory distress syndrome (ARDS) and would require ventilatory support. The most common imaging findings of patients with viral pneumonia include peribronchial thickening and interstitial infiltrates. In severe cases of COVID-19 pneumonia (Fig. 3.33), chest radiography and CT will demonstrate atypical pneumonia with a ground-glass opacity with preserved bronchial and vascular markings, indicating interstitial involvement. Treatment for viral pneumonias is mainly supportive as antiviral medication is only effective in select cases.

s0100 **Bronchiectasis**

p0320 **Bronchiectasis** is an irreversible, abnormal dilation of one or more large bronchi as a result of destruction of the elastic and muscular components of the bronchial

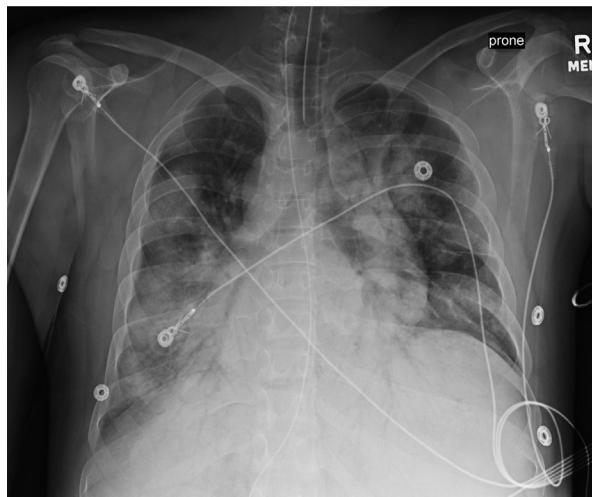


Fig. 3.33 Anteroposterior chest radiograph demonstrating pneumonia associated with COVID-19. (From The Ohio State University Wexner Medical Center, Columbus, Ohio.)

wall. The basic pathogenesis is either congenital or an acquired weakness, typically following inflammation of the bronchial walls, because of a viral or bacterial infection. In the early stage of the disease, the most common symptom is a chronic cough; however, some patients may initially remain asymptomatic. As the bronchiectasis progresses, the cough becomes more productive because the weakened wall allows the bronchus to become dilated, forming a sac-like structure that harbors the pathogenic organism. As the infection grows, the bronchial wall is destroyed, resulting in an abscess. Nonreversible bronchiectasis results in saccular and varicose dilations and constrictions that permanently alter the bronchial tree (Fig. 3.34). Patients may also complain of pleuritic pain, as well as demonstrate recurrent fevers, wheezing, and shortness of breath during the physical examination.

Conventional chest radiography generally demonstrates increased bronchovascular markings and parallel lines outlining the dilated bronchi (“tram lines”) owing to peribronchial fibrosis and inflammation and intrabronchial secretions (Fig. 3.35). High-resolution CT (HRCT) remains the modality of choice to visualize bronchiectasis. HRCT, with or without contrast enhancement, clearly demonstrates dilated airways (those with a luminal diameter more than one and a half times that of the adjacent vessel in cross-section), extension of the bronchi as a result of the destruction

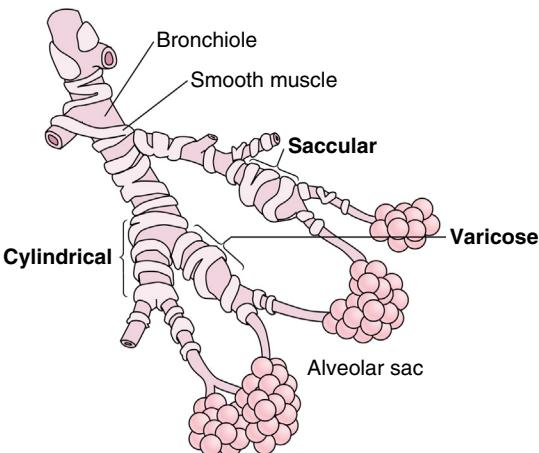


Fig. 3.34 Types of bronchiectasis. (From The Ohio State University Wexner Medical Center, Columbus, Ohio.)

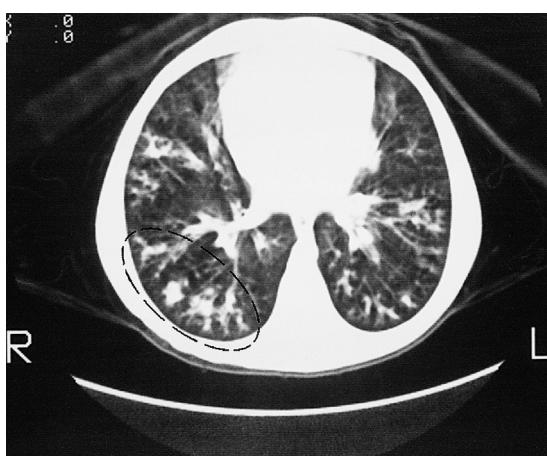


Fig. 3.35 Bronchiectatic changes are seen peripherally on this CT scan of the lungs from a 9-year-old patient with cystic fibrosis. (From American College of Radiology, Reston, Virginia.)

of lung parenchyma, thickening of bronchial walls, and obstruction of airways either by a mucous plug or by air trapping (Fig. 3.36).

s0105 **Tuberculosis**

Tuberculosis (TB) is an infection caused by inhalation of *Mycobacterium tuberculosis*. Although *M. tuberculosis* primarily affects the lungs where it is a major source of spread of the disease, tuberculosis may also be present in other body systems including the genitourinary system, the skeletal system, and the CNS. Most early cases of tuberculosis are asymptomatic; however, patients

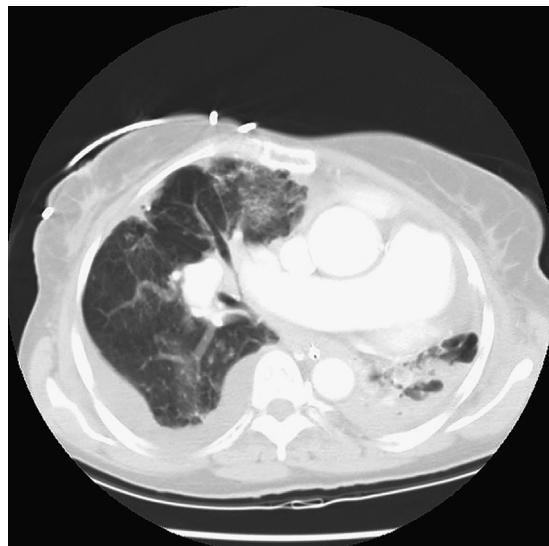
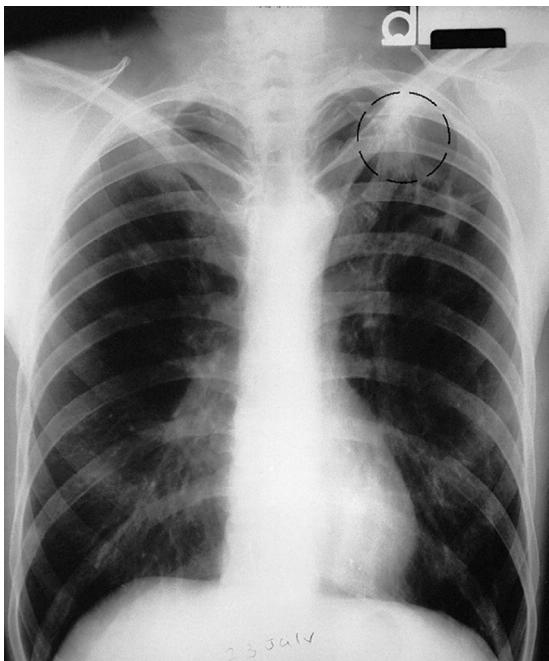


Fig. 3.36 High-resolution CT scan demonstrating bilateral lung bronchiectasis with associated left lung pneumatoceles. (From The Ohio State University Wexner Medical Center, Columbus, Ohio.)

may present with a chronic dry cough. In symptomatic patients, more severe symptoms are present such as malaise, fever, weight loss, and blood-tinged sputum. Worldwide, tuberculosis is the 13th leading cause of death and the second leading cause of infectious death after COVID-19. Risk factors for tuberculosis include diabetes mellitus, immunocompromised (HIV/AIDS), malnutrition, and tobacco use.

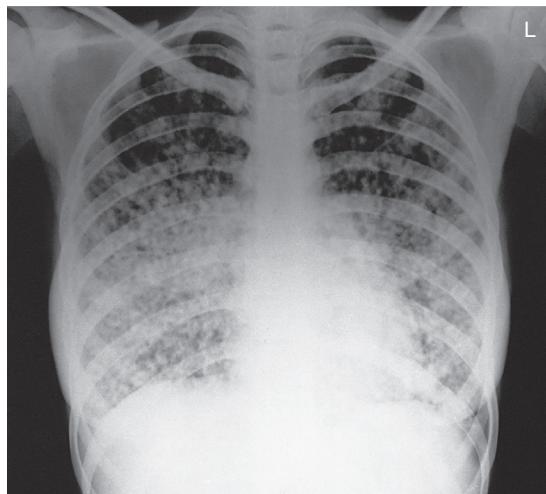
During the infectious process, *M. tuberculosis* organisms are captured by macrophages within the alveoli but are not killed. This creates a cell-mediated immune response, which results in granulomatous lesions that infiltrate the tracheobronchial lymph nodes. These caseating lesions eventually result in necrosis, fibrous scarring, and calcifications, which are visible on chest radiographs, and are known as Ghon lesions. Lesions are mostly seen in the apical region of the chest (Fig. 3.37); therefore, the apical lordotic projection of the chest is useful in the evaluation of TB. Necrosis is a prominent feature of the disease because its infiltration affects the lung parenchyma. This infiltration may expand and result in the formation of a cavity (cavitation) (Fig. 3.38). If these cavities spread to communicate with the bronchus, the bacteria spread throughout the lung. Infection spreads to the lobar or segmental bronchus, causing persistent pneumonia that can be resistant

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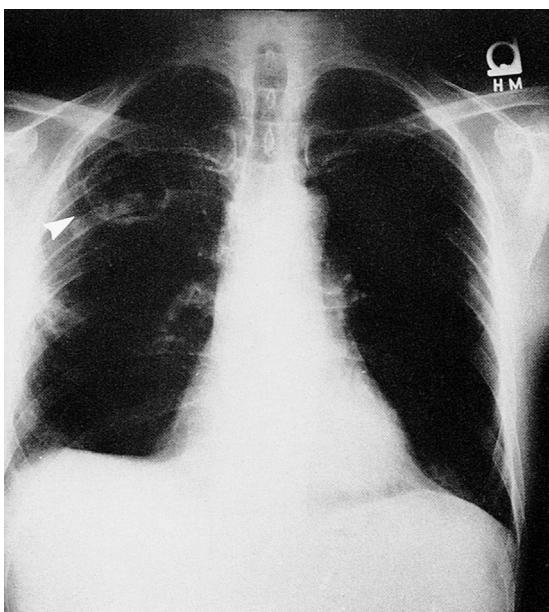
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Fig. 3.37 Tuberculosis of left upper lobe in a 49-year-old male admitted with esophagitis and dull pain in the left subclavicular region. (From The Ohio State University Wexner Medical Center, Columbus, Ohio; American College of Radiology, Reston, Virginia.)



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Fig. 3.39 Miliary tuberculosis (TB) resulting from hematogenous spread of TB, demonstrating small, distinct nodules throughout the lung fields. (From American College of Radiology, Reston, Virginia.)



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Fig. 3.38 Cavitation in the right lung resulting from expansion of tubercular lesion (arrowhead). (From Riverside Methodist Hospital, Columbus, Ohio.)

to antibiotic therapy. In these patients, miliary tuberculosis may form. **Miliary tuberculosis** is an uncontrolled infection of tuberculosis where lesions appear in the lung and extrapulmonary systems. Miliary refers to its characteristic resemblance to millet seeds, which are small, white grains (Fig. 3.39). Initially, the disseminated miliary pattern may not be radiographically identifiable, but when disseminated TB is suspected, chest radiography should be repeated in a few days to better visualize the millet-sized tubercles.

In addition to conventional chest imaging, sputum cultures provide a positive diagnosis. CT images of the chest can also be utilized to visualize disease involvement and progression. The tuberculin skin test (TST) is used to detect and screen asymptomatic infected individuals. Treatment of tuberculosis includes long-term antibiotic therapy, good hygiene, mask wearing, and isolation to further prevent the spread of the disease. In extreme cases where the disease shows drug resistance, surgical resection of a persistent TB infection may be performed to eliminate the bacteria.

Lung Abscess

A **lung abscess** is a localized area of dead (necrotic) lung tissue surrounded by inflammatory debris. These abscesses may result from periodontal disease, pneumonia, neoplasms, or other organisms that invade the lungs. A lung abscess is more common in the right lung

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because of the vertical orientation of the right main bronchus. When the abscess reaches the bronchus, it drains into the bronchus, forming a cavity (cavitation) that is visible on a chest radiograph. Clinical manifestations of a lung abscess include fever, cough, expectoration of pus, and foul sputum. Radiographically, an abscess generally appears as a lobar or segmental consolidation that becomes globular in shape as pus accumulates, or it may appear as a round, thick-walled capsule containing air and fluid. CT may be used to provide better anatomic information or to detect cavity formations. **Empyemas** consist of an accumulation of pus in the pleural cavity, usually caused by some primary bacterial lung infection. They may be caused by the invasion of a lung abscess that results in a bronchopleural fistula.

p0350 Treatment of an abscess and empyema centers on treating the primary condition causing it, including antibiotic therapy, chest physical therapy, postural drainage, and possible drainage of fluids via bronchoscopy. If the abscess is resistant to antibiotics, surgical resection of the abscess may be necessary, and in cases of multiple drug-resistant abscesses, the entire lobe may be surgically removed.

s0115 DIFFUSE LUNG DISEASES

s0120 Chronic Obstructive Pulmonary Disease

p0355 **Chronic obstructive pulmonary disease (COPD)** refers to a group of common pulmonary diseases characterized by persistent respiratory symptoms and chronic airway obstruction. The most common forms are chronic bronchitis and emphysema, which frequently coexist and may be associated with varying degrees of asthma and bronchiectasis—two other causes of airway obstruction.

p0360 Because it may be difficult to determine whether the pulmonary obstruction is caused by chronic obstructive bronchitis, emphysema, or a combination of the two diseases, the designation COPD is commonly used. This disease is irreversible and results in limited airflow and, in the case of emphysema, decreased elastic recoil of the alveoli. Statistics show that the mortality rate of COPD has dramatically increased over the past 20 years, and it is ranked as the fourth most common cause of morbidity and mortality globally. In addition, the number of patients diagnosed with COPD in the United States continues to increase each year—currently there are 16 million Americans suffering with this disease. The predominant risk factor associated with COPD is cigarette

smoking. Air pollution, airborne chemical fumes, and inhalation of hazardous dust such as silica may also increase the risk of COPD but are minimal compared with the effects of cigarette smoke.

Chronic obstructive bronchitis most often arises p0365 from long-term, heavy cigarette smoking or prolonged exposure to high levels of industrial air pollution. Cigarette smoke and industrial air pollutants irritate the mucous lining of the bronchial tree and increase the susceptibility to both bacterial and viral infections. Chronic exposure to these respiratory irritants leads to hyperplasia of the mucous glands, hypertrophy of the smooth muscle, and thickening of the bronchial wall.

Persistent cough and expectoration (expulsion of mucus or phlegm from the throat) are the primary p0370 symptoms of chronic bronchitis. The effects of the disease develop slowly and progressively over months and years, gradually resulting in bronchial obstruction from excess secretion of mucus. Eventually, the lungs remain in a chronically inflated state because more air is inhaled than is exhaled. Additional signs and symptoms of chronic bronchitis include wheezing, shortness of breath, and arterial hypoxemia leading to right-sided heart hypertrophy and failure (cor pulmonale). No dependable radiographic criteria exist for a definitive diagnosis of chronic bronchitis.

Chest radiography may demonstrate hyperinflation p0375 of the lungs. Elimination of the causative agent (e.g., cigarettes) is an important first step in treatment. Pulmonary rehabilitation, including breathing exercises and physical conditioning, helps manage the disease. Antibiotics may reduce the presence of infection; adrenergic and anticholinergic bronchodilators are used to reduce bronchospasm; and oxygen therapy may be prescribed for patients with severe hypoxemia.

Emphysema is a condition in which the lung's alveoli become distended, usually from loss of elasticity or interference with expiration. It is characterized by an increase in the air spaces distal to the terminal bronchioles, with destruction of the alveolar walls. p0380

The primary symptom of emphysema is dyspnea, p0385 which at first occurs only during exertion but eventually even at rest. In the early stages of emphysema, chest radiography may show normal results. However, as the disease progresses, hyperinflation results (Fig. 3.40), and the AP diameter of the chest increases because of increased air in the lungs. Emphysema appears radiographically as a depressed or flattened diaphragm,



Fig. 3.40 Posteroanterior chest radiograph demonstrating hyperinflation and blunting of costophrenic angles caused by emphysema. (From The Ohio State University Wexner Medical Center, Columbus, Ohio.)

abnormally radiolucent lungs, and an increased retrosternal air space (barrel-shaped chest). Conventional chest radiography helps differentiate emphysema from other lung disorders such as TB or lung cancer, which may have similar symptoms. Conventional chest radiography may demonstrate large focal regions (>1 cm in diameter), termed bullae, prominent hilar markings, or blisters filled with air (Fig. 3.41), but smaller lesions are best demonstrated by CT examinations of the chest. HRCT using thin section cuts (1 to 2 mm) clearly demonstrates areas of hypovascularity and bullae associated with emphysema (Fig. 3.42).

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Treatment for emphysema is much like that for chronic obstructive bronchitis. The goals are to alleviate the symptoms, treat any reversible elements (e.g., infection), and prevent further progression of the disease, if possible.

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Because these two forms of COPD represent chronic deterioration of the pulmonary system, the continued problems eventually lead to heart failure. The heart begins to wear out over time in its effort to increase blood flow to compensate for the decreased airflow caused by COPD. This may result in death from

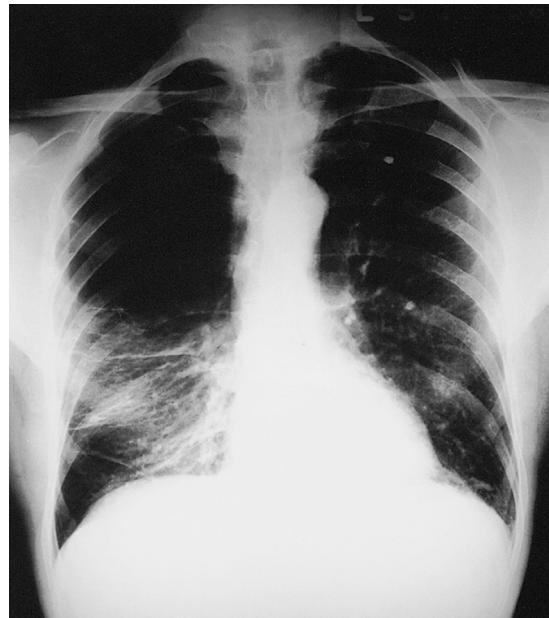


Fig. 3.41 Pulmonary emphysema with a giant emphysematous bleb occupying the upper half of the right lung. (From The Ohio State University Wexner Medical Center, Columbus, Ohio; American College of Radiology, Reston, Virginia.)

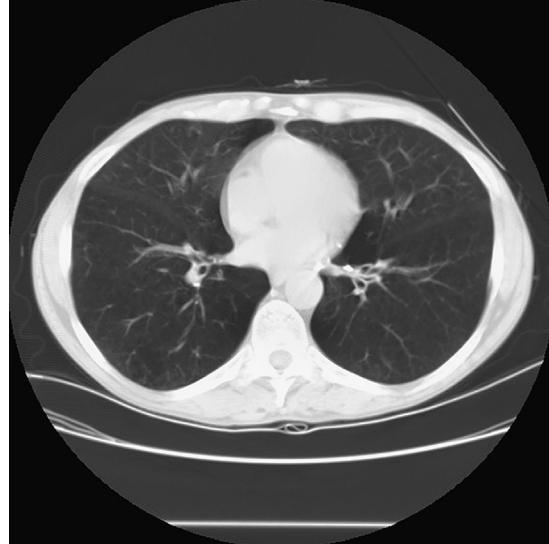


Fig. 3.42 High-resolution CT of the chest demonstrating parenchymal changes associated with emphysema. (From The Ohio State University Wexner Medical Center, Columbus, Ohio.)

associated complications such as respiratory failure, pneumonia, cardiac arrhythmias, or PE. However, some patients may live for many years with COPD and will

eventually develop pulmonary edema and cor pulmonale. Both these conditions are discussed in [Chapter 4](#).

Asthma is a chronic inflammation of the bronchial system resulting in airway obstruction and bronchial hyperresponsiveness. Asthma occurs at any age, but most commonly before the age of 40 years. In the United States asthma attacks are most common in children, females, and multi-race persons. The incidence of asthma has increased over the past 20 years, and it is estimated that over 24 million patients in the United States have this pathologic condition. Genetics play a major role in the development of asthma. Additional risk factors include exposure to allergens, air pollution, cigarette smoke, and recurrent viral respiratory infections. The signs and symptoms of asthma include intermittent attacks of coughing, wheezing, dyspnea, and chest tightness caused by airflow obstruction. Radiography plays a limited role in the diagnosis of asthma. Diagnosis is made through the assessment of arterial blood gas (ABG) tests and expiratory flow rates. Management of asthma most frequently includes the use of inhaled bronchodilators and oral corticosteroids, and the administration of oxygen.

s0125 **Pneumoconioses**

Pneumoconioses are a broad group of lung diseases that result in pulmonary fibrosis from inhalation of foreign inorganic dust, most commonly from a work environment. The effects of an inhaled foreign material depend on its physical and chemical properties, the dose of the agent, and the site of deposition within the bronchial tree. The size of the dust particle inhaled is of particular importance. Most occupationally generated dusts and those occurring naturally are too large to cause pneumoconiosis. Dusts greater than $10\text{ }\mu\text{m}$ are filtered out in the nasal passages or the mucous lining of the tracheobronchial tree; those smaller than $1\text{ }\mu\text{m}$ generally remain suspended in the air and are exhaled. Those most likely to be trapped are 1 to $5\text{ }\mu\text{m}$. In addition to the size criterion, exposure to a substance capable of causing disease for a sufficient duration (dose) and the susceptibility of the host are factors required to cause pneumoconiosis. Mineral dusts responsible for pneumoconiosis generally include silica, coal, asbestos, and beryllium.

Radiography assists in the detection and follow-up of this disease group. Lesions produced by the different pneumoconioses vary but may include nodules, cavitation, and pleural thickening. The three primary types of

pneumoconioses are (1) silicosis, (2) anthracosis, and (3) asbestosis. Treatment is focused on preventing infection, relieving any respiratory symptoms, and maintaining adequate oxygenation.

Silicosis, the oldest known pneumoconiosis, results from inhaling silica (quartz) dust and is common among miners, grinders, and sandblasters. It is the most widespread and most serious type of pneumoconiosis. This disease occurs following 10 to 30 years of exposure to silica dust. Phagocytes located within the bronchioles carry silica dust into the septa of the alveoli. In response to the foreign dust particles, the alveoli form large amounts of fibrous connective tissue, thus destroying normal lung tissue. This disease is clearly visible on conventional chest radiographs as multiple small, rounded, opaque nodules throughout the lungs, resulting from the creation of the fibrous tissue. Except for lung transplantation, no treatment exists for silicosis. Therefore, prevention through the use of protective masks and adequate ventilation is the key to controlling this occupational disease.

Anthracosis (coal workers' pneumoconiosis) results from inhalation of coal dust ([Fig. 3.43](#)) over an extended period of about 20 years. As coal dust is deposited in the

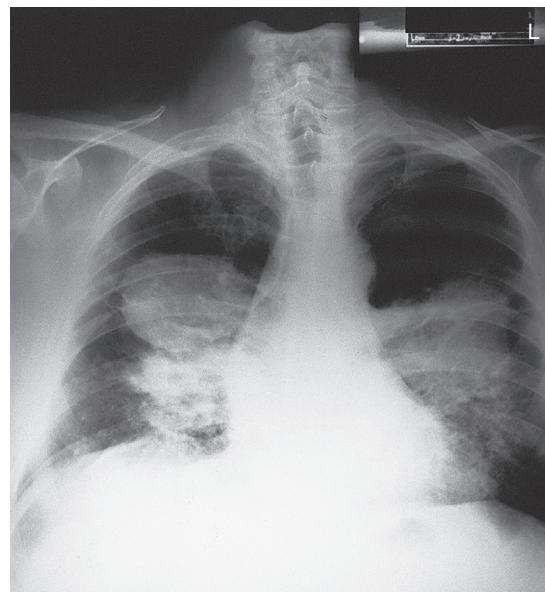


Fig. 3.43 Chest radiograph demonstrating large perihilar nodules. Thoracotomy revealed heavy anthracotic pigmentation, with the two largest nodules containing black fluid, consistent with anthracosis. (From American College of Radiology, Reston, Virginia.)

lungs, “coal macules” develop around the bronchioles and cause their dilation. This dilation does not affect the alveoli or the airflow; thus, impairment of the function of the lungs and the lung architecture is limited. Other than suppressing coal dust in the work environment to prevent anthracosis, no real treatment for anthracosis exists, and usually efforts to treat this condition are futile.

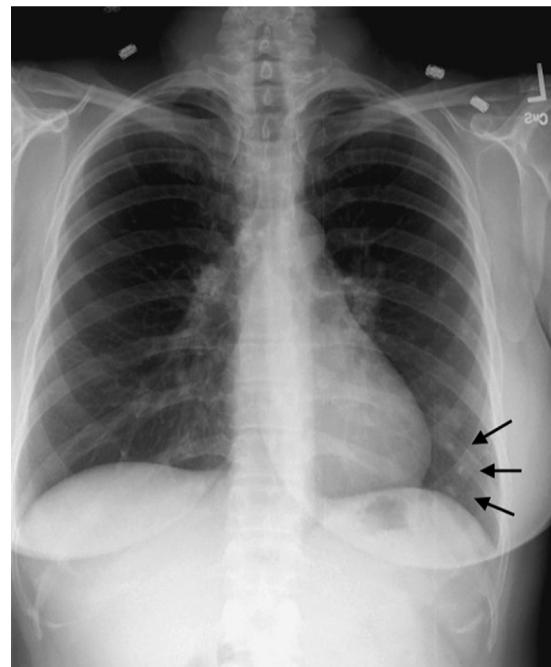
p0425 Asbestosis results from the inhalation of asbestos dust, which causes chronic injury to the lungs. Asbestos dust is found in building materials and insulation. Radiographically, diffuse, small irregular or linear opacities may be demonstrated in the lower lungs, and diaphragmatic pleural calcifications suggest asbestosis. Pleural changes in asbestosis are considered far more striking than parenchymal changes. Pleural thickening may also be present. This disease may be prevented by effectively suppressing asbestos dust in the air of the work environment. Because of a heightened awareness of asbestosis, advances in industry, and the use of occupational face mask ventilators, the incidence of asbestosis has decreased, and further advances are likely to eliminate it in the United States. A cumulative, extended exposure to asbestos dust has been shown to increase the risk of mesothelioma, a rare malignant neoplasm of the pleura. This neoplasm develops at least 15 years after high exposure to asbestos.

s0130 INFECTIOUS DISEASES

s0135 Endemic Mycoses of North America

p0430 Endemic mycoses (fungal infections) are caused by a group of fungi that occur in particular geographic locations. Most infections are asymptomatic; however they present as more severe opportunistic infections in immunocompromised individuals such as those with HIV/AIDS, diabetes mellitus, bronchiectasis, emphysema, TB, lymphoma, or leukemia.

p0435 **Histoplasmosis** is a systemic fungal infection caused by a dimorphic fungus, *Histoplasma capsulatum*, which thrives in soil, especially soil that is fueled by bird or bat excreta. The infectious agent, which is particularly endemic to the Ohio, Missouri, and Mississippi River valleys, enters the body through the respiratory system. Most cases are classified as acute primary histoplasmosis and are so mild that they may go undiagnosed. Symptoms of acute primary histoplasmosis are nonspecific and include fever, cough, and general malaise. However,



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Fig. 3.44 Posteroanterior chest radiograph demonstrating old histoplasmosis with calcified nodes in left lower lobe (arrows). (From The Ohio State University Wexner Medical Center, Columbus, Ohio.)

if the immune system is not effective at controlling and overcoming the fungal infection, it may spread from the lungs to other parts of the body. This condition is termed **progressive disseminated histoplasmosis**. This is considered an opportunistic infection in HIV/AIDS, often leading to severe acute pneumonia. Disseminated histoplasmosis that leads to cavitary formations (chronic cavitary histoplasmosis) is more serious. The cavities resemble those in TB, often affecting the apical portion of the lungs. Dyspnea, cough, and fatigue may persist for months or even years. Diagnosis of histoplasmosis is made by histologic laboratory analysis. Chest radiography may eventually reveal small calcifications as a late manifestation of the disease, although these do not usually appear for 4 or 5 years (Fig. 3.44).

Less than 1% of those who acquire histoplasmosis require treatment because most forms of the acute primary histoplasmosis are self-limiting and may remain undiagnosed. Advanced cases such as chronic cavitary histoplasmosis may result in death. Antifungal therapy is used to treat progressive disseminated histoplasmosis when first diagnosed, and patients with AIDS often

receive intermittent doses of IV antifungal medications necessary for chronic suppression of the infectious agent.

p0445 Coccidioidomycosis is also a systemic fungal infection. It is caused by a dimorphic fungus, *Coccidioides immitis*, which thrives in semiarid soil, particularly in the southwestern United States and northern Mexico. Infective spores in the soil become airborne by winds, digging, or other disruptions. For this reason, agricultural and construction workers are particularly at risk. As with histoplasmosis, most primary coccidioidomycosis infections are mild, usually self-limiting, and may go unrecognized. The most common radiographic finding of primary coccidioidomycosis is a small area of pulmonary consolidation. Lesions may comprise of nodules of varying sizes that appear like malignant nodules and thus require biopsy or surgical excision. Because most cases are mild, treatment consists of bed rest. However, in a few cases, progressive coccidioidomycosis may develop weeks or months after the primary infection, especially in immunosuppressed patients. If disseminated coccidioidomycosis is not treated, it may lead to meningitis. The treatment for meningeal coccidioidomycosis must be continued for many months or years. Progressive coccidioidomycosis could be a deadly disease, as over 70% of patients infected with HIV who develop this disease die of disseminated coccidioidomycosis within 1 month of initial diagnosis.

s0140 Aspergillosis

p0450 Aspergillosis is a fungal infection caused by inhaling the mold *Aspergillus fumigatus*, which is commonly found in soil, dust, building materials, plants, food, and water. When healthy people breathe in the fungal spores it typically is not harmful, but for severely immunocompromised individuals, especially those who use corticosteroids, *Aspergillus* can infect the pulmonary cavities, sinuses, or external auditory canals and spread. Even in healthy individuals, research has found that lung infections caused by influenza can damage the lining of the lungs, allowing *Aspergillus* to invade. Lung infections can form a fungus ball (*aspergilloma*) that is encapsulated in fibrous tissue, which can easily be seen on a chest radiograph. CT imaging of the chest is a fast, noninvasive way to see early signs of the disease. A “halo sign” (a dense, well-delineated nodule) is often suggestive of infection with

aspergillosis, especially in patients who have a history of prolonged neutropenia (a condition of abnormally low levels of white blood cells) (Fig. 3.45).

Sinusitis

The communication with the nasal cavities that subjects the paranasal sinuses to infection and inflammation is called **sinusitis**. Sinusitis often follows acute viral infection of the respiratory tract, and the ethmoid sinuses tend to be the most affected because of their proximity to the nose. Common causes of acute sinusitis include streptococcal, pneumococcal, and staphylococcal bacteria, and *H. influenzae*. Exposure to extremes in humidity or temperature, poor oral hygiene, the presence of a deviated septum, or all these factors may exacerbate the condition. The symptoms of sinusitis include nasal discharge, headache, tenderness in the affected area, toothache, and general malaise.

Computed tomography (CT) is the modality of choice as it demonstrates the swollen mucous membrane and retained exudate caused by the infection. Although conventional upright sinus radiographs do demonstrate the increased density and possible air–fluid levels (Fig. 3.46) from both mucosal swelling and fluid accumulation, CT provides better definition of the extent and degree of the sinusitis (Fig. 3.47). Chronic sinusitis may cause nasal polyps.

Treatment of sinusitis typically involves a saline nasal spray, antibiotic therapy, and analgesics for pain relief. If indicated, a deviated septum that contributes to sinusitis can be corrected surgically.

DISEASES OF THE PLEURA

Pleurisy

Inflammation of the pleura is termed **pleurisy** (or *pleuritis*). Pleurisy presents as sharp focal pleuritic pain made worse with exercise, coughing, sneezing, and deep breathing. Pleurisy can be caused by a variety of different etiologies including respiratory diseases such as tuberculosis, or influenza, as well as other systemic diseases such as rheumatoid arthritis and inflammatory bowel disease. Conventional radiology of the chest as well as CT of the chest may show the underlying disease process that is causing the inflammation. Treatment includes pain-relieving medications and rest, as well as the diagnosis and treatment of any underlying condition.

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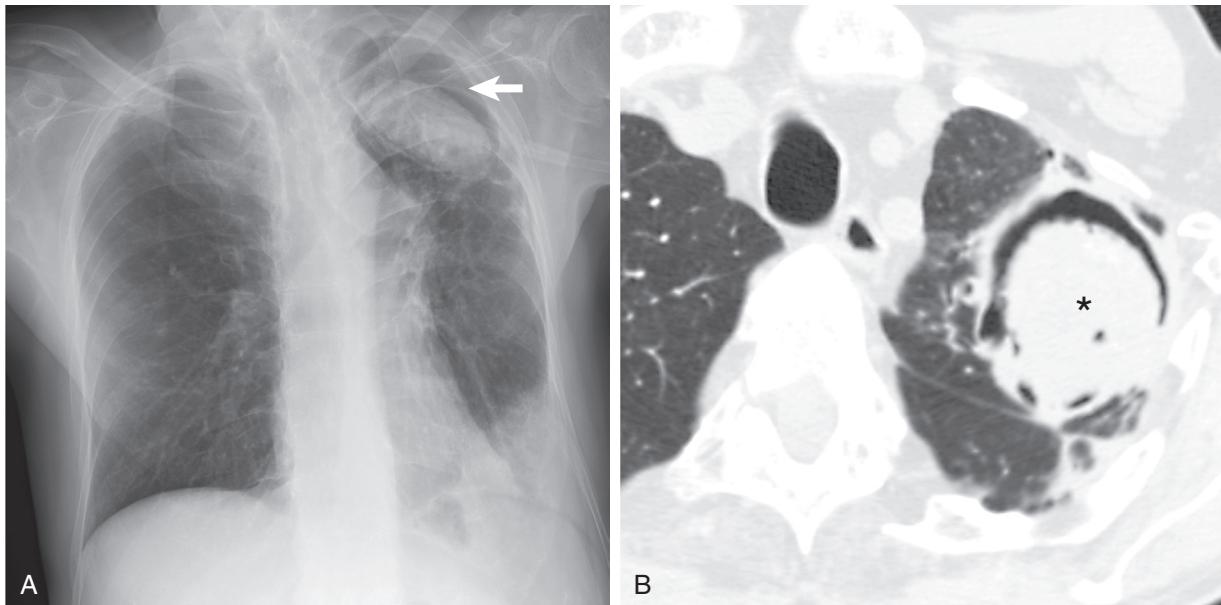
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Fig. 3.45 Aspergilloma in a left upper lobe cavity. (A) Frontal chest radiograph shows an air crescent (arrow) surrounding a dependent intracavitary left upper lobe mass. (B) Axial CT demonstrates a large cavity in the left upper lobe containing a homogeneous soft-tissue mass (asterisk). The mass lies in the dependent portion of the cavity, suggesting that it is mobile. The findings are characteristic of an intracavitary mycetoma. Note scarring and bronchiectasis in the left upper lobe and extensive pleural thickening adjacent to the cavity. (From Walker, C. M., & Chung, J. H. (2019). *Mueller's imaging of the chest* (2nd ed.). Elsevier.)

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Fig. 3.46 Air-fluid level present in the left maxillary sinus reflects sinusitis secondary to an oral-antral fistula in this 26-year-old female. (From American College of Radiology, Reston, Virginia.)

Pleural Effusion

Pleural effusion is a general term to describe the abnormal collection of fluid within the pleural space. Pleural effusion may be the result of many different types of underlying pathology and is a frequent manifestation of serious pulmonary or cardiac disease. It should be regarded not as a disease entity, but rather as a sign of an important underlying condition. Pleural effusion is most often caused by congestive heart failure, but may also be caused by inflammation, as in pleurisy, a PE, or a neoplasm. These pleural effusions are termed **exudates** (a mass of cells and fluid that has seeped out of blood vessels or an organ, especially in inflammation). Pleural effusions may also result from microvascular changes such as those associated with heart failure or ascites and are termed **transudates** (a filtrate of blood that accumulates in tissues outside the blood vessels and causes edema). A pleural effusion containing blood is called a **hemothorax** and most frequently follows trauma to the thorax or thoracic surgery.

Conventional chest radiography is commonly used in the diagnosis of pleural effusion. The radiographic

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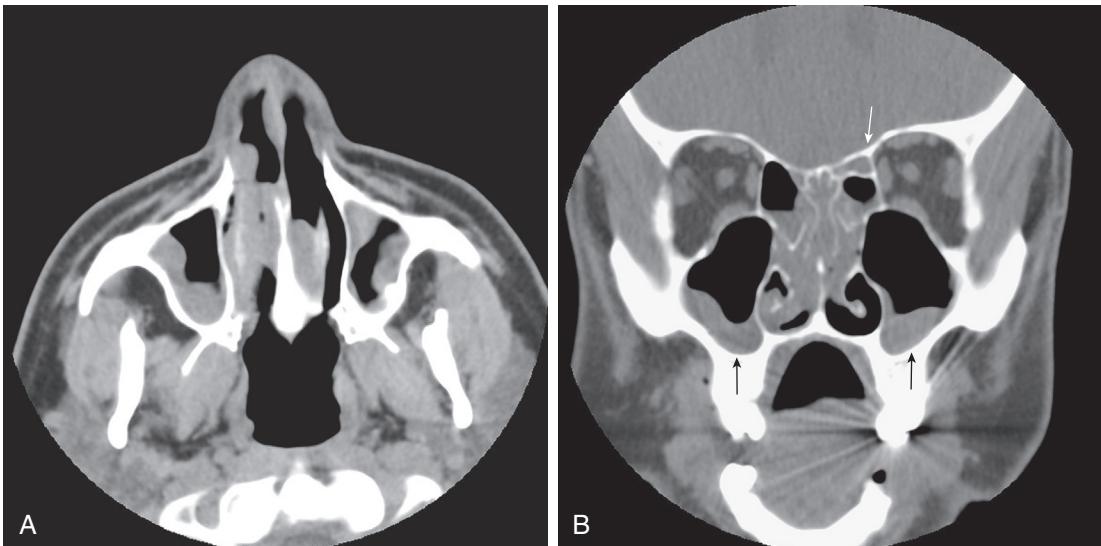


Fig. 3.47 (A) Axial and (B) coronal CT scans of paranasal sinuses, demonstrating bilateral mucosal thickening of the maxillary sinuses and opacification of the nasal cavity (arrows). (From The Ohio State University Wexner Medical Center, Columbus, Ohio.)

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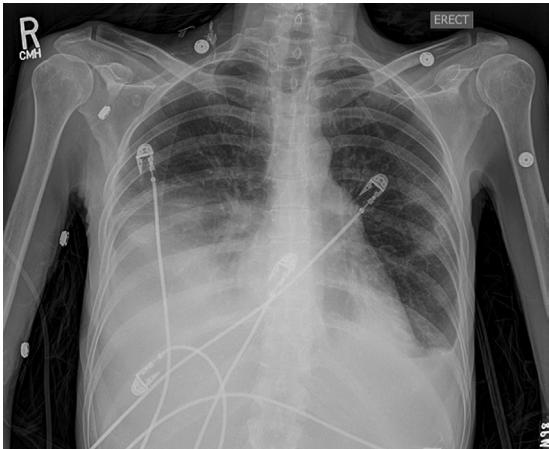


Fig. 3.48 Posteroanterior erect chest radiograph demonstrating bilateral pleural effusion with right lower lobe atelectasis. (From The Ohio State University Wexner Medical Center, Columbus, Ohio.)

signs of pleural effusion include a blunting of the costophrenic angles (Fig. 3.48), which is often best demonstrated on an erect lateral chest radiograph. The blunting occurs as a part of the healing process, and the fibrous changes in the lung tissue may remain even after the pleural effusion has resolved. Lateral decubitus chest radiographs are also valuable (Fig. 3.49) because they can better demonstrate smaller amounts (<100 mL) of

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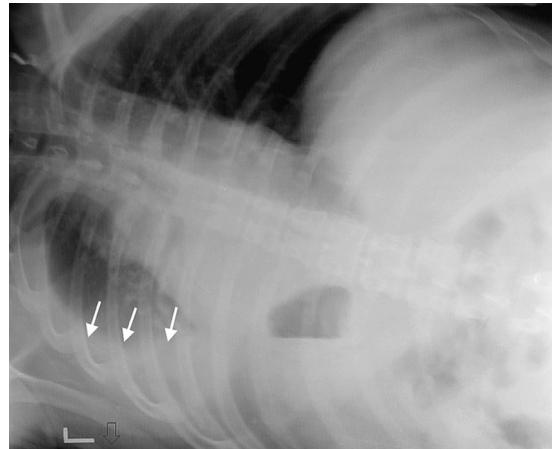


Fig. 3.49 Left lateral decubitus chest shows free pleural fluid layering out against the chest wall (arrows). (From The Ohio State University Wexner Medical Center, Columbus, Ohio.)

fluid in the pleural space compared with either erect PA radiographs or lateral chest radiographs. In severe cases, an entire lung may be opacified and the mediastinum may be shifted to the contralateral side of the chest. Because a pleural effusion is indicative of an underlying pathology, CT may be used to evaluate the lung parenchyma in search of a neoplasm, abscess, or pneumonia obscured by the effusion. Sonography allows for



Fig. 3.50 Sonogram demonstrating pleural effusion, which aids in performing a thoracentesis. (From The Ohio State University Wexner Medical Center, Columbus, Ohio.)

visualization of small amounts of fluid undetected on conventional chest radiographs (Fig. 3.50). Sonography is also useful in treatment through ultrasound-guided aspiration of the fluid contents; a procedure termed *thoracentesis*.

p0485 Treatment of a pleural effusion is to address the underlying pathological condition. Thoracentesis or other interventional techniques may be used to remove excess fluid to alleviate symptoms (such as shortness of breath) and for laboratory analysis, to confirm the presence and type of fluid present in the pleural cavity (Fig. 3.51). In the case of a large pleural effusion or hemothorax, a drain may be placed for continuous drainage of the fluid and to reduce symptoms.

s0165 NEOPLASTIC DISEASES

s0170 Bronchial Carcinoid Tumors

p0490 **Bronchial carcinoid tumors** are slow-growing neuroendocrine tumors found in the tracheobronchial tree. They are rare in occurrence, accounting for 1% to 2% of all primary lung tumors. Bronchial carcinoid tumors occur equally in both sexes, generally affecting adults in their mid-40s, and often have a prolonged course of disease. Fifteen percent of bronchial carcinoid tumors metastasize, most commonly to the liver, brain, bone, or adrenal glands. These tumors are often asymptomatic; however patients may present with a cough, wheezing, hemoptysis, and bronchial obstruction. Conventional radiographs of the chest show bronchial obstruction, overinflation of the lung, and atelectasis. CT scans of

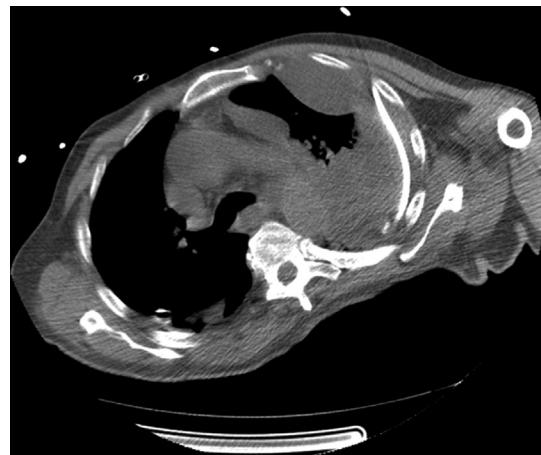


Fig. 3.51 Chest CT scan for placement of a pigtail catheter into the pleural space to drain a large, loculated pleural effusion. (From The Ohio State University Wexner Medical Center, Columbus, Ohio.)

the lung can further determine the extent of the disease and identify smaller lesions. If the disease is discovered before metastasis, surgical resection may be curative.

Lung Carcinoma

Lung cancer is the leading cause of cancer mortality worldwide, with a very low 5-year survival rate (20%). The greatest risk factor for lung cancer is smoking, with a history of smoking occurring in 90% of all lung cancer cases. Other risk factors include family history, environmental exposure (such as radon), prior radiation therapy, and a history of lung disease. Interestingly, in the

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Fig. 3.52 Posteroanterior chest radiograph demonstrating advanced small-cell lung carcinoma. (From The Ohio State University Wexner Medical Center, Columbus, Ohio.)

United States and the United Kingdom, the incidence of lung cancer has been declining since 2001, which reflects the pattern of smoking prevalence, and smoking prevention and cessation programs. In the United States, males are more likely to get and die from lung cancer than females.

Lung cancers are divided into two major categories: (1) non–small-cell lung cancer (NSCLC) and (2) small-cell lung cancer (SCLC). The four main histologic types of bronchogenic cancer are: (1) *squamous cell carcinoma*; (2) *adenocarcinoma*; (3) *undifferentiated large-cell carcinoma* (NSCLC); and (4) *undifferentiated small-cell carcinoma* (SCLC) (Fig. 3.52). These tumors arise from epithelial tissue in the major bronchi near the hilar area and metastasize via the lymph nodes, the bloodstream, or both. Adenocarcinomas are the most common type of bronchogenic cancers, accounting for almost 40% of the cases diagnosed in the United States. A decline in the incidence of squamous cell carcinoma has been noted over the past 20 years, with this tumor currently accounting for about 30% of all lung cancers. Undifferentiated large-cell carcinomas and small-cell carcinomas occur equally in approximately 10% to 15% of patients diagnosed with bronchogenic cancer; however, small-cell carcinoma has a much higher mortality rate, accounting for about one-quarter of deaths from lung cancer in the United States.

In addition to a thorough patient history, conventional chest radiography is essential for the diagnosis of lung carcinoma. The most common radiographic presentation of squamous cell carcinomas is airway obstruction caused by a unilateral hilar mass (Fig. 3.53); however, the lesion must be larger than 6 mm to be visible on a conventional radiograph. As the tumor grows, it may occlude the bronchus, producing atelectasis and pneumonitis. These secondary effects provide more opacity radiographically than does the actual tumor. Adenocarcinomas are usually relatively small and found in the peripheral regions of the lung parenchyma. The radiographic presentation of this neoplasm consists of a solitary radiopaque lung nodule, sometimes called a coin lesion. Histologic confirmation is necessary to make a definitive diagnosis.

CT is essential in demonstrating nodules smaller than 6 mm, which are not visualized with conventional chest radiography. CT can show calcifications to help differentiate malignant lung tumors from benign and is useful in staging the disease by demonstrating the presence or absence of spread to the lymph nodes in the thoracic and upper abdominal areas. Malignant lesions are rarely calcified (Fig. 3.54), whereas benign lesions generally have a calcified center. Staging lung carcinoma is critical to the selection of treatment for the disease. CT or PET imaging can assist in determining metastases to the liver, brain, and adrenal glands (Fig. 3.55), so it is now common practice to include a portion of the upper abdomen during an oncologic CT examination of the chest and from the base of the skull through the mid-femur during a PET scan. Advances in technology have made it possible to perform virtual bronchoscopy to assess the location and extent of the disease. Thoracic MR imaging is of limited value, but it is helpful in assessing tissue planes and the chest wall before surgery, and in cases where apical tumors have invaded the vertebral column. NM bone scans may be used to screen for bone metastases, which are often confirmed with either conventional skeletal radiography or MR.

A patient may undergo percutaneous lung biopsy, bronchoscopy, or brush biopsy. During a brush biopsy, a device with tiny brushes is introduced through a bronchoscope or bronchial catheter to procure cells and tissues under fluoroscopic guidance.

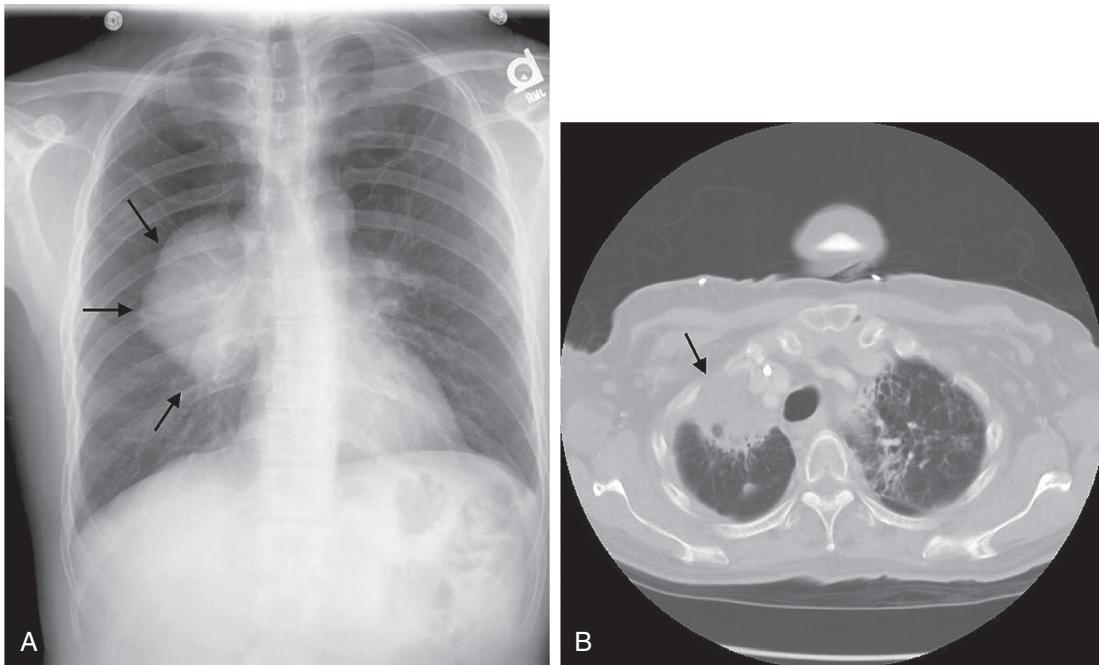
The lung cancer prognosis is very poor, with a 5-year survival rate of 20%. Seventy percent of all lung cancers present in advanced stages and are unresectable. Fairly good prognoses are associated with a

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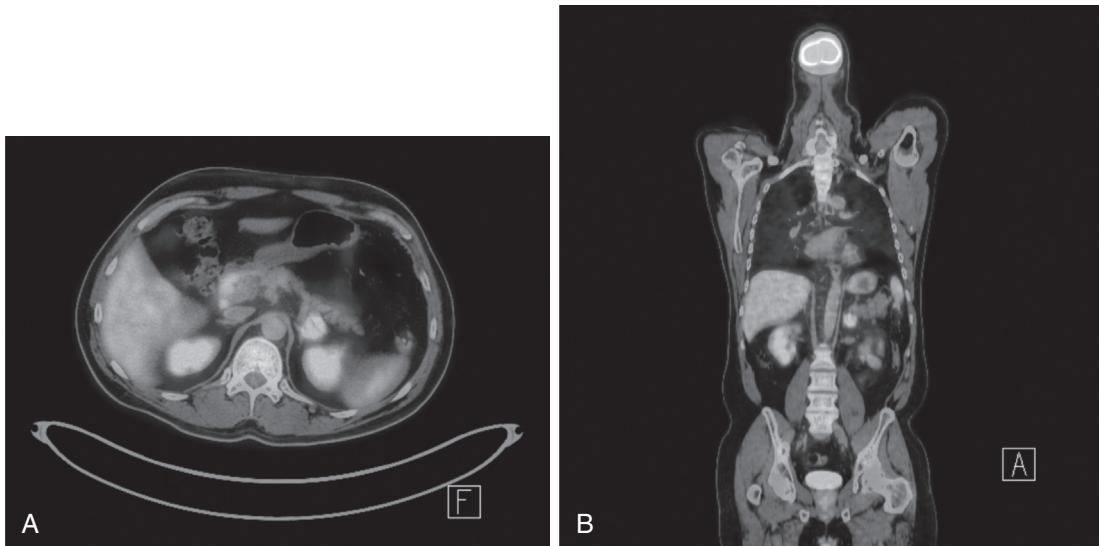
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Fig. 3.53 (A) Bronchogenic carcinoma in a posteroanterior projection, indicated by a large right hilar mass (arrows). (B) Chest CT scan demonstrating a large bronchogenic mass (arrow) in the anteromedial aspect of the right lung with a cavitary lesion just above the level of the right main stem bronchus. (From The Ohio State University Wexner Medical Center, Columbus, Ohio.)



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Fig. 3.54 Chest CT scan of a lesion (arrow) in the upper lobe of the right lung. (From Riverside Methodist Hospital, Columbus, Ohio.)



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Fig. 3.55 (A) Axial and (B) coronal PET and CT demonstrating metastasis of lung carcinoma to the left adrenal gland. (From The Ohio State University Wexner Medical Center, Columbus, Ohio.)

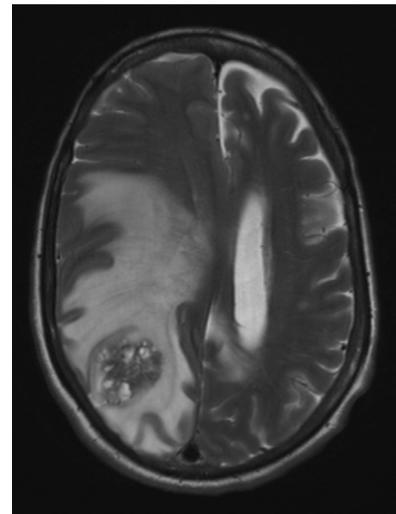
lobectomy in patients with peripheral nodular lesions; however, second primary lesions occur in 6% to 10% of survivors. Small-cell tumors tend to be the deadliest because the cancer has almost always metastasized before diagnosis.

p0525 Lung carcinoma may be treated with surgery, chemotherapy, external radiation therapy, brachytherapy, or any combination of these modalities depending on the type, location, and stage of disease. Chemotherapy, radiation therapy, or a combination of both may be administered before surgical resection, and radiation therapy may also be used for palliative treatment to control the pain associated with skeletal metastasis, spinal cord compression, or brain metastasis (Fig. 3.56). Recent research has led to developments in targeted growth factor receptor therapy, gene therapy, antiangiogenic therapy, and immunotherapeutic treatments.

s0180 Metastases From Other Sites

p0530 Malignant spread to the lungs is much more common than primary lung neoplasms. Many primary malignancies spread to the lungs, most commonly the breast, gastrointestinal tract, female reproductive system, prostate, skin (melanoma), and kidneys.

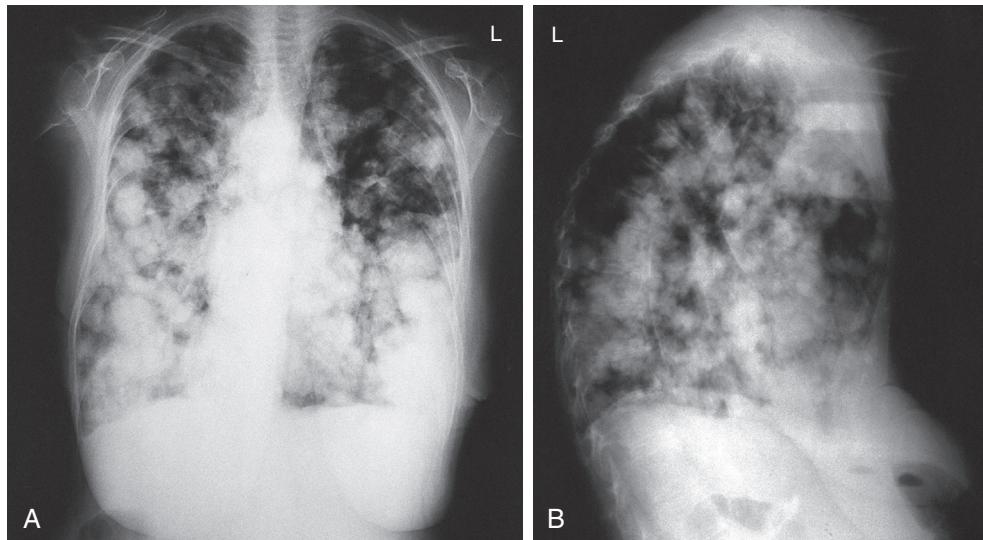
p0535 Primary tumors spread to the lungs via five different routes: (1) through the bloodstream in hematogenous metastases; (2) through the lymph system in lymphogenous metastases; (3) by direct extension in



f0285

Fig. 3.56 Axial MR image of the brain, demonstrating metastatic spread from a primary lung neoplasm. (From Riverside Methodist Hospital, Columbus, Ohio.)

local invasion; (4) through the tracheobronchial system in bronchogenic metastases; and, rarely, (5) by direct implantation from biopsies or other surgical procedures. Radiographically, these metastatic lesions appear as single or multiple rounded opacities throughout the lungs (Fig. 3.57). CT is more sensitive than conventional chest radiography in the detection of small metastatic lesions.



f0290

Fig. 3.57 (A) Pulmonary metastases from uterine cancer demonstrate multiple lesions with the characteristic "cotton ball" appearance. (B) Lateral projection of pulmonary metastases resulting from uterine cancer. (From Riverside Methodist Hospital, Columbus, Ohio.)

b0010

PATHOLOGY SUMMARY OF THE RESPIRATORY SYSTEM

Pathology	Imaging Modality of Choice
Aspergillosis	Chest radiography, CT
Cystic fibrosis	Chest radiography
Respiratory distress syndrome	Chest radiography
Pneumonias	Chest radiography
Bronchiectasis	Chest radiography, high-resolution chest CT
Tuberculosis	Chest radiography, chest CT
COPD	Chest radiography, high-resolution chest CT
COVID-19	Chest radiography, chest CT
Pneumoconioses	Chest radiography
Fungal disease	Chest radiography
Lung abscess	Chest radiography, chest CT
Pleurisy	None
Pleural effusion	Chest radiography, chest CT, sonography
Sinusitis	Sinus CT
Bronchial adenoma	Chest CT
Bronchogenic carcinoma staging	Chest CT, FDG-PET
Metastatic lung disease	Chest CT, FDG-PET, brain MR

COPD, Chronic obstructive pulmonary disease; CT, computed tomography; FDG-PET, fluorodeoxyglucose–positron emission tomography; MR, magnetic resonance imaging; SPECT, single-photon emission computed tomography.

REVIEW QUESTIONS

- o0035 1. Early lesions of tuberculosis are most commonly seen in which region of the lung?
a. Base
b. Apex
c. Costophrenic angle
d. Hilum
- o0040 2. The “sail sign” in an infant is commonly associated with enlargement of the:
a. Heart
b. Pulmonary arteries
c. Thymus
d. Thyroid
- o0045 3. What results from air passing from the mediastinum into the subcutaneous tissues of the chest or neck?
a. Pneumothorax
b. Subcutaneous emphysema
c. Pneumomediastinum
d. Respiratory failure
- o0050 4. A disorder affecting premature infants due to insufficient surfactant production is termed:
a. Cystic fibrosis
b. Respiratory distress syndrome
c. Mediastinal emphysema
d. Pectus excavatum
- o0055 5. Lack of respiratory function or lack of proper oxygen and carbon dioxide exchange best describes:
a. Respiratory failure
b. Hypoxemia
c. Hypercapnia
d. Asthma
- o0060 6. Which of the following is the most common type of bacterial pneumonia?
a. *Mycoplasma* pneumonia
b. *Legionella* pneumonia
c. Pneumococcal pneumonia
d. Staphylococcal pneumonia
- o0065 7. A permanent, abnormal dilation of the bronchi following a bacterial infection is termed:
a. Bronchiectasis
b. Bronchogenic carcinoma
c. Pneumococcal pneumonia
d. Tuberculosis
- o0070 8. The chronic inhalation of quartz dust results in:
a. Histoplasmosis
b. Silicosis
c. Anthracosis
d. Coccidioidomycosis
- o0075 9. An accumulation of pus in the pleural cavity is known as a(n):
a. Coin lesion
b. Empyema
c. Pleural effusion
d. Pleurisy
- o0080 10. The strongest risk factor in the development of lung carcinoma is:
a. Automobile emissions
b. Cigarette smoking
c. Dust
d. Iatrogenic treatment
- o0085 11. Symptoms unique to SARS-CoV-2 pneumonia versus other viral pneumonias include (circle all that apply):
a. Shortness of breath
b. Fever
c. Anosmia
d. Cough
e. Syncope
f. Ageusia
- o0090 12. Explain how technical exposure factors must be changed to compensate for the additive and destructive pathologies of the chest. Give one example of each type of pathology.
- o0095 13. Specify the reasons for obtaining chest radiographs taken in the erect position at a 72-in source-to-image distance.
- o0100 14. What specialized radiographic projection of the chest is used to demonstrate tuberculosis? Why is this projection of benefit?
- o0105 15. Chronic obstructive pulmonary disease (COPD) includes both emphysema and chronic bronchitis. Compare and contrast these two pathologic conditions and explain how both can be considered COPD.
- o0110 16. List the most common primary neoplasms to metastasize to the lungs?