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CHAPTER 3

Pulmonary Infections in the Normal Host

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Pneumonia ranks sixth among the causes of death in the United States and is the leading cause of death due to infection. The factors responsible for this high mortality rate include an increasing elderly population, immunocompromised hosts in greater numbers, new etiologic agents of pneumonia, antibiotic-resistant organisms, and unusual organisms acquired from international travel. The etiologic agent can reach the lungs by several routes. The most common is inhalation of airborne droplets, followed by aspiration of nasopharyngeal organisms, hematogenous spread to the lungs from other extrathoracic sources of infection, direct extension from a localized site of infection, and infection from penetrating wounds.

Clinical features are important in the determination of the etiologic agent of pneumonia (Table 3-1). Community-acquired pneumonias occurring in previously healthy individuals are caused by *Streptococcus pneumoniae* in 50% to 75% of cases and by *Mycoplasma pneumoniae*, viral organisms, or *Legionella pneumophila*. Nosocomial pneumonias (i.e., acquired in the hospital by patients who are already ill) typically are caused by gram-negative organisms or *Staphylococcus aureus*. Certain preexisting conditions are associated with pneumonias due to specific organisms. For example, patients with altered states of consciousness or those in coma are more likely to develop aspiration and subsequently develop infections due to mouth organisms (i.e., gram-negative organisms and anaerobes). *S. aureus* infection can occur after influenza pneumonia; in patients with chronic obstructive pulmonary disease (COPD), *Haemophilus influenzae* infection is common. *S. aureus* and *Pseudomonas aeruginosa* organisms are common superinfectants in patients with cystic fibrosis.

CLASSIFICATION

The pathologic classification of pneumonia is based on the anatomic localization of the disease process. Categories include lobar pneumonia, bronchopneumonia or lobular pneumonia, hematogenous bacterial infection, and acute interstitial pneumonia.

Lobar Pneumonia

Pathologic Features

Lobar pneumonia results when inhaled organisms reach the subpleural zone of the lung and produce alveolar wall injury with severe hemorrhagic edema. This is followed by a rapid multiplication of organisms and invasion of the infected edema fluid by polymorphonuclear leukocytes. Rapid spread occurs through the terminal airways and pores of Kohn, and consolidation of an entire lobe or segment may occur. This process is frequently aborted by administration of antibiotic therapy. The pattern commonly is seen in pneumonias due to *S. pneumoniae. Klebsiella pneumoniae*, *L. pneumophila*, and *M. pneumoniae* can also produce lobar consolidation.

Radiographic Features

This type of pneumonia produces a pattern of confluent opacification, often with air bronchograms (Fig. 3-1). The entire lobe may be involved, but more frequently because

TABLE 3-1 Clinical Clues to the Cause of Pneumonia

Clinical Circumstance	Likely Causative Organisms
Previously well, community-acquired	50% to 75% due to *Streptococcus pneumoniae* (pneumococcus), *Mycoplasma pneumoniae*, virus, or *Legionella pneumophila*
Hospital-acquired, otherwise ill	Gram-negative organisms, including *Pseudomonas aeruginosa, Klebsiella pneumoniae, Escherichia coli*, and *Enterobacter* species; *Staphylococcus aureus*; less commonly, *S. pneumoniae* and *Legionella*
Alcoholism	*S. pneumoniae* most common; gram-negative organisms, anaerobes, and *S. aureus* frequent causes
Diabetes mellitus	Suspect gram-negative organisms and *S. aureus*
Altered consciousness, coma	Gram-negative organisms and anaerobes
Drug addiction	If not an AIDS patient, suspect *Staphylococcus* and gram-negative organisms
After influenza	*S. aureus*
Chronic bronchitis with exacerbation	*Haemophilus influenzae* (common)
Cystic fibrosis	Mucoid, *P. aeruginosa*

From Woodring JH: Pulmonary bacterial and viral infections. In Freundlich IM, Bragg DG (eds): A radiologic approach to diseases of the chest. Baltimore, Williams & Wilkins, 1992.

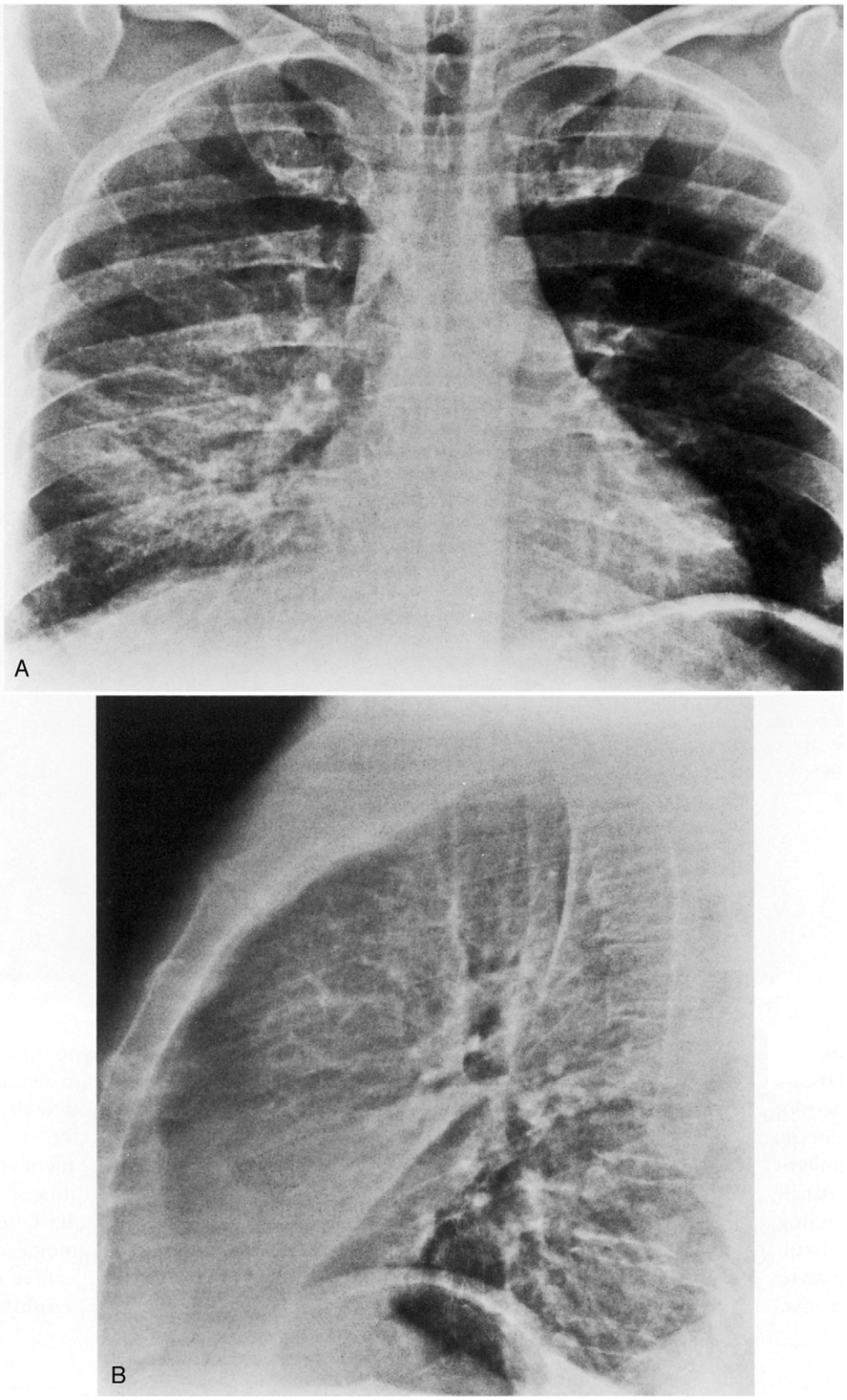


FIGURE 3-1. Posteroanterior (**A**) and lateral (**B**) views of lobar consolidation involving the middle lobe supported the diagnosis of *Streptococcus pneumoniae* (pneumococcus) infection.

of early use of antibiotics, the pneumonia involves only one or more segments within a lobe (i.e., sublobar form). A lobar pneumonia may result in expansion of the lobe due to voluminous edema, which is usually caused by infection with *K. pneumoniae* (Fig. 3-2). The enlargement of the lobe can be recognized radiographically by bulging of the interlobar fissures. Necrosis, cavitation, and development of a unique complication, pulmonary gangrene, may ensue.

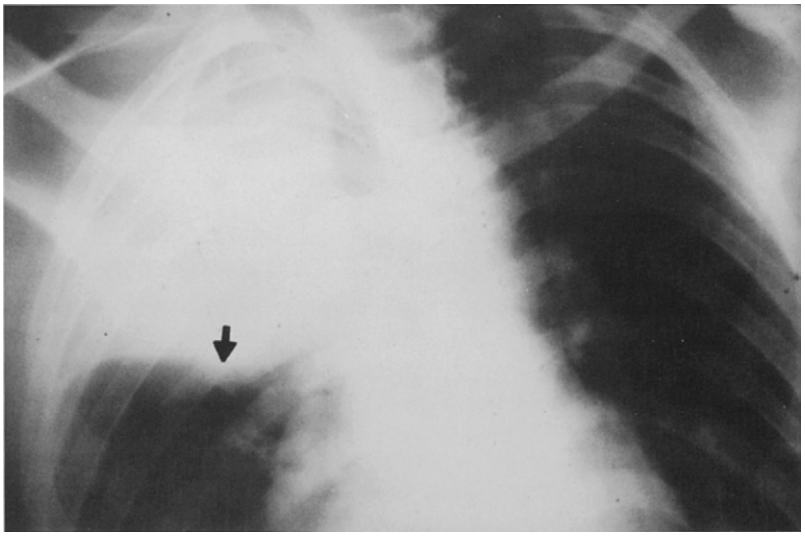


Figure 3-2. Anteroposterior view of a patient with *Klebsiella* pneumonia shows homogeneous opacity of the right upper lobe with slight bulging of the minor fissure *(arrow)*.

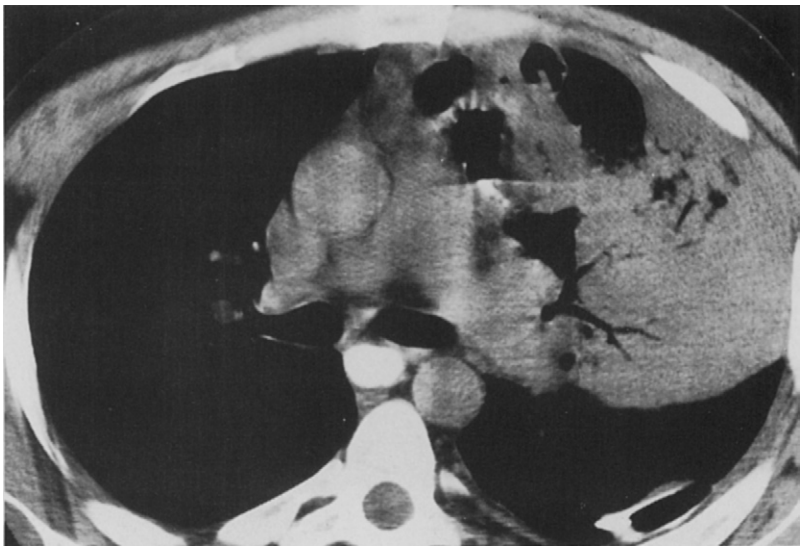


Figure 3-3. CT of a pneumococcal left upper lobar consolidation shows clearly defined air bronchograms and evidence of cavitation.

The computed tomography (CT) features of lobar pneumonia are similar to those seen on standard radiography (Fig. 3-3). There is usually evidence of confluent opacification with air bronchograms. The air bronchograms are often more easily visualized with CT examination. Table 3-2 summarizes the radiographic clues to the cause of pneumonia.

Bronchopneumonia

Pathologic Features

Bronchopneumonia (i.e., lobular pneumonia) results when organisms are deposited in the epithelium of peripheral airways (i.e., distal bronchi or bronchioles), resulting in epithelial ulcerations and formation of a peribronchiolar exudate. The inflammatory process spreads through the airway to involve the peribronchiolar alveoli, which become filled with edema and pus. Lobules may be affected in a patchy pattern initially, and further spread results in involvement of contiguous pulmonary lobules. Eventually, a confluent bronchopneumonia may resemble lobar pneumonia. Offending organisms that produce this type of pathologic response include *S. aureus*, gram-negative organisms, anaerobic bacteria, and *L. pneumophila*.

Radiographic Features

The radiographic appearance of bronchopneumonia pneumonia is most frequently that of multiple, ill-defined nodular opacities that are patchy but that may eventually become confluent and produce consolidation with airspace opacification (Fig. 3-4). The opacification may be multifocal and involve several lobes, or it may be diffuse. As the disease progresses, segmental and lobar opacification develops, similar to the pattern of a lobar pneumonia. Early necrosis and cavitation can occur. The nodular opaci-

TABLE 3-2. Radiographic Clues to the Cause of Pneumonia

Radiographic Finding	Likely Causative Organisms
Round pneumonia	Suspect *Streptococcus pneumoniae* (pneumococcus)
Complete lobar consolidation	*S. pneumoniae*, *Klebsiella pneumoniae*, and other gram-negative bacilli; *Legionella pneumophila* and occasionally *Mycoplasma pneumoniae*
Lobar enlargement	*K. pneumoniae*, pneumococcus, *Staphylococcus aureus*, *Haemophilus influenzae*
Bilateral pneumonia (bronchopneumonia)	*S. pneumoniae* still common, but suspect others, including *S. aureus*, streptococci, gram-negative bacilli, anaerobes, *L. pneumophila*, virus, and aspiration syndromes
Interstitial pneumonia	Virus, *M. pneumoniae*, and occasionally *H. influenzae*, *S. pneumoniae*, and other bacteria
Septic emboli	Usually *S. aureus*; occasionally gram-negative bacilli, anaerobes, and streptococci
Empyema or bronchopleural fistula	*S. aureus*, gram-negative bacilli, anaerobes, and occasionally, pneumococcus; mixed bacterial infections common
Contiguous spread to chest wall	Actinomycosis; occasionally other bacteria or fungi
Cavitation	*S. aureus*, gram-negative bacilli, anaerobic bacteria, and streptococci; cavitation uncommon with *S. pneumoniae* or *L. pneumophila*
Pulmonary gangrene	*K. pneumoniae*, *Escherichia coli*, *H. influenzae*, *Mycobacterium tuberculosis*, *S. pneumoniae*, anaerobes, or fungi
Pneumatoceles	*S. aureus*, gram-negative bacilli, *H. influenzae*, *M. tuberculosis*, and measles; *S. pneumoniae* rare
Lymphadenopathy	*M. tuberculosis*, fungi, virus, *M. pneumoniae*, common bacterial lung abscess, and rarely plague, tularemia, and anthrax
Fulminant course with acute respiratory distress syndrome (ARDS)	Virus, *S. aureus*, streptococci, *M. tuberculosis*, and *L. pneumophila*

From Woodring JH: Pulmonary bacterial and viral infections. In Freundlich IM, Bragg DG (eds): A Radiologic Approach to Diseases of the Chest. Baltimore, Williams & Wilkins, 1992.

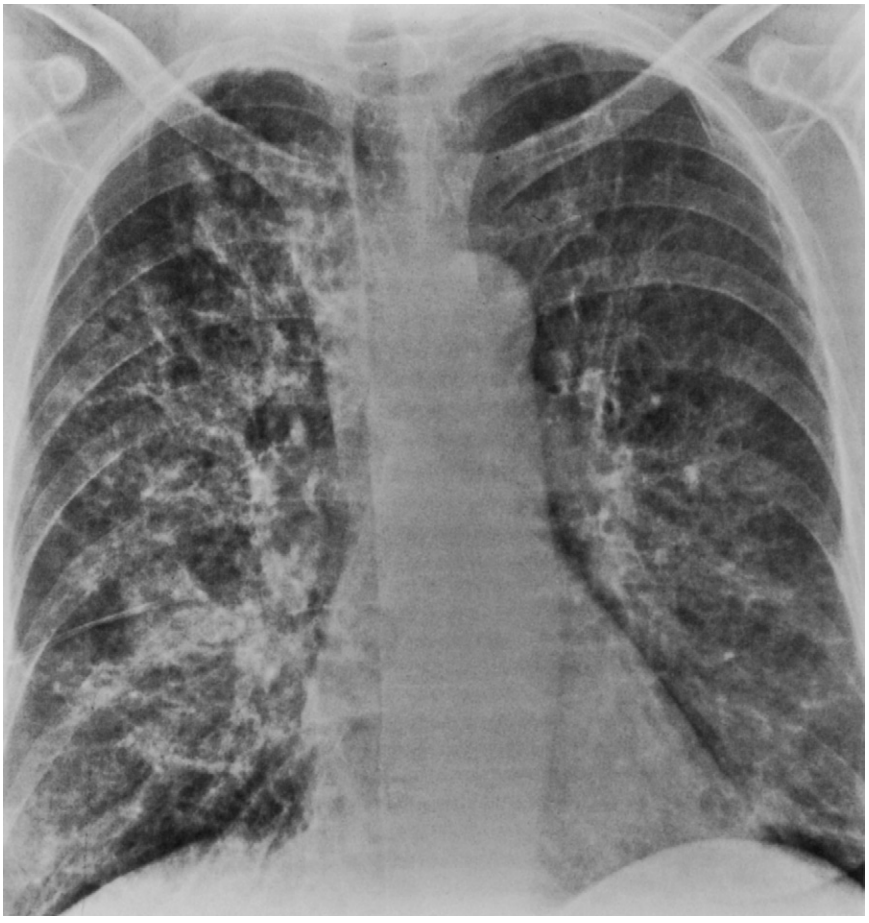


FIGURE 3-4. Bronchopneumonia. The posteroanterior view demonstrates bilateral, patchy, and inhomogeneous opacities, which have become confluent in some areas. The patient was diagnosed with viral influenza pneumonia.

ties of bronchopneumonia can be identified with facility on CT scans. The small nodules, usually less than 1 cm in diameter, represent peribronchiolar areas of consolidation or ground-glass opacity. They are called *acinar or airspace nodules*, but these nodules histologically are found in a peribronchiolar location. They are ill-defined and may be of homogenous soft tissue opacity and obscuring vessels, or they may be hazy and less dense so that adjacent vessels are clearly seen (i.e., ground-glass opacity). These nodules usually have a centrilobular location because of their proximity to small bronchioles.

Acute Interstitial Pneumonia

Pathologic Features

This type of pneumonia is usually produced by viral organisms, which result in edema and mononuclear cell infiltration around the bronchi and bronchiolar walls and extend into the interstitium of the alveolar walls.

Radiographic Features

Bronchopneumonia or an acute interstitial pneumonia may be seen with viral infections (Fig. 3-5). The early radiographic appearance is that of thickening of end-on bronchi and tram lines. However, this often evolves into a reticular pattern that may be seen extending outward from the hila.

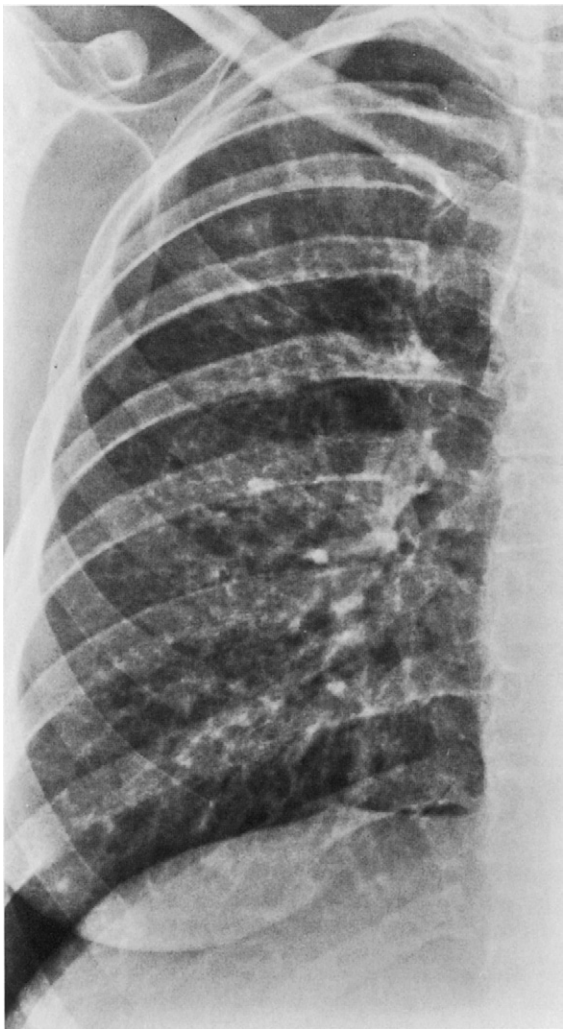


Figure 3-5. Acute interstitial pneumonia due to varicella (chickenpox). Coned-down view of the right lung demonstrates a fine reticulonodular pattern, which is more prominent centrally.

Hematogenous Spread of Infection

Pathologic Features

Hematogenous spread to the lungs from bacterial infection may occur, although this is unusual. One of the most frequent manifestations is septic infarcts. They usually originate from right-sided tricuspid endocarditis or infected thrombi within major systemic veins. This phenomenon is seen in intravenous drug abusers and patients with long-standing indwelling central catheters.

Radiographic Features

Septic infarcts tend to be multiple and peripheral and to abut the pleural surface. They occur more frequently in the lower lobes. These nodules or wedge-shaped opacities may show evidence of cavitation (Fig. 3-6). CT often demonstrates a vessel connected to the area of infarction. On CT, the septic infarcts appear as wedge-shaped, peripheral opacities abutting the pleura. They may contain air bronchograms or rounded lucencies of air, sometimes referred to as *pseudocavitation*. True cavitation is common. Occasionally, septic bacterial infection may result in diffuse massive seeding of the lungs with a miliary pattern (i.e., very small nodular pattern), although this is much more common with hematogenous dissemination of granulomatous infections.

COMPLICATIONS OF PNEUMONIA

Box 3-1 outlines the complications of pneumonia.

Cavitation

Necrosis of lung parenchyma with cavitation (Fig. 3-7) may occur in pneumonia, particularly that produced by virulent bacteria, including *S. aureus*, streptococci, gram-negative bacilli, and anaerobic bacteria. If the inflammatory process is localized, a lung abscess will form. It is usually rounded and focal, and it appears to be a mass (Fig. 3-8). With liquefaction of the central inflammatory process, a communication may develop with the bronchus; air enters the abscess, forming a cavity, which often contains an air-fluid level. The walls of the cavity may be smooth, but more often, they are thick and irregular.

Multiple, small cavities or microabscesses may develop in necrotizing pneumonia (Fig. 3-9). They are recognized as multiple areas of lucency within a consolidated lobe or segment. A similar appearance may be produced by consolidation superimposed on areas of preexisting emphysema. If the necrosis is extensive, arteritis and vascular thrombosis may occur in an area of intense inflammation, causing ischemic necrosis and death of a portion of lung. This is a particular complication of *Klebsiella* pneumonia and other pneumonias producing lobar enlargement. The radiographic features include multiple areas of cavitation, often with air-fluid levels. Portions of dead lung may slough and form intracavitary masses.

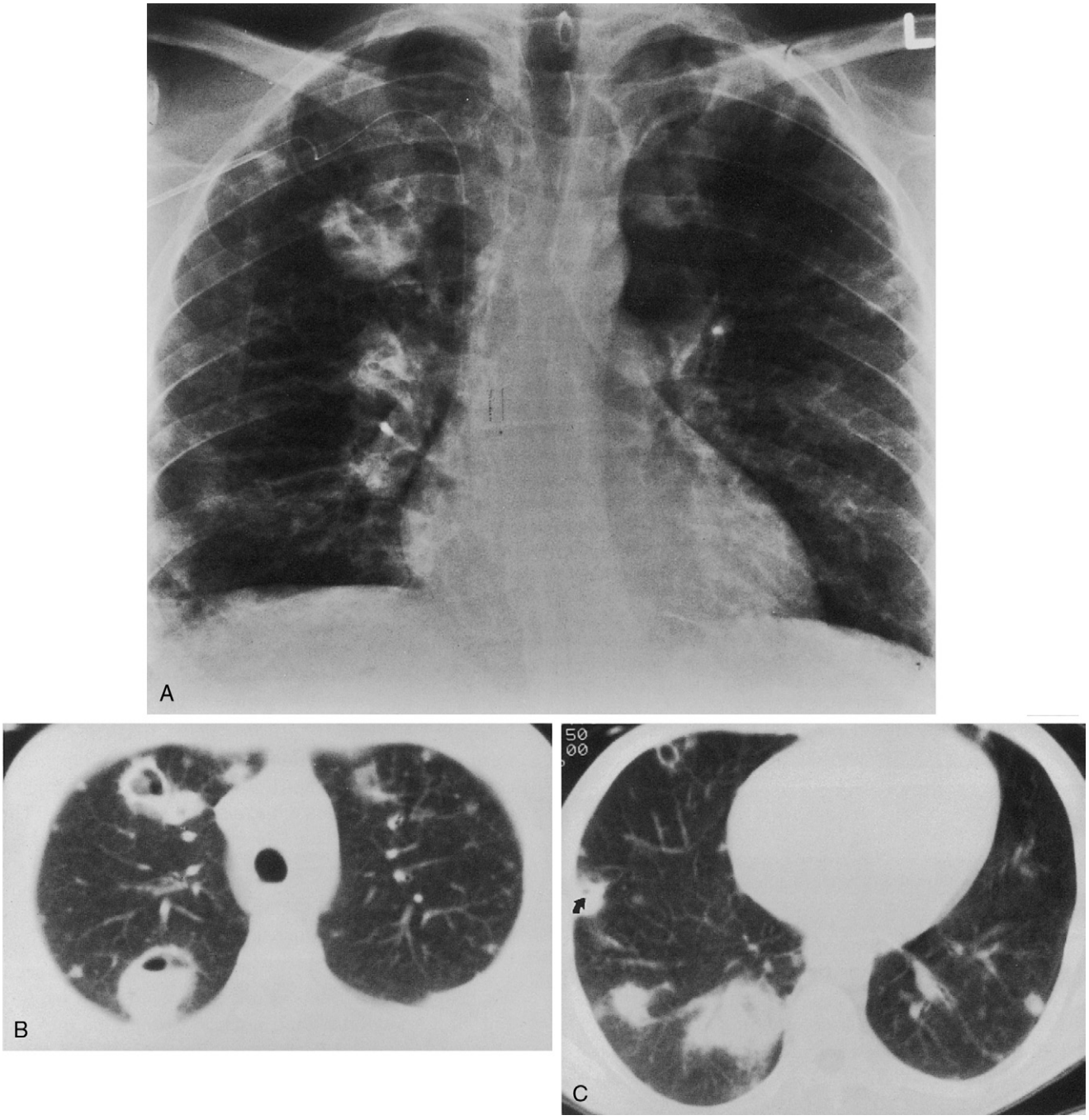


FIGURE 3-6. Septic infarcts in an intravenous drug abuser. **A**, The posteroanterior chest radiograph shows multiple, bilateral cavitary nodules. **B** and **C**, CT examination demonstrates that most of the infarcts are peripheral in location; some abut the pleura and occasionally are wedge shaped. True and pseudocavities *(curved arrow)* are present.

Pneumatocele Formation

Pneumatoceles are usually associated with pneumonia caused by virulent organisms; the classic offender is *S. aureus* (Fig. 3-10). They usually form subpleural collections of air, which result from alveolar rupture. Radiographically, they appear as single or multiple, cystic lesions with thin and smooth walls. They may show rapid change in size and location on serial radiographs.

Hilar and Mediastinal Adenopathy

Intrathoracic lymphadenopathy that can be recognized on standard radiographs is uncommon in most bacterial and viral infections; some notable exceptions include *Mycobacterium tuberculosis*, *Pasteurella tularensis*, and *Yersinia pestis*. Adenopathy may be associated with fungal infections or bacterial infections that are long-standing or virulent, as in lung abscesses. CT may show slightly enlarged

***Box 3-1.* Complications of Pneumonia**

CAVITATION
Organisms
- *Staphylococcus aureus*
- Streptococci
- Gram-negative bacilli
- Anaerobes

Types
- Lung abscess (single, well-defined mass often with air-fluid level)
- Necrotizing pneumonia (small lucencies or cavities)
- Pulmonary gangrene (sloughed lung)

PNEUMATOCELES
S. aureus
Occur in children
Thin walls, multiple

ADENOPATHY
Common with granulomatous infections (tuberculosis, fungi)
Uncommon with most bacterial and viral infections

PLEURAL EFFUSIONS AND EMPYEMA
Common (40%)
Parapneumonic
Empyema (bronchopleural fistula)

OTHER COMPLICATIONS
Acute respiratory distress syndrome (ARDS)
Bronchiectasis
Slow resolution in the elderly
Recurrent pneumonias

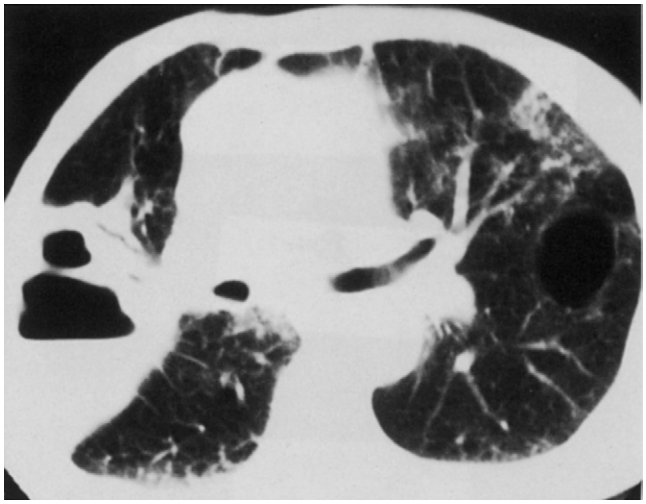


Figure 3-7. Cavitary pneumonia due to gram-negative organisms. CT shows two areas of cavitation with an air-fluid level in the more posterior area, indicating bronchial communication.

nodes (>1 cm) in patients with common bacterial infections that are not visible on standard radiography.

Pleural Effusions and Empyema

Pleural effusion is a common complication of pneumonia, occurring in about 40% of cases (Fig. 3-11). Most effusions are parapneumonic, but infection of the pleural space with empyema requiring drainage is an important but uncommon complication of some pneumonias. Empyemas can be recognized by the presence of gross pus within the pleural space, by a white blood cell count in the pleural fluid of greater than 15,000 cells/mm^3, by the presence of bacteria within the pleural fluid, or by a pH less than 7.2. Chapter 18 provides more detail on the pleural complications of pneumonia.

Parenchymal necrosis in an underlying pneumonia may produce a fistula between the bronchus and the pleural space (i.e., bronchopleural fistula), and this results in an empyema with an air-fluid level. Further discussion of these entities can be found in Chapter 18.

Other Complications

Rapidly progressive and fulminant bacterial or viral pneumonia may result in the acute respiratory distress syndrome (ARDS). In the preantibiotic era, bronchiectasis was an extremely common complication of bacterial pneumonia, but the incidence of bronchiectasis has declined with the advent of antibiotics. Most pneumonias clear within 2 or 3 weeks, but in elderly patients, resolution may take 3 to 4 months. Necrotizing pneumonias also tend to resolve slowly. Recurrent pneumonias are frequently found in patients with predisposing factors such as chronic obstructive lung disease, bronchiectasis, alcoholism, and diabetes. Although recurrent or persistent pneumonia in the same location raises the possibility of an obstructing endobronchial lesion due to lung carcinoma, cancer accounts for less than 5% of such cases.

PNEUMONIAS CAUSED BY GRAM-POSITIVE BACTERIA

The most common gram-positive bacteria causing pneumonia include *S. pneumoniae* (pneumococcus), *S. aureus*, and *Streptococcus pyogenes*.

Streptococcus pneumoniae

S. pneumoniae (Box 3-2) is responsible for one third to one half of community-acquired pneumonias in adults. These infections occur more frequently in the winter and early spring. Pneumococcal pneumonia occurs in healthy people, but it is much more common in alcoholic, debilitated, and other immunocompromised individuals.

The radiographic features include consolidation that is usually unilateral, although it may be bilateral, and it typically affects the lower lobes (see Fig. 3-1). Although it is a lobar pneumonia, it is uncommon for the lobe to be completely consolidated. Cavitation is rare, and large pleural effusions are uncommon. When present, they suggest the development of empyema. Sometimes, especially in children, the pneumonia may have a rounded, masslike appearance (Fig. 3-12). This is called a *round pneumonia*; it results from centrifugal spread of the rapidly replicating bacteria by way of the pores of Kohn and canals of Lambert from a single primary focus in the lung.

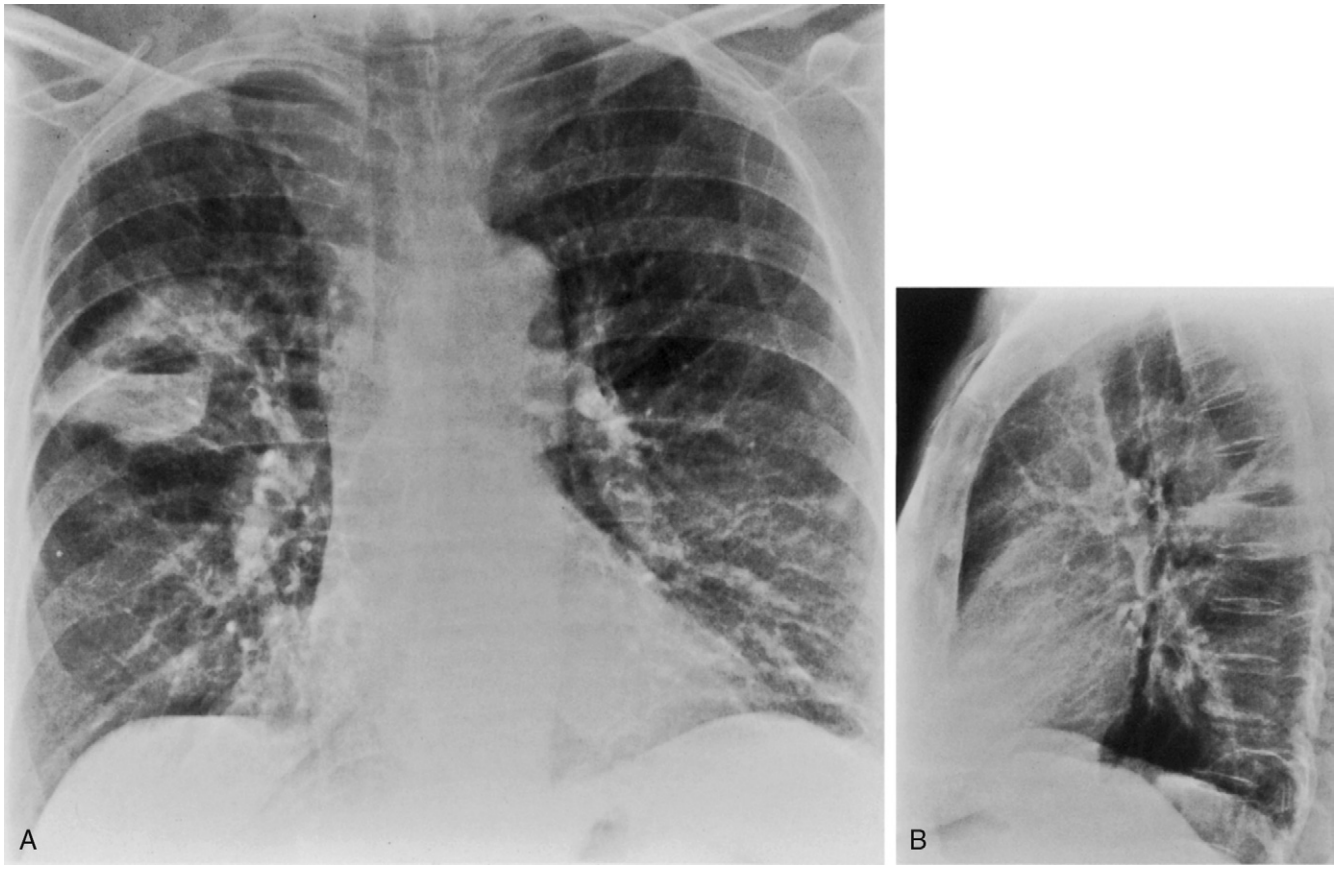


Figure 3-8. Primary lung abscess due to aspiration. The posteroanterior (**A**) and lateral (**B**) views show a well-defined, masslike opacity in the superior segment of the right lower lobe. There is cavitation with an air-fluid level and a thick wall.

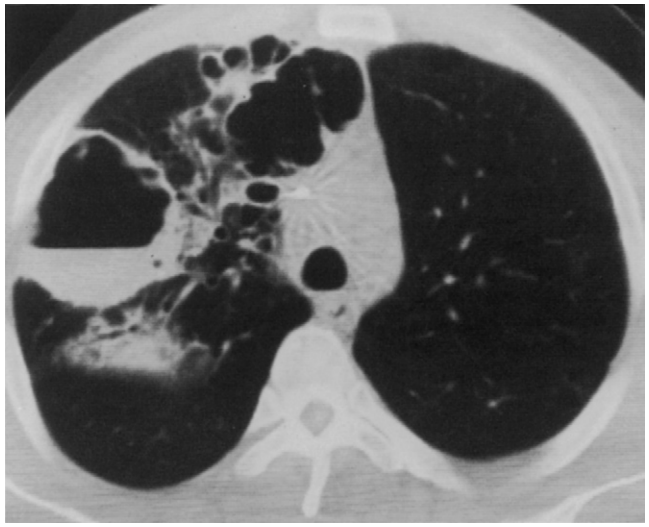


Figure 3-9. Microabscesses caused by *Pseudomonas* pneumonia in the right upper lobe. Multiple, thin-walled, multiloculated cavities can be seen with little surrounding parenchymal opacity.

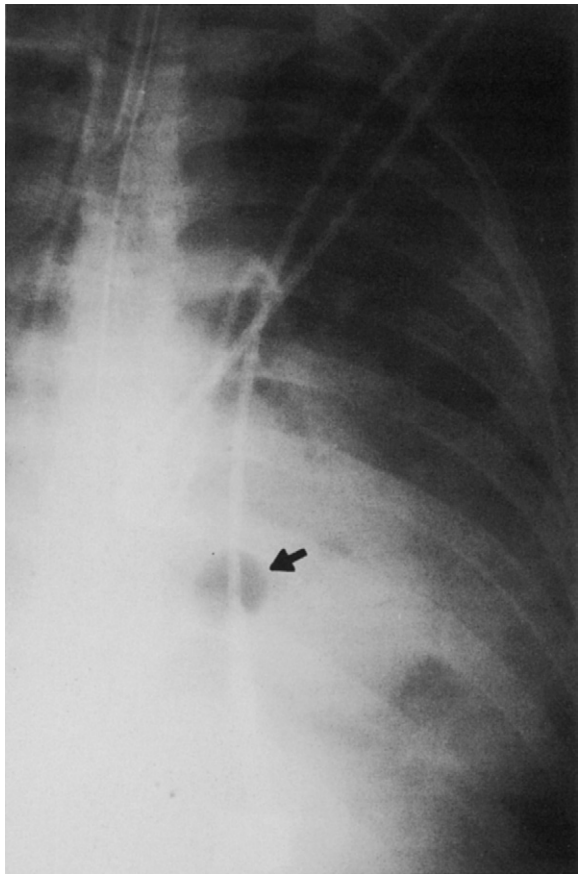


Figure 3-10. Pneumatocele. Coned-down (anteroposterior) view of the chest in a patient with fulminant staphylococcal pneumonia shows a rounded lucency in left lower lobe caused by a pneumatocele *(arrow)*.

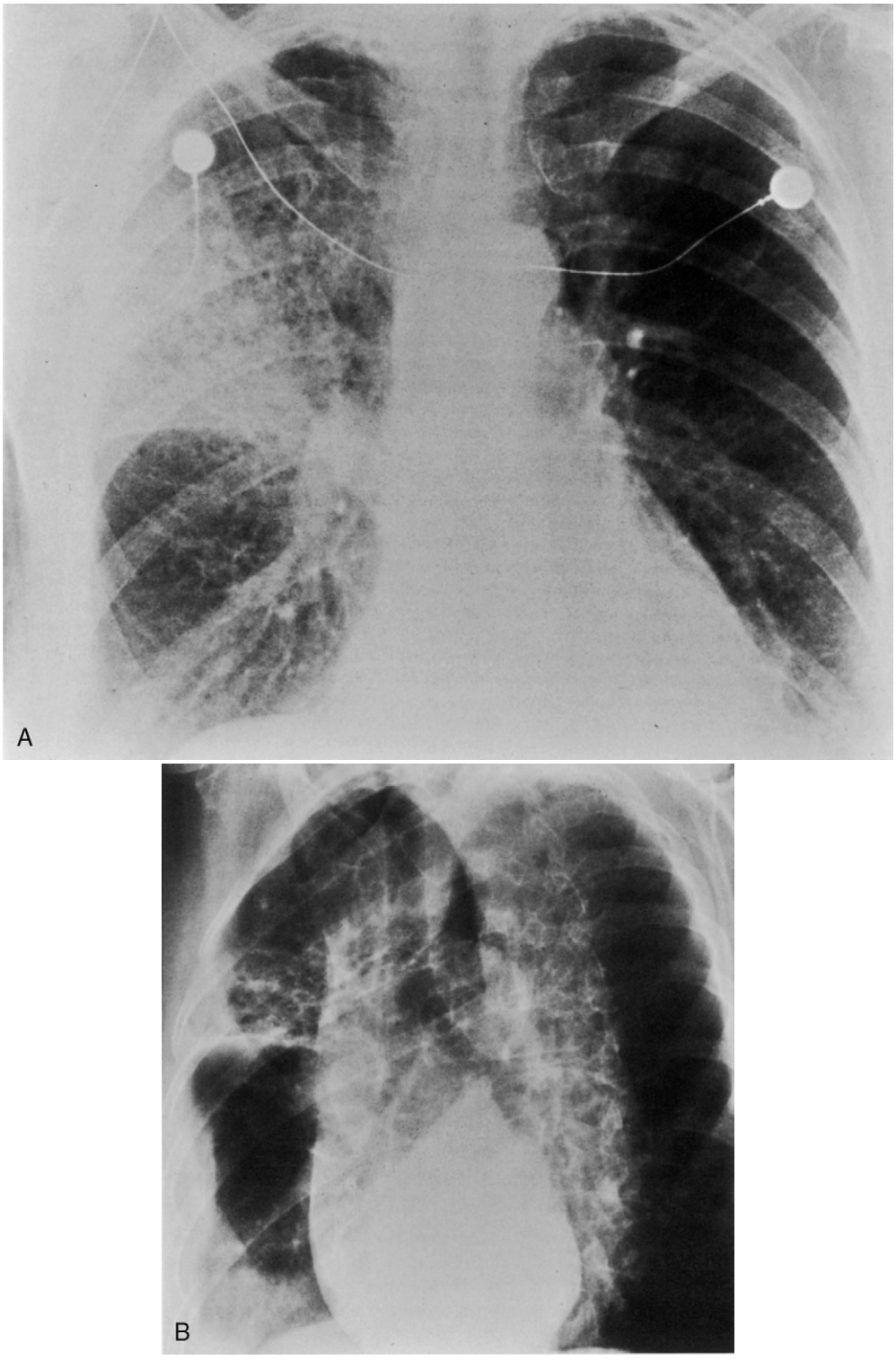


Figure 3-11. Parapneumonic effusion (pneumococcal pneumonia). **A**, The posteroanterior view shows a right upper lobe consolidation. **B**, An oblique view 2 days later demonstrates a right effusion.

Staphylococcus aureus

S. aureus (Box 3-3) is a gram-positive coccus, and the spherical organisms occur in pairs and clusters. This pneumonia rarely develops in healthy adults, but it is sometimes a complication of viral infections and is much more common in infants and children. In infants, unilateral or bilateral consolidation involving the lower lungs is the most frequent radiographic presentation. Pneumatoceles, thin-walled cysts filled with air or partially filled with fluid, may develop and occasionally rupture into the pleural space, resulting in pneumothorax. In adults, the disease is usually bilateral and is preceded by an atypical pneumonia such as

Box 3-2. Streptococcus pneumoniae

CHARACTERISTICS
Most common community-acquired pneumonia
More common among adults
Occurs in healthy and debilitated individuals

RADIOGRAPHIC FEATURES
Lower lobes
Consolidation
Lobar or sublobar
Round pneumonia in children

Box 3-3. Staphylococcus aureus

CHARACTERISTICS
Gram-positive coccus
Infants and children (more common)
Occurs after viral infection
Septic emboli
- Intravenous drug abusers
- Indwelling catheters

RADIOGRAPHIC FEATURES
Children
- Consolidation
- Lower lungs
- Pneumatoceles

Adults
- Bilateral
- Cavitation
- Empyema

Septic emboli (infarcts)
- Multiple
- Nodules or wedge-shaped opacities
- Peripheral, abut pleura
- Cavitation
- Seen on computed tomography
- Pseudocavitation or true cavitation
- Feeding vessel

influenza. Cavitation is a common feature, and the cavities may be multiple, thick walled, and irregular (Fig. 3-13). There is a high incidence of large pleural effusions, and empyema resulting from bronchopleural fistula is a common complication. Methicillin resistant staphylococcus aureus (MRSA) pneumonia usually occurs as a nosocomial infection in health care centers particularly in older, immunocompromised or intensive care unit patients.

Staphylococcal infection in the lungs may occur by way of the hematogenous route. This is usually the result of septic emboli, which arise in the central veins or as vegetations on cardiac valves, particularly in intravenous drug abusers and patients with indwelling intravenous catheters. The radiographic appearance is that of multiple nodular masses with or without cavitation, as previously described.

Streptococcus pyogenes

Streptococci (Box 3-4) are gram-positive cocci that occur in pairs and chains. The pneumonia occasionally occurs in epidemic proportions. This form of pneumonia is much less common than that caused by *Staphylococcus* or *S. pneumoniae* (pneumococcus).

The radiographic features include lower lobe consolidation, often occurring with a segmental distribution. Pleural effusions occur frequently, but localized empyema is unusual.

PNEUMONIAS CAUSED BY GRAM-NEGATIVE AEROBIC ORGANISMS

Pneumonias caused by gram-negative organisms usually are nosocomial pneumonias that affect hospitalized patients. These pneumonias tend to occur in patients maintained on artificial ventilators or in those who have intravenous catheters or a variety of other ancillary support systems. The incidence of gram-negative pneumonia acquired in the community is increasing, which may be related to the

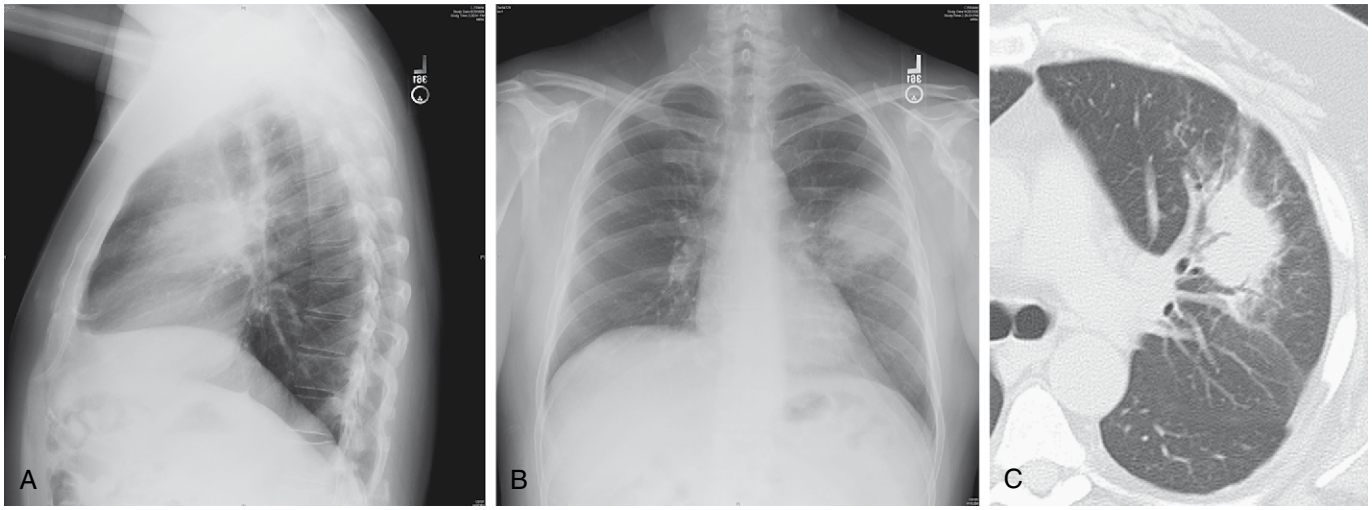


FIGURE 3-12. Rounded pneumonia. The lateral (**A**) and posteroanterior (**B**) chest radiographs and CT (**C**) of an adult patient shows an ill-defined, rounded opacity in the left upper lobe due to rounded pneumonia caused by pneumococcus. The opacity simulated a lung neoplasm radiographically, but it completely resolved after antibiotic therapy.

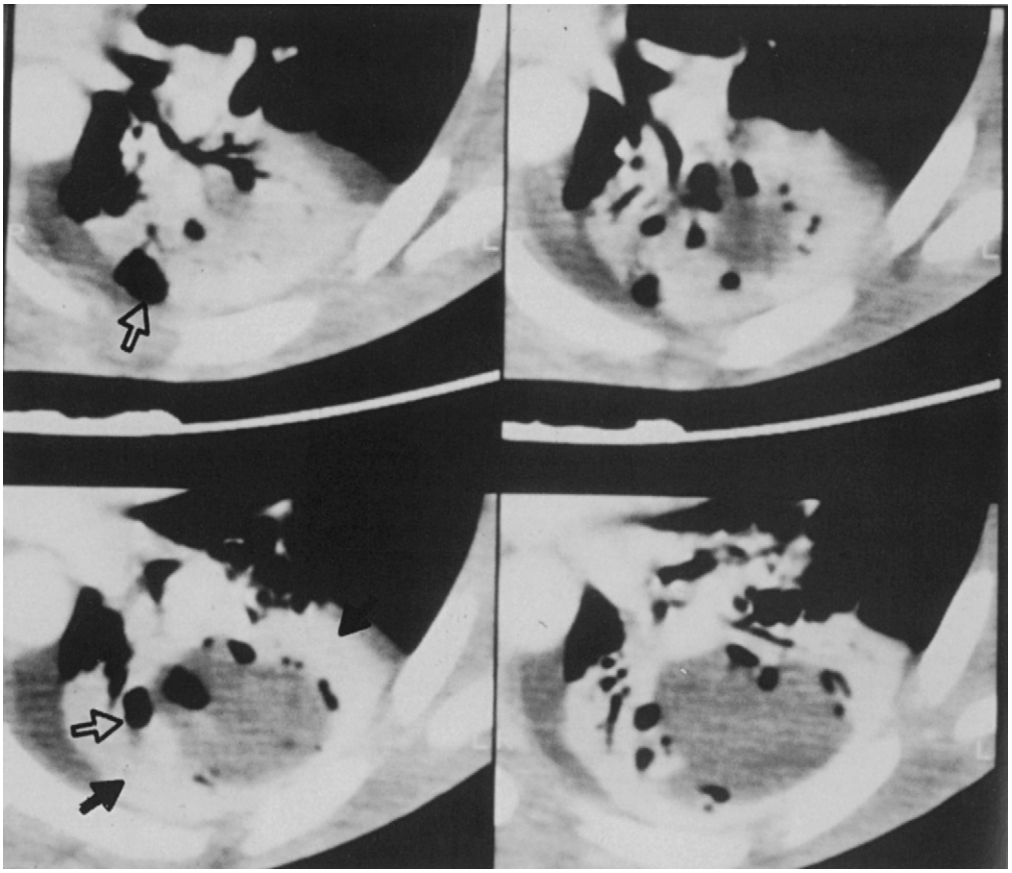


Figure 3-13. Staphylococcus aureus abscess. In the composite of four CT images of a patient with a left lower lobe staphylococcal abscess, notice the thick walls of the cavity *(closed arrows)* and the retained thick exudate in the center. Pockets of air in the peripheral regions of the cavity probably represent small pneumatoceles *(open arrows)*. (Courtesy of Dorothy L. McCauley, MD. New York University Medical Center, New York, NY.)

Box 3-4. **Streptococcus pyogenes**

CHARACTERISTICS
Gram-positive cocci
Uncommon but occasionally epidemic

RADIOGRAPHIC FEATURES
Consolidation
Segmental
Lower lobes
Effusion

Box 3-5. **Klebsiella pneumoniae**

CHARACTERISTICS
Middle-aged or elderly patients
Chronic lung disease and alcoholic patients

RADIOGRAPHIC FEATURES
Lobar consolidation
Bulging fissures
Cavitation
Pulmonary gangrene

overgrowth of resistant organisms because of widespread use of broad-spectrum antibiotics.

Klebsiella pneumoniae

Klebsiella pneumonia (Box 3-5) usually occurs in middle-aged or elderly patients, in those with underlying chronic lung disease, and in alcoholic individuals. Radiographic features consist of an upper lobe consolidation. Cavitation is common, and the lobar consolidation may lead to an expanded lobe with bulging interlobar fissures (see Fig. 3-2). If necrosis is extensive, pulmonary gangrene may develop.

Escherichia coli

E. coli pneumonia (Box 3-6) may be caused by direct extension from the gastrointestinal or genitourinary tract across the diaphragm or result from bacteremia. As is true of most of the gram-negative pneumonias, it is frequently characterized by the development of necrosis and multiple cavities. The lower lobes are more frequently involved.

Pseudomonas aeruginosa

P. aeruginosa pneumonia (Box 3-7) usually occurs in hospitalized patients, particularly those with debilitating disease (see Fig. 3-9). Organisms that affect the lungs often result from contamination of suction and tracheostomy devices. Radiographic features include a lower lobe predilection. However, the consolidation may spread rapidly to affect both lungs. Pleural effusions are uncommon. Multiple, irregular nodules may develop and are usually associated with bacteremia. These nodules may cavitate.

Haemophilus influenzae

H. influenzae pneumonia (Box 3-8) usually develops in patients with COPD. The appearance is typically that of a bronchopneumonia with homogeneous segmental opacities, usually in the lower lobes. Cavitation and pleural effusions are rare.

ASPIRATION PNEUMONITIS AND ANAEROBIC PNEUMONIA

Pulmonary aspiration (Box 3-9) is a common clinical problem. Many conditions predispose persons to aspiration, including reduced levels of consciousness, alcoholism, drug addiction, esophageal disease, periodontal and gingival disease, seizure disorders, and nasogastric tubes.

Box 3-6. **Escherichia coli**

CHARACTERISTICS
Direct extension from gastrointestinal or genitourinary tract
Results from bacteremia

RADIOGRAPHIC FEATURES
Necrosis, multiple cavities
Affects lower lobes

Box 3-7. **Pseudomonas aeruginosa**

CHARACTERISTICS
Hospitalized, debilitated patients
Tracheostomy tubes and suction devices

RADIOGRAPHIC FEATURES
Lower lobes, consolidation
Rapid spread to both lungs
Multiple, irregular nodules
Cavitation
Pleural effusions uncommon

Box 3-8. **Haemophilus influenzae**

CHARACTERISTICS
Chronic obstructive pulmonary disease (COPD)
Bronchopneumonia

RADIOGRAPHIC FEATURES
Homogeneous, segmental
Affects lower lobes

Box 3-9. **Aspiration Pneumonitis and Anaerobic Pneumonia**

CHARACTERISTICS
Common occurrence
Predisposing factors
- Reduced consciousness
- Alcoholism
- Drug addiction
- Seizures
- Esophageal disease
- Poor oral hygiene

CLINICAL SYNDROMES
Café coronary syndrome
- Obstruction of larynx or upper trachea
- Aphonia, respiratory distress, asphyxia

Bronchial obstruction
- Aspiration pneumonitis or pneumonia
  - Mouth organisms
  - Slow progression
- Aspiration of gastric acid
  - Mendelson's syndrome

RADIOGRAPHIC FEATURES
Normal appearance
Opaque foreign body in airway
Air trapping if bronchus obstructed
- Inspiratory-expiration radiographs
- Fluoroscopy

Atelectasis
Aspiration pneumonia
- Superior segments of lower lobes
- Posterior segments of upper lobes
- Basilar segments of lower lobes

Primary lung abscess
- Focal walled-off area of anaerobic pneumonia
- Superior segments of lower lobes
- Thick-walled cavity
- Air-fluid level
- Rounded, masslike lesion may precede cavitation

Aspiration pneumonitis
- No infection
- Patchy basilar opacities

Mendelson's syndrome (aspiration of gastric acid)
- Chemical pneumonitis and acute lung injury

Diffuse consolidation resembling pulmonary edema

Aspiration of particulate matter or foreign bodies may produce different clinical syndromes, depending on the size of the aspirated material and the level of airway obstruction. Large food particles or foreign bodies may be aspirated into the larynx and upper trachea, resulting in the so-called café coronary syndrome, which is caused by acute upper airway obstruction. These patients exhibit respiratory distress and aphonia.

Results of chest radiographs are usually normal for patients who have aspirated foreign bodies. If the foreign body is opaque, it may be visible in the airways. Air trapping may occur if the foreign body causes airway obstruction of one of the major bronchi. This can be demonstrated by inspiratory and expiratory radiographs, decubitus views, or chest fluoroscopy. Occasionally, complete obstruction of the bronchus results in atelectasis and, if the foreign body is unrecognized, in the development of distal pneumonitis or bronchiectasis.

Ninety percent of aspiration pneumonias and lung abscesses are caused by anaerobic organisms. The pathogens include *Prevotella*, *Bacteroides*, *Fusobacterium*, and *Peptostreptococcus*. Because of the presence of oxygen in the lung, the progression of anaerobic infection is slow, beginning in the dependent lung zones. If the patient is in a supine position when the aspiration occurs, the superior segments of the lower lobes are most commonly affected, with the right side affected more frequently than the left (Fig. 3-14). Aspiration can also affect the posterior segments of both upper lobes. Chronic or recurrent aspiration, particularly in patients who are in the upright position, usually results in consolidation involving the basilar segments of the lower lobes. The middle lobe and lingula are uncommon sites for aspiration pneumonia. Aspiration is the most common cause of a primary lung abscess (see Fig. 3-8).

A *primary lung abscess* refers to a focal, walled-off area of anaerobic pneumonia with central liquefaction necrosis. It is most commonly identified in the superior segments of either lower lobe. Lung abscesses have a fairly thick wall and may or may not have an air-fluid level. A rounded, masslike lesion may precede the development of cavitation.

Occasionally, aspiration of nontoxic material that contains insufficient bacteria to produce an infection or insufficient volume to produce atelectasis may occur. The radiographic appearance usually consists of basilar patchy opacities resembling atelectasis, and these areas clear within several days. Mendelson's syndrome is a specific form of aspiration that results from the aspiration of gastric acid. This event produces a chemical pneumonitis and acute lung injury. The radiographic manifestations of gastric aspiration are similar to those of noncardiogenic pulmonary edema. The distribution is usually diffuse.

ATYPICAL PNEUMONIA SYNDROME

Atypical pneumonia syndrome (Box 3-10) describes pneumonias that do not respond to usual empiric antimicrobial therapy or do not have clinical features distinctive from the usual bacterial pathogens responsible for community-acquired pneumonias. Originally, these atypical pneumonias were thought to be caused by viruses. However, other treatable organisms have emerged as important causes of atypical pneumonia, including *M. pneumoniae*, *L. pneumophila*, and *Chlamydia*. These nonviral, atypical pneumonias are for the most part readily treatable with antibiotics.

Most patients with atypical pneumonia present with a nonspecific syndrome consisting of fever, usually without shaking chills, and nonproductive cough, headache, myalgias, and some degree of dyspnea. This contrasts with the classic presentation of bacterial pneumonia, which is characterized by abrupt onset with fever, shaking chills, and purulent sputum, often with chest pain. Patients with the latter signs and symptoms usually have a bacterial pneumonia attributable to pneumococci, group A streptococci, *Klebsiella*, *S. aureus*, or *H. influenzae*. Many of the atypical pneumonias are associated with extrapulmonary manifestations. For example, diarrhea is a prominent part of *Legionella* and *Mycoplasma* infection.

Mycoplasma pneumoniae

M. pneumoniae (Box 3-11) accounts for approximately 20% of all cases of pneumonia. It usually occurs during the winter months in enclosed populations, such as students in college dormitories. The incubation period is 2 to 3 weeks, and the onset is often insidious, with low-grade fever and nonproductive cough. Extrapulmonary manifestations may include otitis, nonexudative pharyngitis, and diarrhea.

The radiographic features are usually those of a fairly diffuse, interstitial, fine reticulonodular pattern. This may evolve to patchy airspace consolidation, particularly in the lower lobes (Fig. 3-15). Hilar adenopathy is seen in approximately 20% to 40% of patients. The radiographic appearance is very similar to that of many viral infections. The diagnosis is made by serologic evaluation.

Legionnaires' Disease

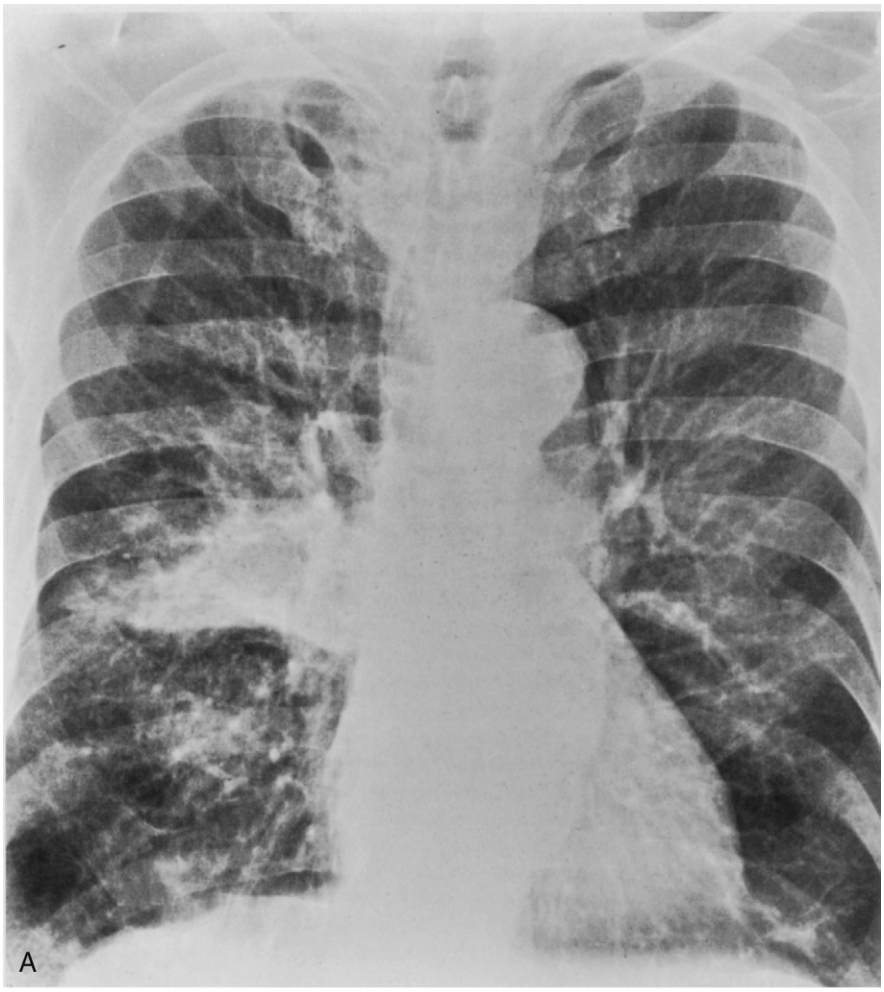
The first outbreak of Legionnaires' disease was recognized in Philadelphia at a Legionnaires' convention (Box 3-12).

Clinical Features

Clinical features include acute febrile illness without pneumonia; systemic disease with primarily pulmonary manifestations; a peak incidence in patients older than 60 years; a predisposition in smokers and those with alcoholic liver disease; high fever, shaking chills, and cough with small amounts of mucoid sputum; pleuritic chest pain; watery diarrhea in about one half of patients; and headache. The organism is spread by airborne transmission, usually through moist air exhaust or cooling towers.

Radiographic Features

The radiographic features of Legionnaires' disease often consist of segmental opacification and consolidation, particularly of an upper lobe. Rapid development of coalescence with complete consolidation of an involved lobe and rapid extension to adjacent lobes are common features (Fig. 3-16). Parenchymal changes are extensive, but pleural effusions are uncommon. The diagnosis of Legionnaires' disease is usually made by serology using indirect fluorescent antibody. Direct identification of the organism may



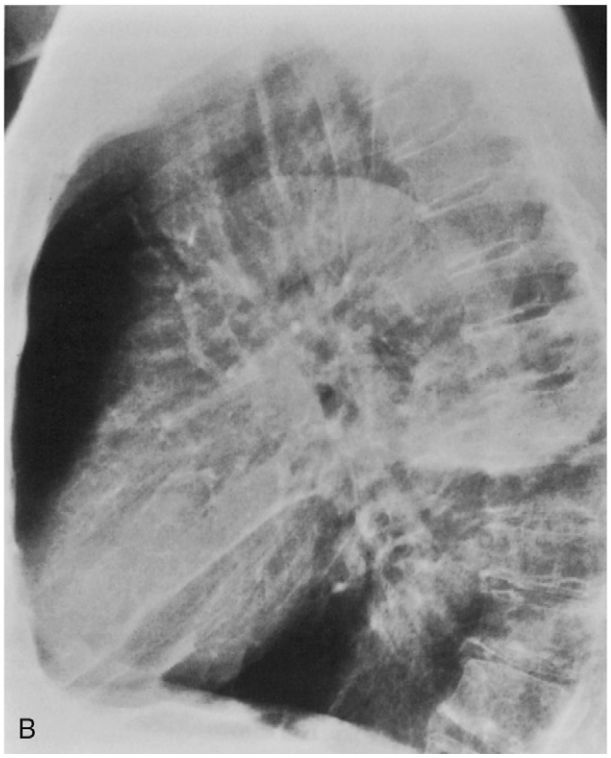


FIGURE 3-14. Aspiration pneumonia in a patient with a history of seizures. The posteroanterior (**A**) and lateral (**B**) chest radiographs demonstrate consolidation in the superior segment of the right lower lobe.

Box 3-10. Atypical Pneumonia Syndrome

ATYPICAL PNEUMONIA
Clinical Features
Nonproductive cough
Fever
Dyspnea
Headache, myalgias
Extrapulmonary manifestations
Organisms
Legionella
Mycoplasma
Chlamydia
Viruses

TYPICAL PNEUMONIA
Clinical Features
Abrupt onset
Fever with chills
Productive cough
Purulent sputum
Chest pain
Organisms
Streptococcus pneumoniae (pneumococcus)
Group A *Streptococcus*
Staphylococcus aureus
Haemophilus influenzae

Box 3-11. Mycoplasma pneumoniae

CHARACTERISTICS
Accounts for 20% of pneumonias
Occurs most often in winter
Affects enclosed populations

RADIOGRAPHIC FEATURES
Diffuse
Reticulonodular pattern evolves to patchy consolidation
Hilar adenopathy (20% to 40% of cases)
Similar to viral infections

be confirmed by direct fluorescent antibody (DFA) techniques using properly collected specimens.

Chlamydia

Chlamydia, a long recognized cause of pneumonia in neonates, is an increasingly frequent cause of community-acquired atypical pneumonia in adult patients (Box 3-13). It is caused by the TWAR agent *(Chlamydia pneumoniae)*. *Chlamydia* pneumonia may occur in compromised and noncompromised adults as an atypical pneumonia. The disease is characterized by fever and nonproductive cough. It is often preceded by pharyngitis.

Radiographic features may be similar to those of *Mycoplasma* pneumonia. However, more commonly there is a localized area of consolidation in the middle or lower lobes, which may be patchy or homogeneous (Fig. 3-17).

Other Nonviral Atypical Pneumonias

Atypical nonviral pneumonias are rare. They include psittacosis; Q fever, a rickettsial disease; and tularemia.

Chlamydia psittaci is the etiologic agent of psittacosis, which may be transmitted by any avian species, and it is contracted by inhalation of infected aerosol material. The clue to the diagnosis is the history, which should include information about any contact with birds. Psittacosis usually mimics a standard bacterial pneumonia on chest radiography.

Coxiella burnetii is the etiologic agent of Q fever, which is a rickettsial disease. It is most common in the western and southwestern parts of the United States, and it can be transmitted by infected dust from animals. The radiographic features vary, but the most specific pattern simulates mycoplasma or viral pneumonia and usually consists of bilateral, diffuse reticulonodular opacities.

Tularemia, another animal-associated, atypical pneumonia, is transmitted by ticks in summer and rabbits in winter. There is an ulceroglandular form, which produces a skin papule that eventually ulcerates at the port of entry. Regional lymph nodes may become enlarged and eventually drain and ulcerate. In the typhoidal form, no portal of entry is apparent, but patients are characteristically extremely ill with gastrointestinal symptoms. Pneumonia may occur in patients with either of these presentations.

The most common radiographic feature is that of a localized and homogenous opacity, but lobar consolidation has also been reported. Occasionally, multiple lobes are involved. Bilateral hilar adenopathy may occur.

VIRAL PNEUMONIAS

Primary respiratory viruses (Box 3-14) include the parainfluenza and influenza group of viruses, respiratory syncytial virus (RSV), adenovirus, and picornavirus. The incidence of these infections varies with the age of the patient. For example, in children, RSV is responsible for up to 85% of epidemic lower respiratory tract infections and up to 60% of all pneumonias; in adults, the influenza and parainfluenza groups are responsible for most of the epidemic viral pneumonias. They usually occur during late winter. Adenovirus and picornavirus cause nonepidemic respiratory infections. Other viruses (e.g., cytomegalovirus) produce pneumonia as part of a systemic infection.

In all cases, the infection usually begins in the larger central airways. At this stage, the chest radiograph frequently appears normal. The radiologic correlates of severe inflammation and edema of the bronchial walls include coarse reticular opacities in the form of rings and parallel lines (i.e., tram tracks) due to bronchial wall thickening in the central perihilar lung zones. When the small airways are involved, bronchiolitis develops. Involvement of terminal bronchioles may lead to airway obstruction. This is more likely to occur in infants and young children because the cross-sectional area of the airways is small. Diffuse overinflation and air trapping can be visualized.

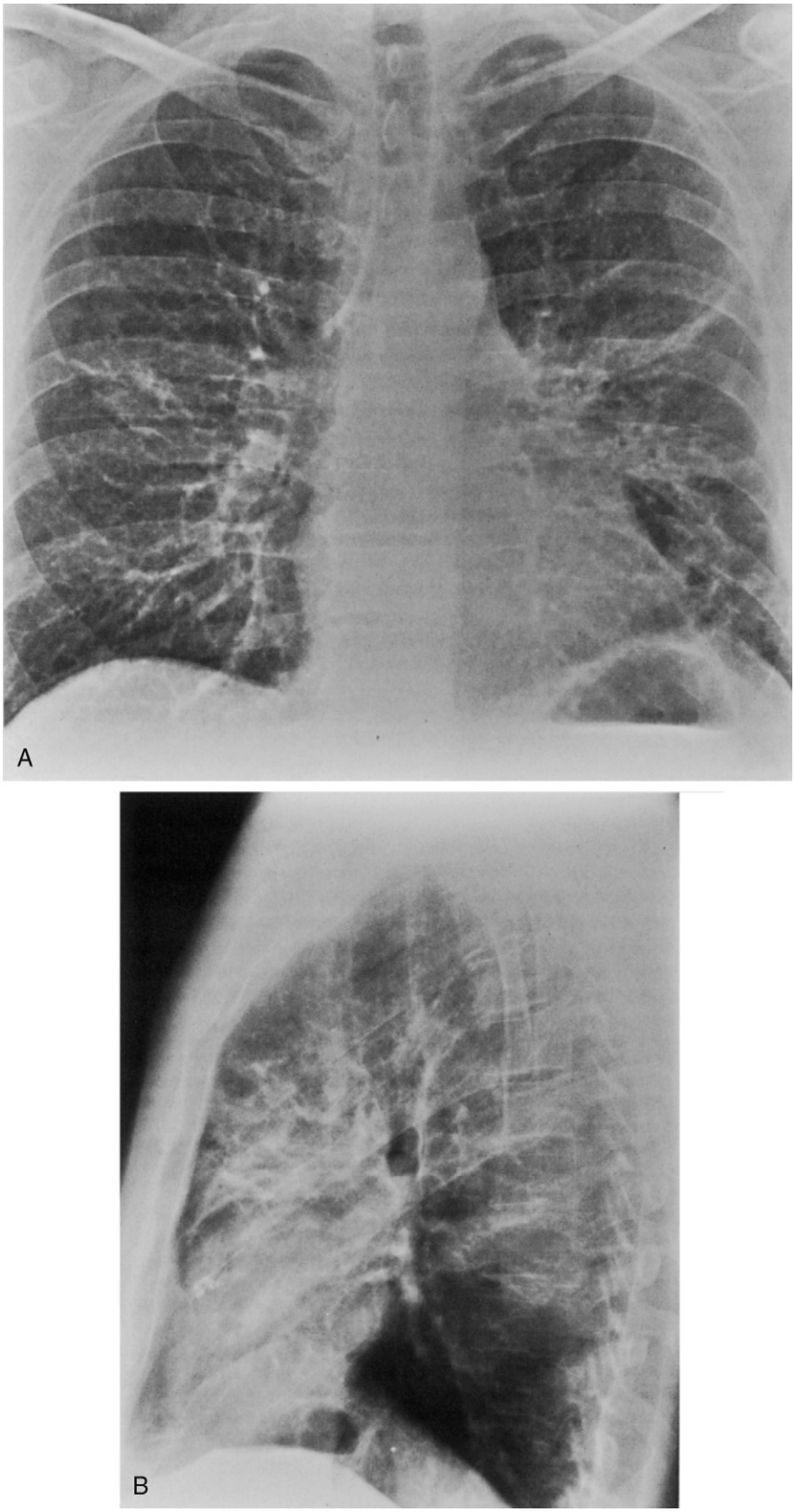


FIGURE 3-15. *Mycoplasma* pneumonia. **A** and **B**, Patchy, bilateral areas of inhomogeneous consolidation involve multiple lobes.

Box 3-12. Legionnaires' Disease

CHARACTERISTICS
Respiratory or systemic symptoms
Patients older than 60 years
Diarrhea common
Airborne spread through moist air exhaust or cooling towers
Diagnosis by serology with indirect fluorescent antibody

RADIOGRAPHIC FEATURES
Consolidation
Affects upper lobes
Rapid spread to other lobes

When the infection spreads to the alveoli, the disease is usually limited to the parenchyma around the terminal airways. The radiographic features in children and adults usually consist of a diffuse reticulonodular pattern, often with focal and patchy areas of consolidation (see Fig. 3-4). Multiple lobes are usually involved. CT may reveal the anatomic localization of the disease. The bronchiolitis and surrounding inflammation produces nodular opacities, which are located in the center of the lobules. Branching centrilobular opacities represent impaction of small airways, and their appearance has been referred to as the *tree-in-bud pattern* (Fig. 3-18). Other common CT findings of viral pneumonia include ground-glass attenuation with a lobular distribution and foci of segmental and subsegmental consolidation.

Influenza

Influenza is one of the most frequently reported contagious diseases. Symptoms include fever, nonproductive cough, weakness, and myalgias. Most patients who develop severe pneumonia have underlying disease or superinfection with bacterial organisms.

Radiographic features may reflect the complicating bacterial pneumonia. However, a diffuse reticulonodular pattern may be seen in infants and children with the disease.

Adenovirus

Adenovirus may occur in epidemic or pandemic proportions. When pneumonia develops, there may be destructive changes involving the peripheral airways, leading to chronic bronchitis, bronchiectasis, and bronchiolitis obliterans. Symptoms tend to persist after resolution of pneumonia. Radiographic features are very similar to pneumococcal pneumonia in pattern and distribution.

Respiratory Syncytial Virus

RSV, rarely reported in adults, is the most prevalent respiratory viral pathogen in the first 6 months of life. It usually produces focal and diffuse bronchiolitis. If radiographs are abnormal, they usually show increased lung volumes and air trapping, and linear interstitial opacities occasionally may be identified.

Varicella-Herpes Zoster

Varicella-herpes zoster (i.e., chickenpox) infection may be responsible for severe pneumonia in adults. The radiographic features are fairly characteristic. They consist of nodules ranging from 4 to 6 mm in diameter, with ill-defined margins diffusely distributed throughout both lungs (Fig. 3-19). Radiographic resolution usually occurs over many weeks. One of the interesting sequelae of chickenpox pneumonia is the development of diffuse, discrete pulmonary calcifications that can be identified on routine radiographs obtained after the infection (Fig. 3-20). Histoplasmosis should be considered in the differential diagnosis of this radiologic appearance.

Cytomegalovirus

Cytomegalovirus infection is discussed in Chapter 4.

Epstein-Barr Virus

The Epstein-Barr virus is the presumed etiologic agent for infectious mononucleosis. Although upper respiratory symptoms predominate, patients may develop a nonproductive cough. The chest radiograph is usually normal, but occasionally, pronounced hilar lymph node enlargement with an ill-defined, diffuse reticular pattern in the lungs may be seen.

GRANULOMATOUS INFECTIONS

Mycobacterial Disease

Mycobacteria are aerobic, nonmotile, non–spore-forming rods that have in common the characteristics of staining bright red with carbol fuchsin and resistance to discoloration by strong acid solutions. The organisms are therefore referred to as acid-fast bacilli (AFB). There are several mycobacterial species, but the most important include *Mycobacterium leprae*, the cause of leprosy; *M. tuberculosis* and *Mycobacterium bovis*, responsible for tuberculosis; and the nontuberculous mycobacteria that are important etiologic agents in the development of pulmonary disease.

Tuberculosis

Characteristics

In the latter part of the 19th century, tuberculosis (Box 3-15) was a leading cause of death in the United States. The advent of drug therapy and improved public health measures led to a steady decline in the incidence of tuberculosis after World War II until 1985. For the next 7 years, a slow but steady increase in the incidence of tuberculosis was observed. This rise was primarily attributed to a large number of cases associated with acquired immunodeficiency syndrome (AIDS). Immigration into the United States of individuals from third world countries also might have contributed to the increased prevalence of tuberculosis.

Since 1993, the rate of tuberculosis has declined considerably. In 2006, the rate of tuberculosis in the United States was the lowest since the beginning of national record keeping in 1953. The tuberculosis rate is continuing to decline, but the rate of decline has recently slowed.

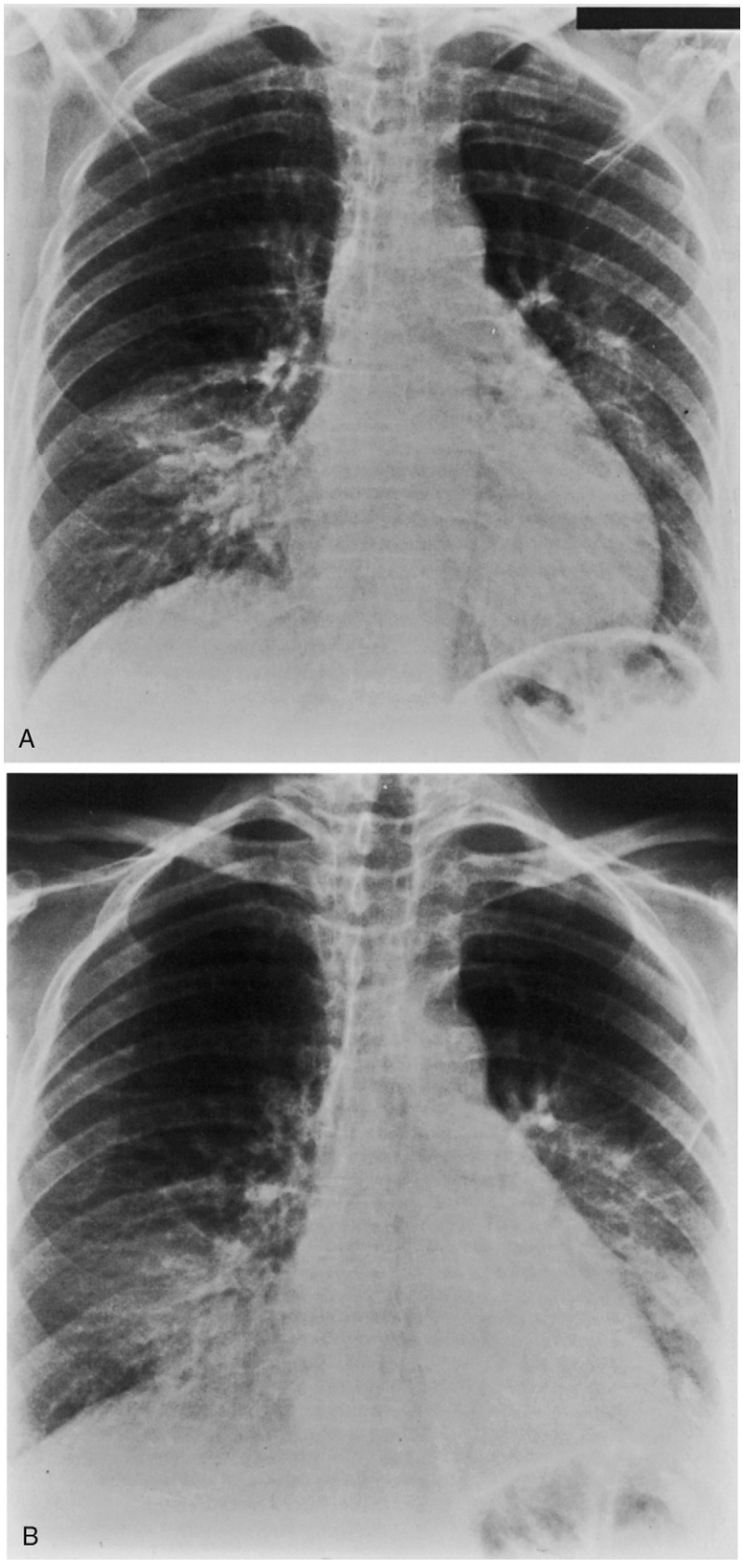


FIGURE 3-16. Legionnaires' disease. **A**, The posteroanterior chest radiograph shows consolidation involving the right middle lobe and left middle lung zones. **B**, Twenty-four hours later, the consolidation has become more extensive bilaterally.

Box 3-13. *Chlamydia* **Pneumonia**

CHARACTERISTICS
Chlamydia pneumoniae (TWAR agent)
Nonproductive cough
Preceding pharyngitis

RADIOGRAPHIC FEATURES
Localized consolidation in lower lobes
Patchy or homogeneous pattern

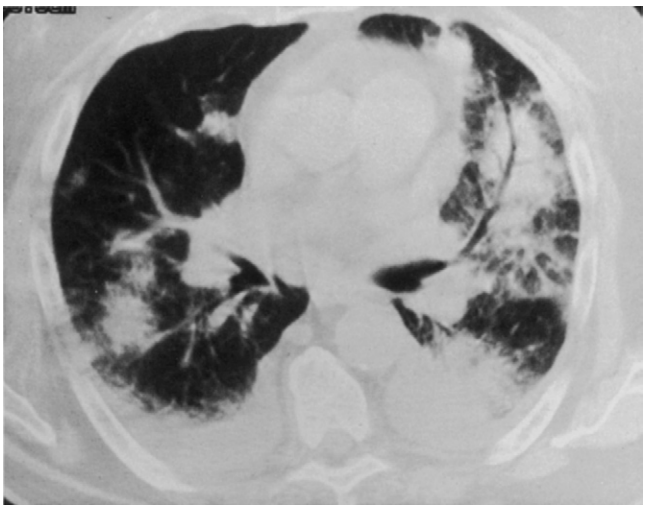


FIGURE 3-17. *Chlamydia* pneumonia. CT scan demonstrates bilateral, patchy areas of consolidation.

Box 3-14. **Viral Pneumonias**

CHARACTERISTICS
Viral organisms
- Influenza
- Parainfluenza
- Respiratory syncytial virus (RSV)
- Adenovirus
- Picornavirus

RADIOGRAPHIC FEATURES
Larger airways
- Normal radiograph
- Tram tracks and ring shadows

Small airways (bronchiolitis)
- Normal appearance
- Overinflation and air trapping
- Tree in bud opacities - CT

Alveoli
- Diffuse reticulonodular opacities
- Focal patchy consolidation
- Ground glass opacities - CT

From 1993 to 1997, there was also a decrease in the percentage of multidrug-resistant tuberculosis cases among persons with no prior history of tuberculosis, with a reduction from 2.4% to 1.1%. Since 1997, the rate has remained steady at approximately 1%.

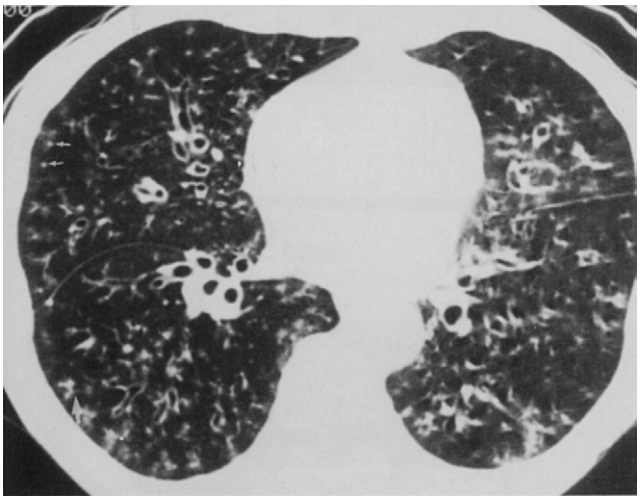


FIGURE 3-18. Tree-in-bud appearance. Peripheral branching opacities *(single arrow)* and centrilobular nodules 2 to 3 mm deep to the pleura *(double arrows)* can be identified. The appearance results from small airways filled with secretions and inflammatory debris.

In the United States, tuberculosis case rates vary considerably among different racial and ethnic populations and are lowest among whites. For example, compared with whites, the case rates are nearly 25 times higher for Asians and 10 times higher for blacks and Hispanics. The rate of tuberculosis among foreign-born persons in the United States is nearly 10 times higher than that of persons born in the United States. Other susceptible populations include the aged and the immunocompromised, particularly patients with AIDS.

Pathology and Pathogenesis

Infection with tuberculosis occurs as the result of inhalation of airborne droplets containing the tubercle bacilli. The initial infection, referred to as *primary tuberculosis*, is most common in the lower lobes. The bacteria are ingested by macrophages and initially spread to local lymph nodes at this stage, and they then may disseminate throughout the body. The infection is usually contained if the host is immunocompetent. However, walled-off tubercle bacilli representing a dormant focus of tuberculosis may activate under appropriate conditions. This may occur in the second type of tuberculosis, referred to as *reactivation or postprimary tuberculosis*.

Reactivation or post primary tuberculosis can occur any time after the primary infection, but the highest rate of reactivation occurs during the first and second years after the initial infection. Reactivation tuberculosis usually involves the lung apex, but a dormant focus of tuberculosis may become active in other organs, such as the bones, kidney, or brain. Clinically active disease may develop at the time of primary tuberculous infection (i.e., primary progressive tuberculosis) or when dissemination occurs (i.e., miliary tuberculosis). Clinical reactivation disease results when there is an ineffective T-cell immune reaction. The typical pathologic feature of tuberculosis is the caseating granuloma.

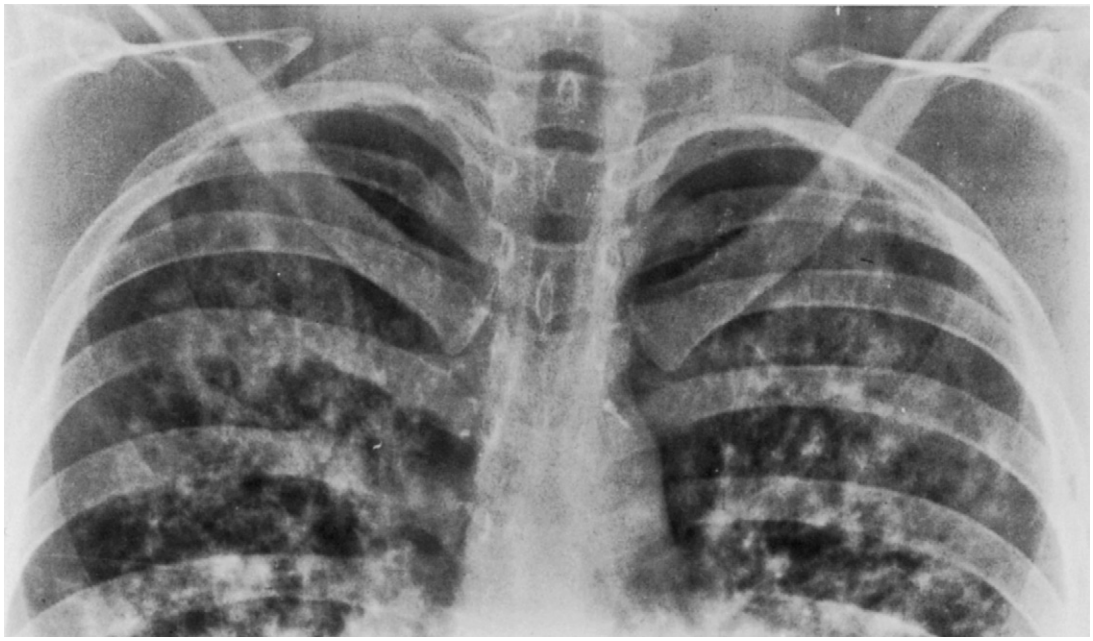


FIGURE 3-19. Varicella (chickenpox) pneumonia. Coned-down view of the upper lobes shows multiple, ill-defined nodules in both upper lobes.

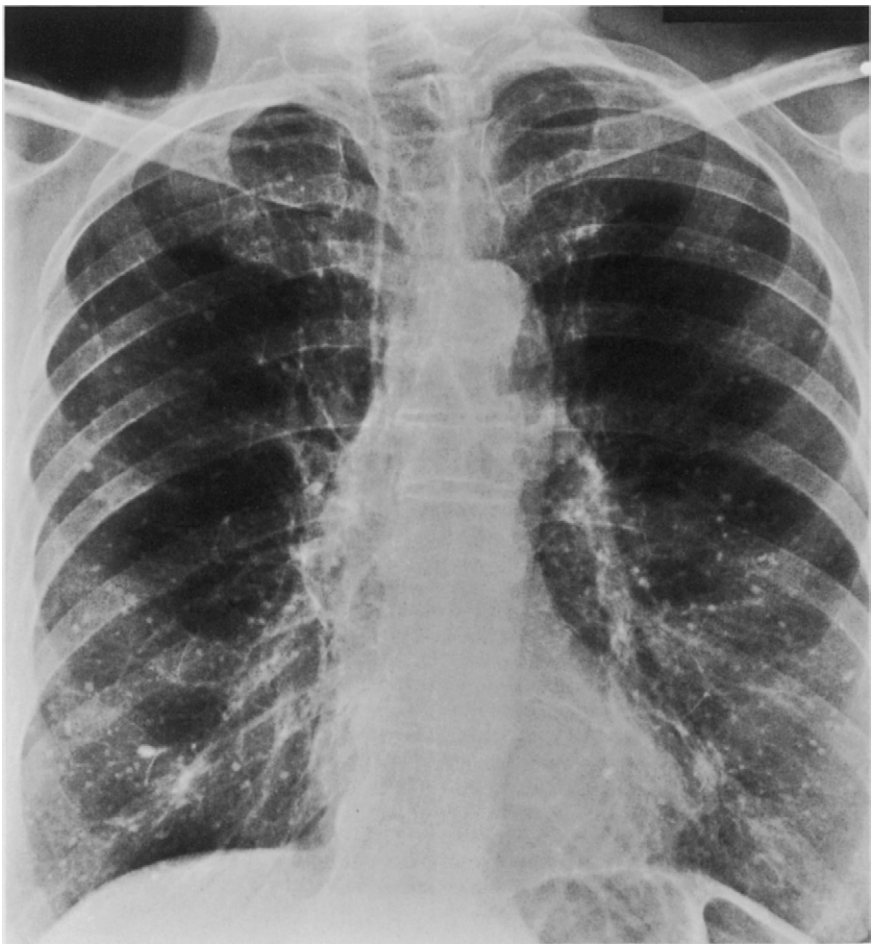
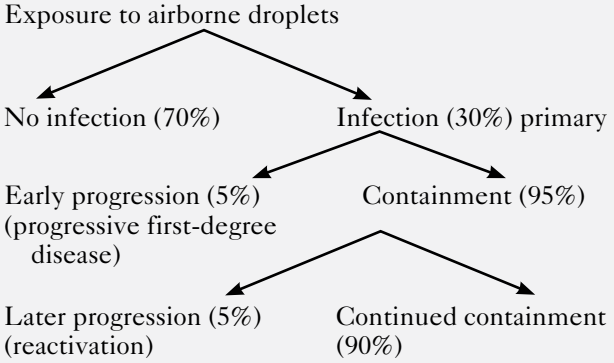


FIGURE 3-20. Healed varicella pneumonia. Multiple 1- to 3-mm calcified nodules can be seen in both lungs.

Box 3-15. **Tuberculosis Clinical Features**

EPIDEMIOLOGY
Increased incidence since 1985 due to AIDS, immigrants
Susceptible populations
- Human immunodeficiency virus positive
- Diabetes
- After gastrectomy
- Homeless
- Elderly in nursing homes
- Immigrants from endemic areas

PATHOGENESIS
Exposure to airborne droplets



CLINICAL FINDINGS
Primary
- Asymptomatic
- Symptomatic pneumonia

Reactivation
- Chronic cough
- Weight loss
- Hemoptysis

Positive skin test for 95%
Diagnosis by culture of organism

Clinical Findings

Patients with primary tuberculosis are usually asymptomatic but occasionally may have a symptomatic pneumonia. Patients with acute or chronic reactivation tuberculosis usually present with a chronic cough, weight loss, and occasionally with hemoptysis and dyspnea. The symptoms are often insidious. Ninety-five percent of patients with active tuberculosis have a positive tuberculin skin test result. The diagnosis must be made on the basis of culture of the organism, although the presence of AFB on the smear from the sputum is strong presumptive evidence of tuberculosis.

Classification of tuberculosis into primary or reactivation phases is based on the radiographic appearance. In third world countries and in the United States during 19th and early 20th centuries, primary tuberculosis was a disease of children, and reactivation tuberculosis was typically a disease of young adults. However, a significant change in the pattern of adult tuberculosis has occurred in the past several decades. Because of diminished exposure of children to tuberculosis, the disease often occurs in the primary form in adults. This has resulted in atypical radiographic manifestations of tuberculosis in adults, attributable to primary infection rather than reactivation of the disease.

Radiographic Features

Primary Tuberculosis

The radiographic features of primary tuberculosis are summarized in Box 3-16. Primary tuberculous pneumonia can occur in any lobe of the lung but is more common at the lung bases (Fig. 3-21). In more than one half of cases, the disease occurs in the lower lobes. Any chronic consolidation, particularly in the bases of the lungs, may suggest tuberculosis. Cavitation, although rare in primary tuberculosis, is more frequently reported in adults than in children with the primary form of disease.

Mediastinal and hilar adenopathy is another feature of primary tuberculosis (Fig. 3-22). It may occur alone or in association with consolidation in the lung. It tends to be particularly predominant in children. CT may be helpful in identifying and localizing adenopathy. On CT scans, tuberculous adenopathy has a predilection for the right paratracheal, right tracheobronchial, and subcarinal regions. Occasionally, atelectasis may result from extrinsic obstruction of a bronchus by enlarged lymph nodes. On CT scans obtained with intravenously administered contrast material, these nodes often demonstrate low-attenuation necrotic centers.

Pleural effusion due to tuberculous pleurisy, also a feature of primary infection, develops when subpleural foci of tuberculosis rupture into the pleural space. Patients present 3 to 7 months after the initial exposure. Organisms are rarely found in the fluid, and the diagnosis must be confirmed with a pleural biopsy.

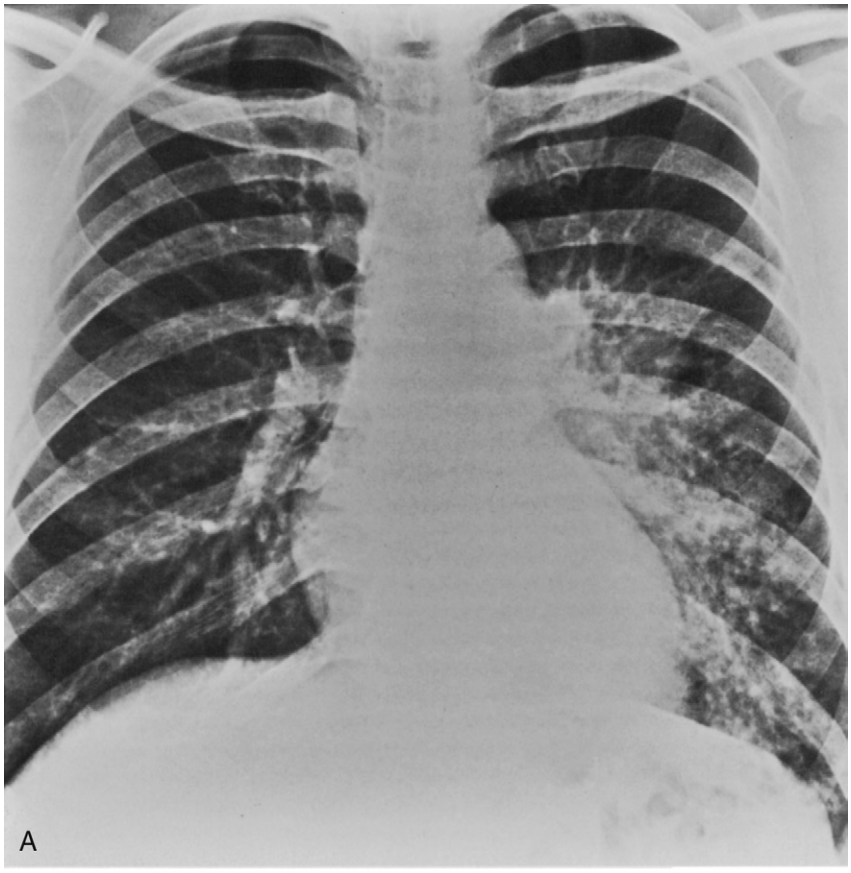
Box 3-16. **Tuberculosis: Radiographic Features**

PRIMARY TUBERCULOSIS
Tuberculous pneumonia
- Basilar consolidation
- Cavitation rare

Mediastinal and hilar adenopathy
- Children
- Right side
- CT shows rim enhancement

Pleuritis
Ghon lesion and Rhanke complex
Calcification
Healed lesions

REACTIVATION TUBERCULOSIS
Apical and posterior segments, upper lobes, and superior segments, lower lobes
Patchy areas of consolidation
Cavitation
Bronchogenic spread, tree in bud opacities on CT
Chronic pattern
- Fibronodular
- Fibrocalcific
- Volume loss
- Bronchiectasis



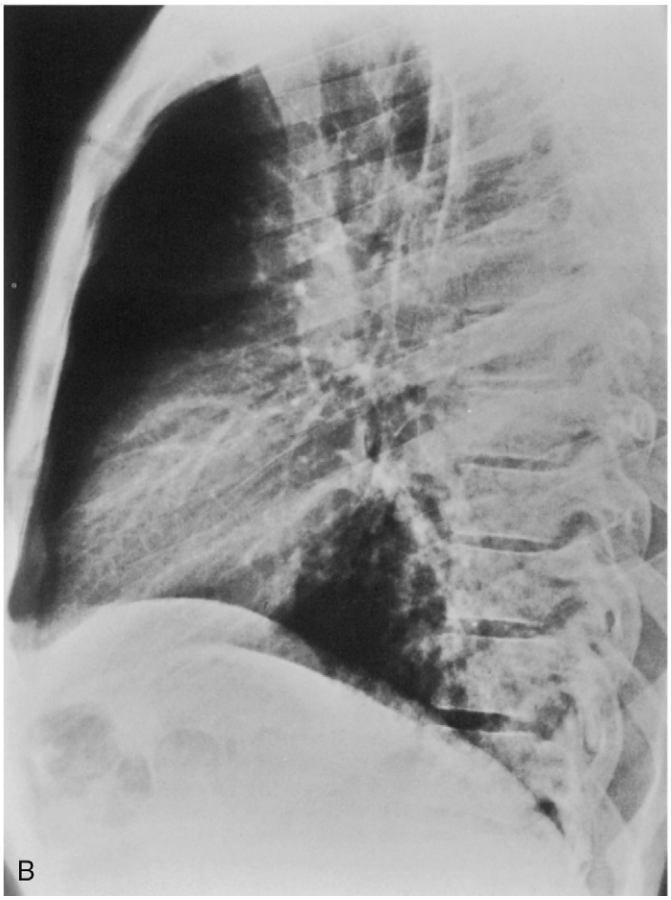


FIGURE 3-21. Posteroanterior (**A**) and lateral (**B**) views show primary tuberculous pneumonia. A patchy consolidation can be seen in the left lower lobe.

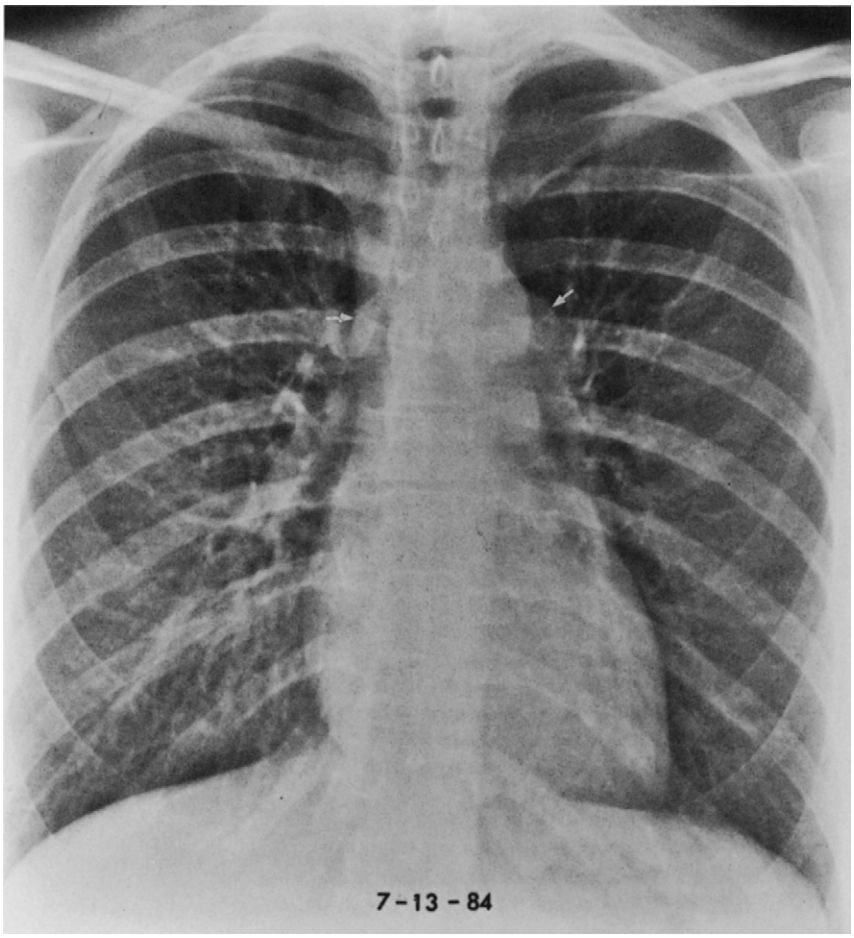


Figure 3-22. Mediastinal adenopathy in primary tuberculosis. A young, black woman presented with cervical adenopathy. The posteroanterior chest radiograph shows enlargement of the right paratracheal and left aorticopulmonary window nodes *(arrows)*.

The *Ghon lesion* (Fig. 3-23) is a manifestation of primary tuberculosis, which usually occurs in childhood and is self-limited. The host defense mechanisms handle the initial infection, and the area of consolidation in the lung slowly regresses to a well-circumscribed nodule. This nodule then shrinks and may disappear completely or remain as a solitary, calcified granuloma. The adenopathy regresses and may also exhibit calcification (i.e., Rhanke complex).

Reactivation Tuberculosis

Reactivation tuberculosis usually occurs in the apical and posterior segments of the upper lobes and in the superior segment of the lower lobes. It is characterized by chronic, patchy areas of consolidation (Fig. 3-24). Cavitation is a hallmark of reactivation tuberculosis (Fig. 3-25). Cavities result when areas of caseation necrosis erode into the bronchial tree, expelling liquefied debris. CT is more sensitive than plain radiography in the detection of small cavities (Fig. 3-26). They may have thick or thin walls, which can be smooth or irregular. Bronchogenic spread of tuberculosis occurs when a cavity erodes into an adjacent airway and organisms spread endobronchially to other parts of the lung.

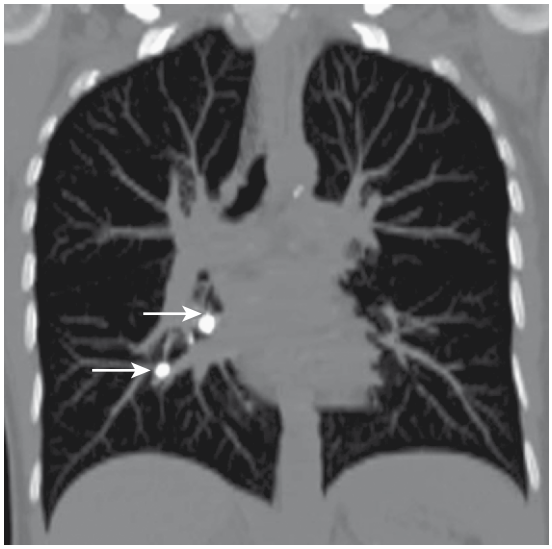


Figure 3-23. Ghon lesion and Rhanke complex. Coronal reformation chest CT image (bone windows) of a patient previously exposed to *Mycobacterium tuberculosis* shows a calcified right lower lobe nodule *(arrow)*, together with a calcified right hilar node (i.e., Rhanke complex) *(arrow)*.

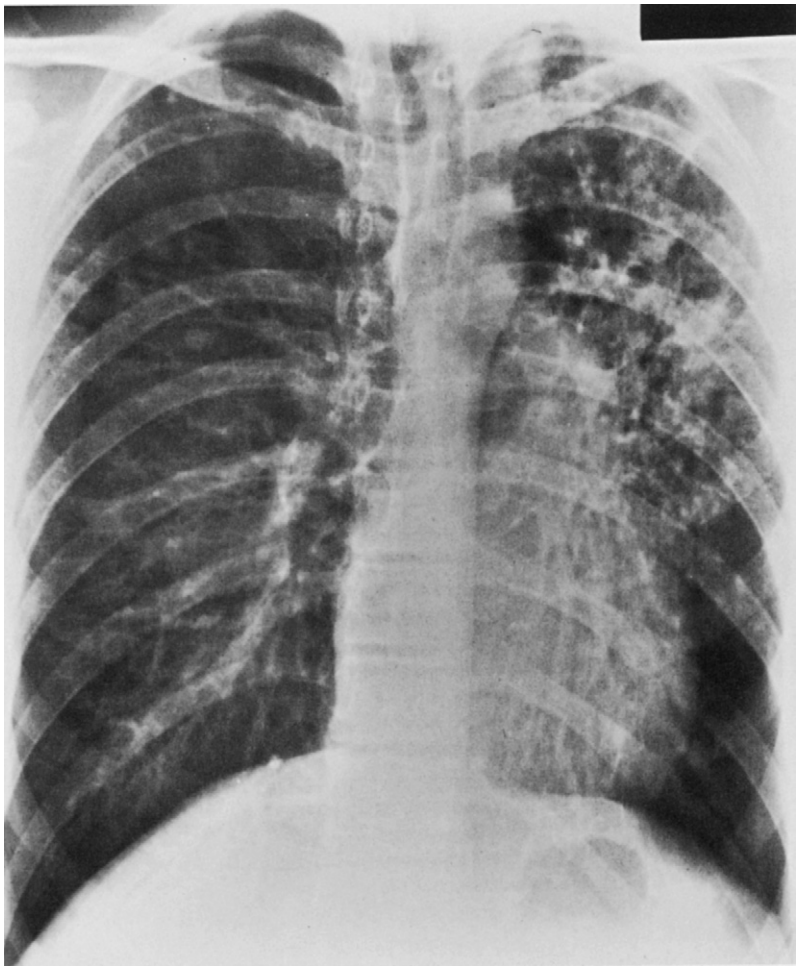


Figure 3-24. Reactivation tuberculosis. Patchy areas of consolidation involve the left upper lobe and superior segment of the left lower lobe. There is also evidence of some volume loss with a shift of the trachea to the left, a common finding with *Mycobacterium tuberculosis* infection, even in the early stages of disease. Nodular lesions can be identified in the right upper lobe.

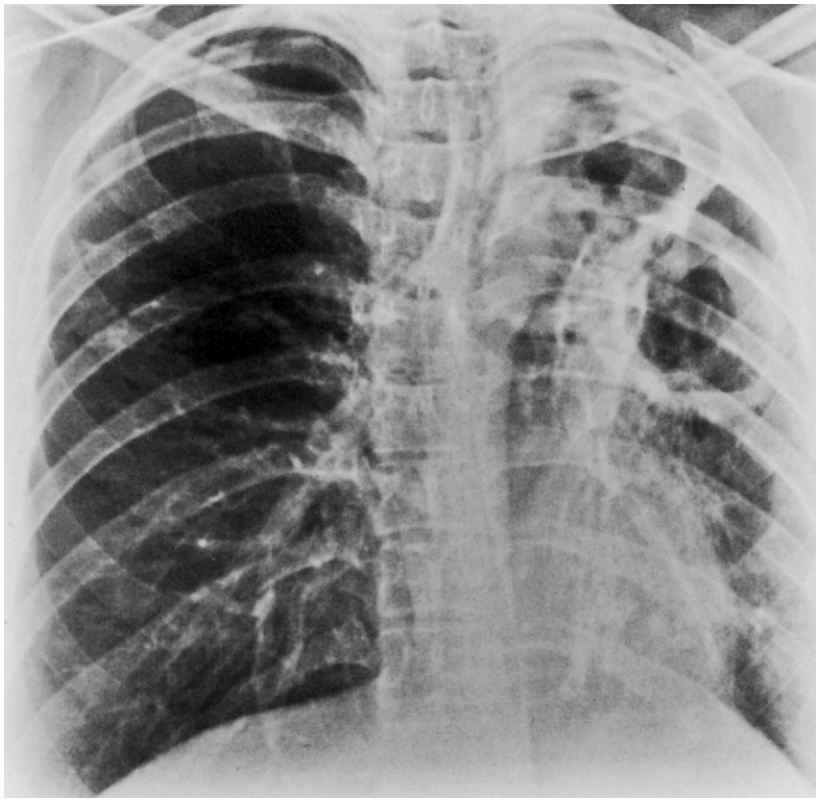


Figure 3-25. Cavitary tuberculosis. The posteroanterior chest radiograph shows multiple cavities in the left upper lobe. A thick-walled cavity can be seen lateral to the left hilum. There is pronounced volume loss in the left upper lobe and apical pleural thickening.

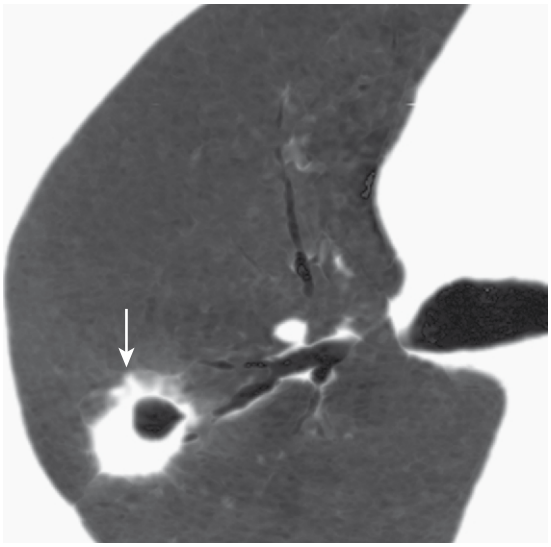


Figure 3-26. Cavitary tuberculosis. Minimal intensity projection CT image of a patient with reactivation tuberculosis shows a thick-walled cavity *(arrow)* in the posterior segment of the right upper lobe.

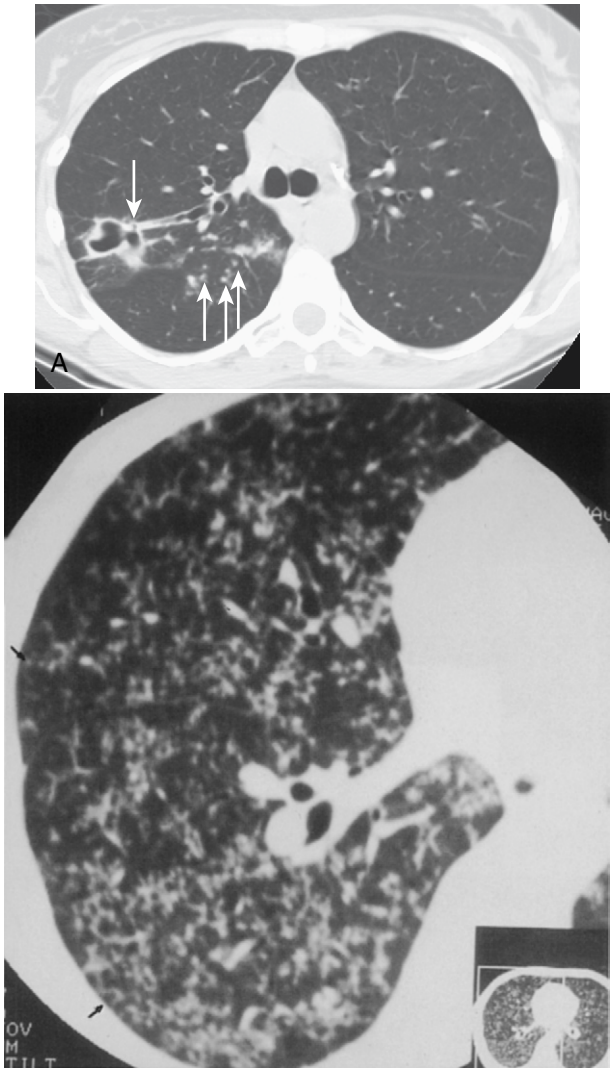


Figure 3-27. Bronchogenic spread of tuberculosis. **A**, CT shows a cavitary nodule communicating with the right upper lobe posterior segment bronchus *(single arrow)*, with associated centrilobular nodular opacities in the superior segment of the right lower lobe *(three arrows)*. **B**, CT of another patient shows a typical tree-in-bud pattern. Centrilobular nodules and branching opacities can be identified close to the pleural surface *(arrows)*.

The typical radiographic features (Fig. 3-27) consist of ill-defined nodules that usually are 5 to 6 mm in diameter. They are numerous and often bilateral. On CT, the pattern of bronchogenic spread can easily be recognized by a tree-in-bud pattern. This consists of centrilobular, branching, linear opacities with or without the presence of centrilobular nodules within 3 to 5 mm of the pleural surface or interlobular septa. This pattern is best appreciated on high-resolution CT (HRCT). It is not specific for bronchogenic spread of tuberculosis and may occur in other inflammatory diseases involving the peripheral airways.

The chronic lesion of reactivation tuberculosis usually consists of fibronodular opacities in the upper lobes, often with the presence of calcification (Fig. 3-28). It is usually associated with volume loss and retraction of the hila. Another feature of chronic reactivation tuberculosis is bronchiectasis. Tuberculosis should be considered in the differential diagnosis of upper lobe bronchiectasis. The activity of tuberculous disease cannot be determined by radiographs; it is confirmed only by positive cultures. However, tuberculosis is considered radiographically stable if there has been no change over 6 months.

Other Radiographic Features of Tuberculosis

Unusual patterns of tuberculosis (Box 3-17) may occur in the patient who has altered host resistance to the primary infection. *Miliary tuberculosis* is a term used to describe diffuse hematogenous dissemination of tuberculosis that has progressed when the host defense system is overwhelmed by massive hematogenous dissemination of organisms. It may occur at any time after the primary infection. The radiographic appearance (Fig. 3-29) is that of multiple, tiny nodules in the interstitium of the lung that are approximately 1 to 2 mm in diameter. CT may allow earlier detection than standard radiography (Fig. 3-30). Miliary disease takes up to 6 weeks to become apparent on plain radiographs.

Pneumothorax occasionally results from tuberculosis. Tuberculosis may also cause ulceration of the bronchi, and advanced endobronchial tuberculosis may produce lobar atelectasis and strongly simulate a primary carcinoma of the lung. A localized nodular focus of tuberculosis, referred to as a *tuberculoma* (Fig. 3-31), occurs in any portion of the lung and may result from primary or reactivation tuberculosis. It is usually solitary, spherical, and smooth. It may contain a central calcification, but tuberculomas occasionally may be multiple and simulate metastatic disease.

Tuberculous empyema and *bronchopleural fistula* may result from a tuberculous pleural effusion. Such effusions can become loculated and remain dormant for years.

Radiographic patterns of tuberculous disease in patients with acquired immune deficiency syndrome (AIDS) may vary. They are described in Chapter 4.

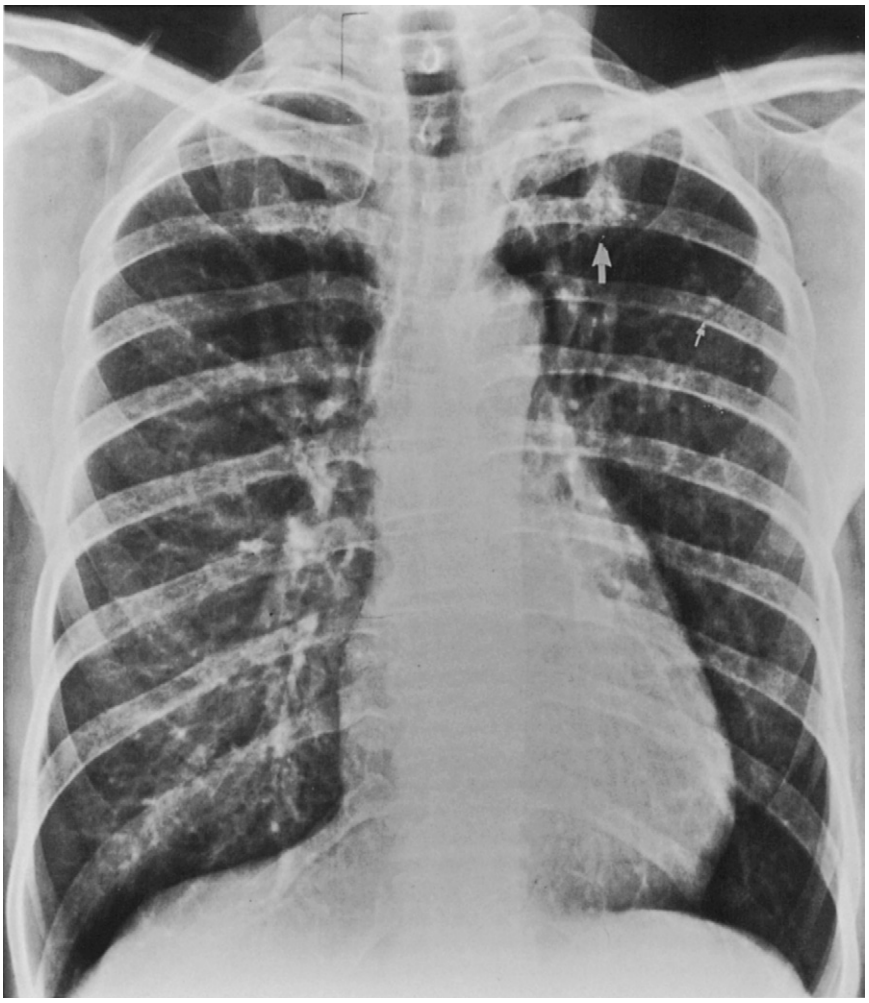


FIGURE 3-28. Fibrocalcific tuberculosis. The posteroanterior chest radiograph demonstrates the features of chronic, healed tuberculosis. Apical pleural thickening and multiple, calcified nodular and irregular opacities can be seen in the left upper lobe *(arrows)*. Volume loss is not a prominent feature in this case. Although such an appearance suggests inactive disease, serial radiographs are necessary to determine stability. Viable organisms may be present, and the development of clinically active disease may rarely occur.

BOX 3-17. **Tuberculosis: Other Radiographic Features**

Miliary tuberculosis
  Hematogenous dissemination
  Diffuse, 1- to 2-mm nodules
Pneumothorax
Endobronchial tuberculosis
  Lobar or segmental atelectasis
Tuberculoma
  Single or multiple
  Nodules larger than 1 cm
Tuberculous empyema
Bronchopleural fistula

Nontuberculous Mycobacterial Infections

Characteristics

Some nontuberculous mycobacteria (Box 3-18) are pathogenic in humans. The most important of these organisms are *Mycobacterium avium-intracellulare*, often referred to as the MAC complex, and *Mycobacterium kansasii*. These organisms often exhibit common features. They are usually found in the soil and water. Bronchopulmonary disease is caused by inhalation of the organisms, but no human-to-human transmission occurs. Unlike tuberculosis, nontuberculous mycobacterial infections do not manifest separate patterns of primary or reactivation disease.

Certain geographic areas have a preponderance of these forms of nontuberculous mycobacterial disease. For example, *M. kansasii* is more prevalent in the western and southern United States, and MAC is found more often in the southeastern United States.

The three major clinical presentations depend to some degree on the immune status of the host (Chapter 4 describes MAC disease in AIDS patients). In human immunodeficiency virus (HIV)–negative hosts, MAC typically affects male patients who are heavy smokers with underlying COPD. Similar infections may occur in patients with silicosis or bronchiectasis. The radiographic features of *M. kansasii* and MAC in this group of patients are indistinguishable from tuberculosis. However, MAC lung disease may develop in older women who are considered immunologically competent and who do not have a background of

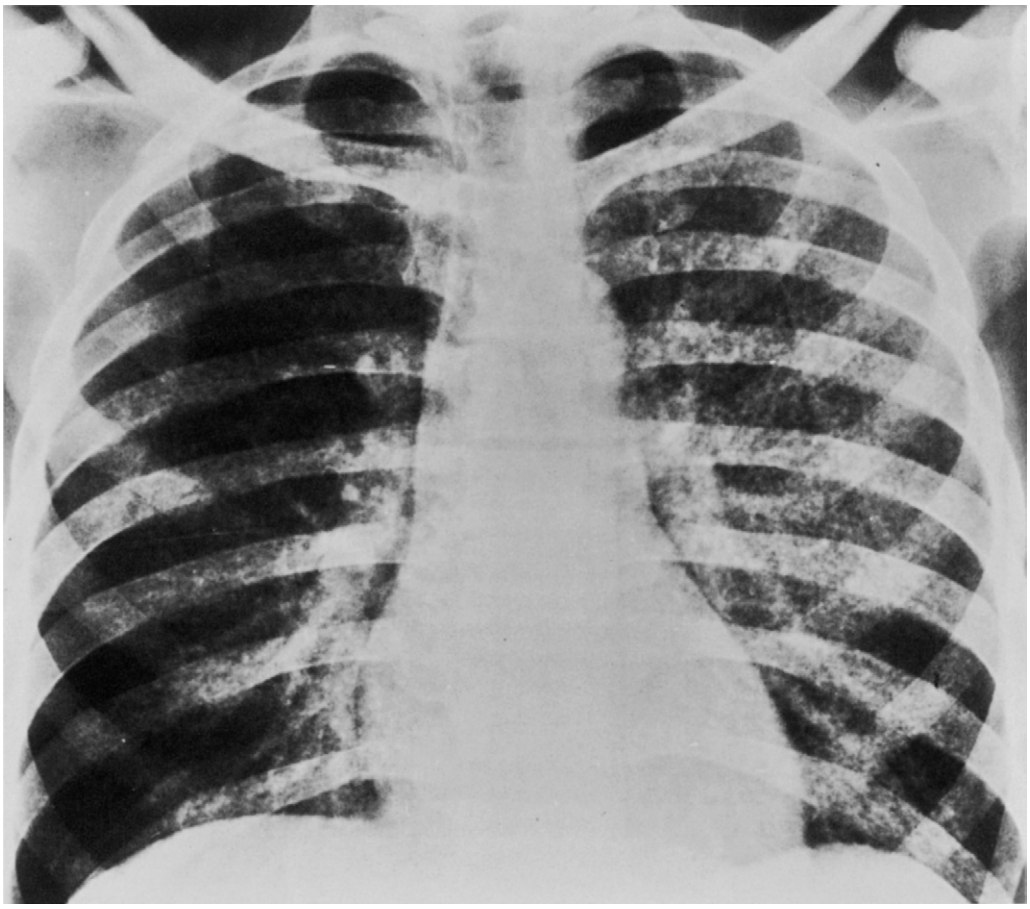


Figure 3-29. Miliary tuberculosis. The posteroanterior chest radiograph demonstrates innumerable tiny, 1- to 2-mm nodules in both lungs.

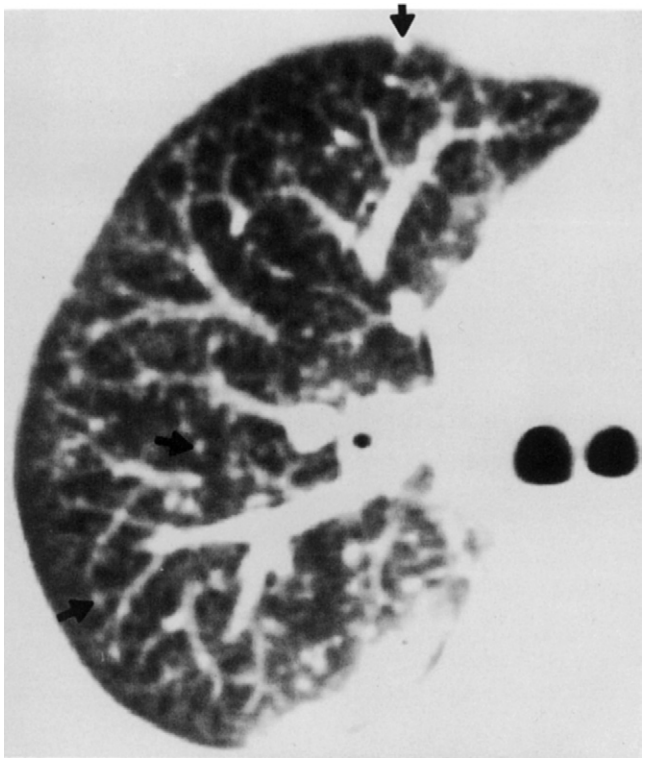


Figure 3-30. CT findings for miliary tuberculosis. In contrast to bronchogenic spread, the nodules are diffuse and uniformly distributed *(arrows)*.

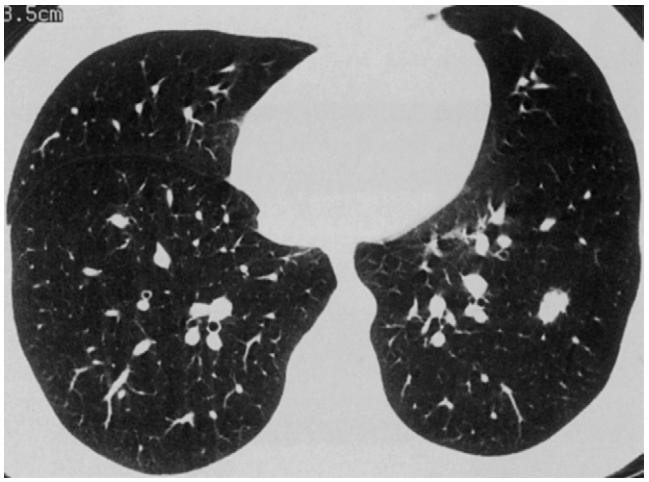


Figure 3-31. Tuberculoma. CT shows a somewhat lobulated nodule in the left lower lobe. There was no evidence of calcification or other manifestations of tuberculosis in the lungs.

COPD. This disease is usually noncavitary. Many women with this form of nontuberculous mycobacterial infection share similar clinical characteristics and bodily features, including scoliosis and pectus excavatum. It is uncertain whether these skeletal features predispose patients to infection due to poor tracheobronchial secretion drainage and ineffective mucociliary clearance or they are associated

Box 3-18. **Nontuberculous Mycobacterial Infections**

CHARACTERISTICS
Organisms
- *Mycobacterium avium-intracellulare* complex (MAC)
- *Mycobacterium kansasii*
- Found in soil and water

No human-to-human transmission
Human immunodeficiency virus–negative patients
- Men with chronic obstructive pulmonary disease (COPD)
- Immunologically competent older women without COPD
- Silicosis
- Bronchiectasis

RADIOGRAPHIC FEATURES
Classic form
- Almost identical to tuberculosis
- Frequent cavitation
- Slowly progressive

MAC in older women
- Bronchiectasis (CT finding)
- Focal nodules (CT finding)
- No cavitation (CT finding)

with markers for specific genotypes that affect body morphotype and susceptibility to infection.

Because nontuberculous mycobacteria are common contaminants, the identification of invasive disease caused by these infections should be made only when defined clinical, radiographic, and microbiologic criteria have been met as defined by the American Thoracic Society (ATS) and Infectious Disease Society of America (IDSA) guidelines. Radiologic criteria include the presence of nodular or cavitary opacities on the chest radiograph or an HRCT scan that shows multifocal bronchiectasis with multiple small nodules. Establishing a diagnosis of nontuberculous mycobacteria does not necessitate the need for treatment in all cases: rather, the decision to institute multidrug therapy should be based on an assessment of the relative risks and benefits of therapy on an individual patient basis.

Radiographic Features

The classic form of atypical mycobacterial infection produces features almost identical to those of reactivation tuberculosis (Fig. 3-32). Involvement occurs in the apical and posterior segments of the upper lobes and superior segment of the lower lobes. Cavitation is common, and multiple cavities may be observed. The disease tends to be slowly progressive.

MAC lung disease occurring in older women who are usually nonsmokers without evidence of COPD is noncavitary and is associated with bronchiectasis. The classic radiographic features are best appreciated on CT (Fig. 3-33). The findings are those of cylindrical bronchiectasis associated with multiple, small, focal lung nodules that are approximately 5 mm in diameter. Any lobe may be involved, but disease in the lingula and middle lobe has the highest prevalence. Occasionally, airspace disease may be delineated. Evidence indicates that patients with these findings are truly infected and not colonized with MAC and that the MAC infection causes the bronchiectasis rather than colonizing preexisting disease.

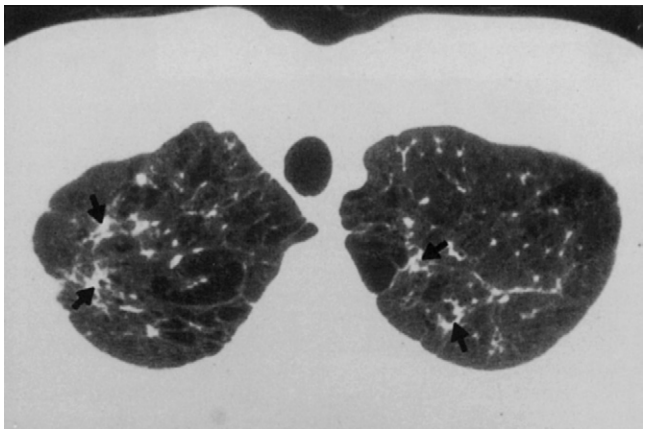


FIGURE 3-32. Atypical mycobacterial infection. Chest CT of a patient with emphysema shows the appearance of classic atypical mycobacterial infection. Biapical fibronodular opacities *(arrows)* are accompanied by architectural distortion resembling the appearance of reactivation tuberculosis.

Fungal Diseases of the Lung

The wide variety of fungi that may produce lung disease can be divided into two groups. Some are truly pathogenic and can produce pulmonary infection in normal hosts. They include *Histoplasma*, *Coccidioides*, *Blastomyces*, and *Cryptococcus*. A second group of fungi are secondary invaders or opportunistic organisms, which produce disease in immunosuppressed patients. This group includes *Aspergillus*, *Candida*, *Cryptococcus*, and *Mucor*. The latter group is discussed in Chapter 4.

Histoplasmosis

Characteristics

Histoplasma capsulatum (Box 3-19) is a dimorphous fungus that gains entry to the lung by inhalation. Distribution is worldwide, and in the United States, it occurs along river valleys, particularly the Ohio, Mississippi, and St. Lawrence. The organism exists in the soil, particularly when it is contaminated by the excrement of birds (e.g., pigeons) or bats. Many epidemics may occur when there is heavy exposure due to demolition or construction in areas containing these droppings, such as bat caves, chicken houses, or attics of old buildings. In endemic areas, up to 80% of the population may be infected, but most individuals are asymptomatic. Inhalation of spores results in a localized infection of the lung, which then migrates to mediastinal and hilar lymph nodes and eventually migrates to the spleen and liver. The organisms usually are destroyed, and there is no residual of the initial infection, although a scar or calcification may occur. If individual foci of infection and

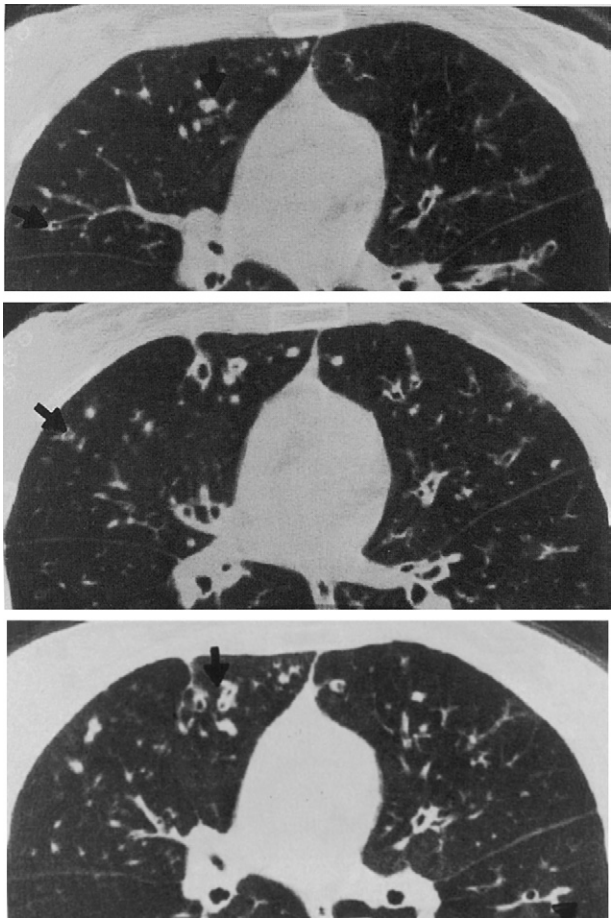


Figure 3-33. *Mycobacterial avium* complex infection. Three selected images from a chest CT study of an elderly woman show scattered nodules and peripheral areas of bronchiectasis with mucous plugging *(arrows)*.

Box 3-19. **Histoplasmosis**

CHARACTERISTICS
Dimorphic fungus
River valleys in the United States
Soil containing excrement of birds or bats

ENDEMIC AREAS
80% of population infected
Most asymptomatic

PATHOGENESIS AND PATHOLOGY
Inhalation of spores
↓
Localized lung infection
↓
Hilar and mediastinal nodes
↓
Dissemination to liver and spleen
↙ ↘
Containment **Chronic cavitary lung infection**

RADIOGRAPHIC FEATURES
Acute phase
  Consolidation (segmental or sublobar)
  Ipsilateral mediastinal or hilar adenopathy
Epidemic form
  Multiple nodules
  May or may not have adenopathy
  Healed phase (calcification)
Solitary histoplasmoma
  Up to 4 cm
  Central nidus of calcium
Chronic cavitary form (simulates tuberculosis)
Additional features
Splenic calcification
Adenopathy (eventually calcifies)
Broncholith
Fibrosing mediastinitis
Disseminated (miliary pattern)

necrosis persist, they may enlarge, resulting in a chronic cavitary lesion indistinguishable from that of tuberculosis. Pathologically, well-defined granulomas may be found during the acute phase of disease in the lung, in the mediastinum, and in the various organs to which the organism disseminates. When healed, these granulomas are small and densely calcified.

Outbreaks of histoplasmosis are usually associated with constitutional symptoms and nonproductive cough. Many cases never come to medical attention.

Radiographic Features

The radiographic manifestations of histoplasmosis vary. The acute phase of the disease is characterized by single or multiple areas of consolidation, which are usually segmental or sublobar in distribution. These areas may be accompanied by ipsilateral hilar or mediastinal adenopathy, and occasionally, adenopathy alone may be the only finding. In the epidemic form of the disease, multiple, discrete nodules may be seen throughout both lungs; nodules may occur alone or be associated with hilar adenopathy (Fig. 3-34). They are usually 1 to 5 mm in diameter, discrete, and poorly marginated. With healing, the nodules may remain visible as multiple, discrete, calcified lesions less than 1 cm in diameter with or without calcified hilar lymph nodes (Fig. 3-35). A third radiographic pattern consists of a solitary granuloma or histoplasmoma, which is usually well defined and can range in size from several millimeters to 4 cm. It typically contains a central or target type of calcification. These lesions usually occur in the lower lobes, and they may have associated smaller, calcified satellite nodules.

Additional radiographic features may be identified in patients with *Histoplasma* infection. They include calcifications in the spleen, which often are best detected on CT. Mediastinal lymphadenopathy is common as a sole manifestation of histoplasmosis or accompanying pulmonary consolidation or nodules. Nodes frequently calcify as healing occurs. Calcified lymph nodes may lead to two complications: broncholiths and fibrosing mediastinitis. Calcified lymph nodes may over time erode into a bronchus, producing broncholithiasis and its resulting symptom complex. Patients may have unexplained chronic cough and hemoptysis. CT can best identify the

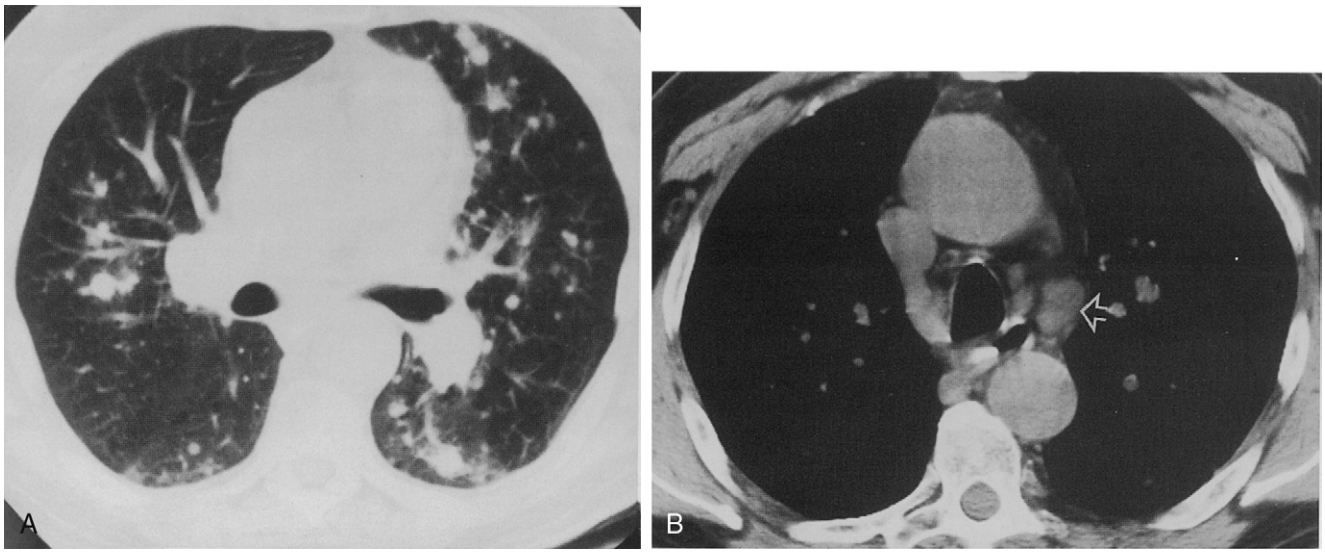


FIGURE 3-34. CT shows acute histoplasmosis. **A**, The lung windows demonstrate multiple, bilateral pulmonary nodules. **B**, On the mediastinal windows, there is adenopathy in the aorticopulmonary window *(arrow)*.

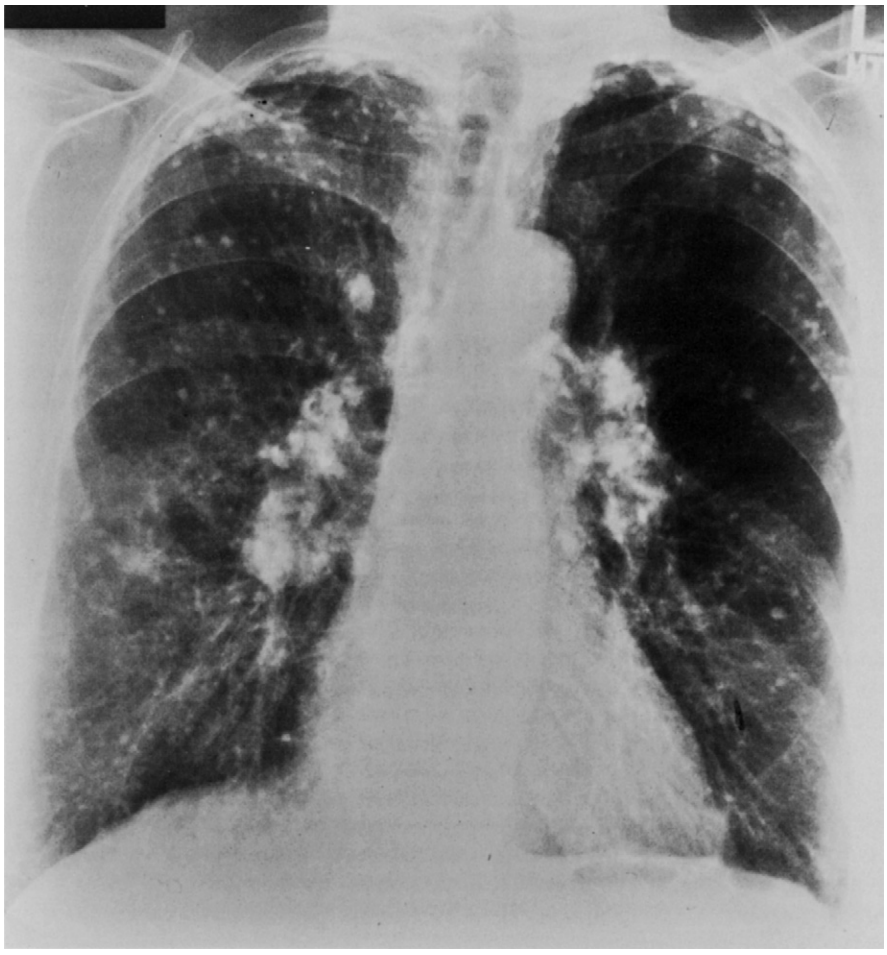


FIGURE 3-35. Healed histoplasmosis is characterized by multiple, small, calcified nodules in both lungs and by densely calcified hilar and mediastinal nodes.

intrabronchial calcification that may be associated with distal atelectasis of a segment or lobe (Fig. 3-36). The other complication, fibrosing mediastinitis, is discussed in Chapter 17. This condition is caused by the effect of large, calcified lymph nodes constricting and encasing important mediastinal structures, particularly the superior vena cava, with resultant superior vena caval syndrome; the trachea; right main bronchus; and central pulmonary arteries. Compression of pulmonary veins may lead to venous infarcts in the lungs.

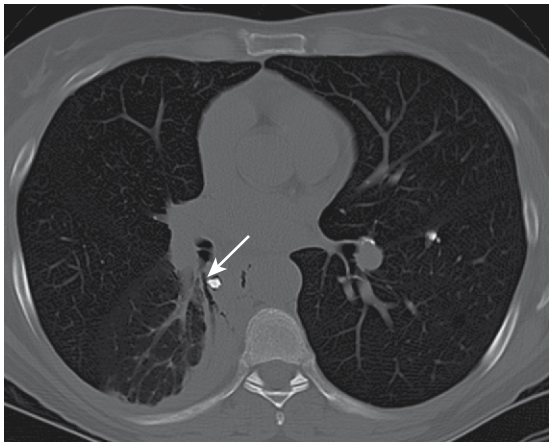


FIGURE 3-36. Broncholith. CT (bone window setting) demonstrates a small, rounded calcification *(arrow)* eroding into the superior segment right lower lobe bronchus and shows distal atelectasis. Notice the small, calcified granuloma in left lower lobe.

A rare chronic form of histoplasmosis can simulate tuberculosis. It usually consists of thin- or thick-walled cavities with patchy areas of consolidation, particularly involving the upper lobes with fibrosis and retraction. Disseminated histoplasmosis, which may occur in normal individuals, is much more common in immunosuppressed patients. Radiographically, the appearance is identical to that of miliary tuberculosis.

Coccidioidomycosis

Characteristics

Coccidioides immitis infection (Box 3-20) follows inhalation of infected spores in endemic areas such as desert areas of the southwestern United States and Central and South America. Clinical manifestations vary. Most individuals are asymptomatic, or they may experience a mild flulike illness of the lower respiratory system. Acute, severe disease may be associated with fever, cough, and pleuritic chest pain.

Pathology and Pathogenesis

With the initial inhalation of the spores, a local response or pneumonitis occurs. The immune system eventually destroys the organism, with resolution of the pneumonia. About 5% of individuals may have a chronic, often asymptomatic pulmonary lesion, such as a pulmonary nodule or cavity. Similar to tuberculosis, reactivation of the initial focus can occur. Dissemination of the organism to hilar and mediastinal nodes is common, and diffuse dissemination is rare but almost universally fatal.

Radiographic Features

The initial pneumonic form of the disease is characterized by an area of consolidation anywhere in the lung but most commonly in the lower lobes. It is usually sublobar, segmental, or patchy. It may be bilateral. Hilar and mediastinal lymph node involvement occurs in about 20% of cases, and rarely, it can be seen in the absence of the parenchymal consolidation. Most of these lesions resolve spontaneously without therapy.

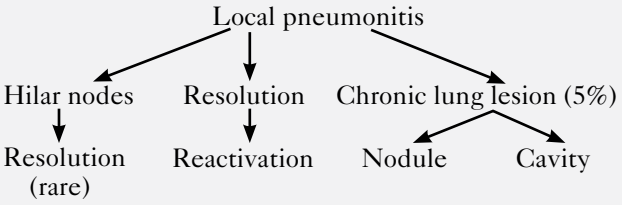
***Box 3-20.* Coccidioidomycosis**

CHARACTERISTICS

Endemic areas
- Deserts
- Southwestern United States

Symptoms
- Flulike illness
- No symptoms

PATHOLOGY AND PATHOGENESIS



RADIOGRAPHIC FINDINGS

Pneumonic form
- Sublobar, segmental, patchy consolidation (lower lobes)
- Adenopathy (20%)

Chronic form
- Solitary or multiple nodules
- Thin-walled cavity (classic form found in 10% to 15%)

Disseminated pattern
- Nodules 5 mm to 1 cm
- Rare

The radiographic features of chronic coccidioidomycosis include solitary or multiple nodules. These tend to cavitate rapidly, and the cavities typically have very thin walls (Fig. 3-37). The thin-walled cavity is the classic lesion of coccidioidomycosis, but it occurs in only 10% to 15% of cases. Disseminated coccidioidomycosis is rare and is characterized radiographically by nodules ranging from 5 mm to 1 cm in diameter. A classic miliary pattern can also be observed.

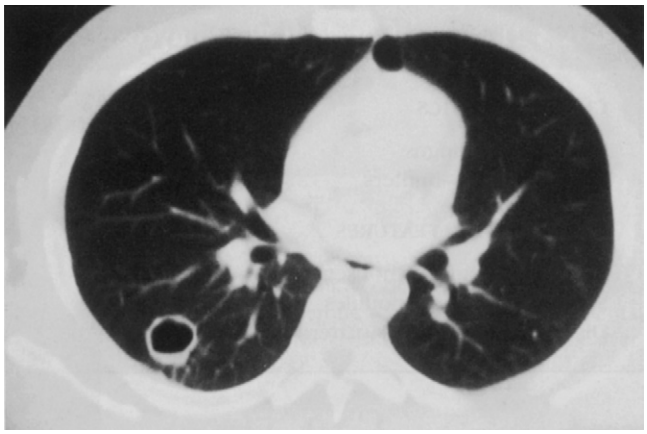


FIGURE 3-37. Coccidioidomycosis. CT demonstrates a relatively thin-walled cavity in the right lower lobe. The classic lesion of coccidioidomycosis has a paper-thin wall.

Box 3-21. North American Blastomycosis

CHARACTERISTICS
Dimorphic fungus
Wooded areas (hunters)

RADIOGRAPHIC FEATURES
Patchy segmental or nonsegmented consolidation
Solitary or multiple nodules
Disseminated (miliary pattern)

North American Blastomycosis

Characteristics

Blastomyces dermatitidis (Box 3-21) is a dimorphic fungus that grows in a mycelial form in the soil. Infection can occur by inoculation of the skin or by inhalation of organisms into the lungs. The organism is endemic in North America, occurring mostly in the same areas where histoplasmosis occurs but also in the southeastern United States. Blastomycosis is an infection associated with hunters because the organisms are prevalent in wooded areas.

Pathology and Pathogenesis

The organism is usually inhaled from the soil, and if the initial port of entry is the lung, a focal pneumonic process will occur. The disease can be self-limited, or a disseminated form can occur.

Radiographic Features

The radiographic findings are nonspecific but consist of areas of inhomogeneous consolidation in a segmental or nonsegmental distribution in any area of the lung. The next most common manifestation is that of solitary and multiple pulmonary nodules. The solitary nodules may simulate lung carcinoma. These nodules are 3 to 6 mm in diameter. A third pattern results from disseminated disease and consists of a diffuse nodular or micronodular pattern.

Cryptococcal Disease

Characteristics

Cryptococcus neoformans (Box 3-22) is an encapsulated, yeastlike fungus that exists in the soil and in the yeast form in humans. The soil may be contaminated by pigeon or chicken excreta. Seventy percent of individuals who have clinical disease are immunocompromised (see Chapter 4). The central nervous system is the most frequently affected site.

Box 3-22. Cryptococcal Disease

CHARACTERISTICS
Spores in soil contaminated with pigeon and chicken excreta
Of patients with clinical disease, 70% are immunocompromised
Central nervous system involvement

RADIOGRAPHIC FINDINGS
Single or multiple nodules larger than 1 cm
Affects lower lobes

Radiographic Features

In the normal host, the most common finding is that of single or multiple pulmonary nodules that are approximately 1 to 5 cm in diameter and that usually occur in the lower lobes (Fig. 3-38). Cavitation, lymph node enlargement, and pleural effusion are uncommon. Adenopathy is rarely identified. Characteristically, the single or multiple nodules tend to abut the pleura.

Candidiasis

Characteristics

Candidiasis (Box 3-23) may be caused by a group of various organisms in the *Candida* genus, of which *Candida albicans* is the most important species. *C. albicans* lives in human and animal sources and may be a normal inhabitant of the

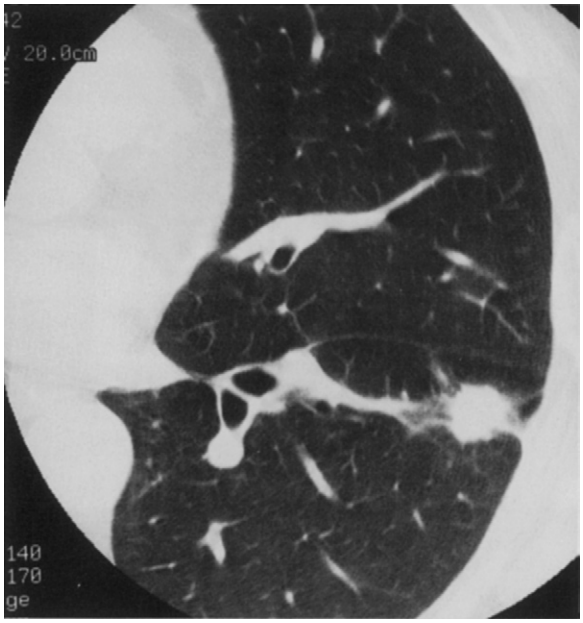


FIGURE 3-38. *Cryptococcus* infection in a patient with lymphoma. CT demonstrates an irregular nodule with a tag extending to the pleura.

Box 3-23. Candidiasis

CHARACTERISTICS
Candida albicans most common
Immunocompromised hosts
Exists in oropharynx

PATHOLOGY AND PATHOGENESIS
Mucous membranes and skin
Pulmonary features
  Aspirated organisms from oral cavity
  Results from fungemia

RADIOGRAPHIC FINDINGS
Multiple, patchy, bilateral areas of consolidation
Multiple nodules with or without cavitation

oral pharynx. As a result, short of an open lung biopsy, the true invasiveness or pathogenicity of this organism when recovered from the sputum is difficult to determine. It is an unusual infection found in immunocompromised individuals.

Pathology and Pathogenesis

The most common sites of infection are the mucous membranes and skin. Pulmonary candidiasis is unusual but may occur as a primary infection of the lungs, presumably resulting from aspiration of the organisms from the oral cavity. In most immunocompromised patients, pulmonary infection accompanies a diffuse, widespread fungemia.

Radiographic Features

The radiographic findings are usually nonspecific. Although most fungal diseases, particularly in immunocompromised hosts, are characterized by multiple nodules with cavitation, *Candida* pneumonia is more likely to produce areas of consolidation that are multiple and patchy and involve both lungs. Cavitation and hilar adenopathy are rare, and pleural effusion occurs in approximately 25% of cases.

Actinomycosis

Characteristics

Actinomyces (Box 3-24) is a rod-shaped bacterium rather than a fungus, but it is often considered a fungus because of its clinical presentation and radiographic findings. The organism is found in the mouth, and pulmonary infection usually occurs in people with extensive dental caries and poor oral hygiene. Involvement results from aspiration of these organisms.

There are three forms of actinomycosis: cervicofacial, gastrointestinal, and thoracic. The hallmark of the pulmonary disease is a focal abscess with extension to the chest wall, with secondary complications such as osteomyelitis, bronchopleural fistula, and pericarditis. The organism is an anaerobe, and anaerobic cultures must be obtained to confirm the diagnosis. Typical sulfur granules may be identified on pathologic specimens.

***Box 3-24.* Actinomycosis**

CHARACTERISTICS
- Rod-shaped bacterium, anaerobe
- Mouth organisms
- Poor oral hygiene
- Forms
  - Cervicofacial
  - Gastrointestinal
  - Thoracic
    - Focal abscess
    - Invasion of chest wall

RADIOGRAPHIC FEATURES
- Consolidation
- Rounded abscess
- Chest wall invasion (best seen on CT)
  - Bone destruction
  - Osteomyelitis and periostitis
  - Pleural effusion

Radiographic Features

The radiographic features initially consist of an area of consolidation in the lung. This area may become rounded and suggest an abscess. Classic signs include extension of the disease process into the chest wall with bone destruction and osteomyelitis (Fig. 3-39). Chest wall invasion is best appreciated on CT. Pleural effusions are moderately common. Invasion of the ribs or vertebral bodies characteristically causes bone destruction and fairly extensive reactive periostitis.

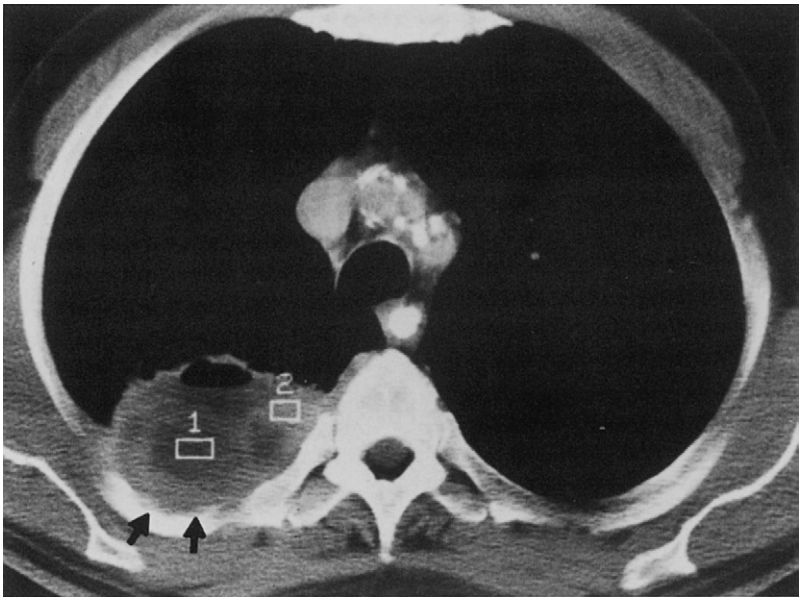


Figure 3-39. CT shows actinomycosis in a patient who developed a right upper lobe, posterior segment necrotic consolidation after dental extraction. Notice the erosion of the cortex of the overlying rib *(arrows)*.

Nocardiosis

Characteristics

Nocardia (Box 3-25) is a gram-positive organism, and although it is classified as a bacterium, it shares many features with fungal disease. It is weakly acid fast and can be confused with mycobacteria or *Legionella*. It is similar to *Actinomyces*, but the disease usually occurs in immunocompromised patients rather than in normal hosts (see Chapter 4).

Radiographic Features

Focal consolidation is the most common finding, although the disease can appear as single or multiple nodules with cavitation. Unlike aspergillosis, progression of disease usually is rather slow. Chest wall involvement may occur but is rare.

Aspergillosis

Aspergillus (Table 3-3) is a dimorphic fungus. The most common of the many species is *Aspergillus fumigatus*. *Aspergillus* grows widely in soil and water, in decaying vegetation, and in animal material.

Aspergillosis occurs in several different forms in the lung, including noninvasive (mycetoma) and semi-invasive aspergillosis, invasive aspergillosis, and allergic bronchopulmonary aspergillosis. The type of involvement depends on the immune status of the host. Infection is initiated by the inhalation route, and *Aspergillus* spores may exist in the mouth and airways of normal hosts. Immunocompetent or mildly immunosuppressed patients may acquire mycetomas or semi-invasive aspergillosis, whereas those who are severely immunosuppressed develop invasive aspergillosis. Allergic bronchopulmonary aspergillosis usually occurs in asthmatic patients.

Box 3-25. **Nocardiosis**

CHARACTERISTICS
Gram-positive, acid-fast bacilli
Immunocompromised hosts

RADIOGRAPHIC FINDINGS
Single or multiple nodules with or without cavitation
Slow progression
Focal consolidation

Aspergilloma or Mycetoma: Noninvasive Aspergillosis

Characteristics

The most common radiographic form of aspergillosis is the mycetoma or fungus ball. The fungus ball consists of aspergillus hyphae, mucus, and cellular debris developing within a preexisting cyst, cavity, bulla, or area of bronchiectasis. It grows as a saprophytic organism and usually is noninvasive. A high prevalence of mycetoma has been found among patients with sarcoidosis or cystic fibrosis. Symptoms usually include hemoptysis, which may be life threatening.

Radiographic Features

The radiographic appearance of a fungus ball or mycetoma can be quite characteristic (Fig. 3-40). Typically, there is a solid, round opacity within a cavity or thin-walled cyst. Air may dissect into the solid mass, creating the appearance of an air crescent. In most cases, the fungus ball is mobile, and changes in position occur with changes in body posture. Extensive pleural thickening at the apex of the thorax frequently accompanies the development of a mycetoma. In making the differential diagnosis, necrotizing squamous cell carcinoma and an intrapulmonary abscess should be considered.

No treatment is necessary for asymptomatic individuals, but for those who develop severe hemoptysis, there

TABLE 3-3 Aspergillosis

Aspergilloma or Mycetoma	Semi-invasive Aspergillosis	Invasive Aspergillosis	Allergic Bronchopulmonary Aspergillosis
Characteristics			
Fungus ball	Mildly immunosuppressed hosts	Immunocompromised hosts	Hypersensitivity reaction to *Aspergillus* in mucous plugs
Preexisting Cavity Bulla Bronchiectasis	Focal consolidation→cavity→air crescent→thick-walled cavity→fungus ball	Granulocytopenia	Mucoid impaction
Saprophytic			Asthmatic patients
Sarcoidosis, cystic fibrosis			
Hemoptysis			
Radiographic Features			
Round opacity within cyst or cavity	Cavity ± fungus ball	Single or multiple nodules	Mucoid impaction Central branching opacities Central bronchiectasis
Air crescent	Air crescent	Cavitation	Lobar consolidation
Mobile	Pleural thickening	Air crescent	Chronic: upper lobe scarring and bronchiectasis
Plural thickening		Halo sign on CT	

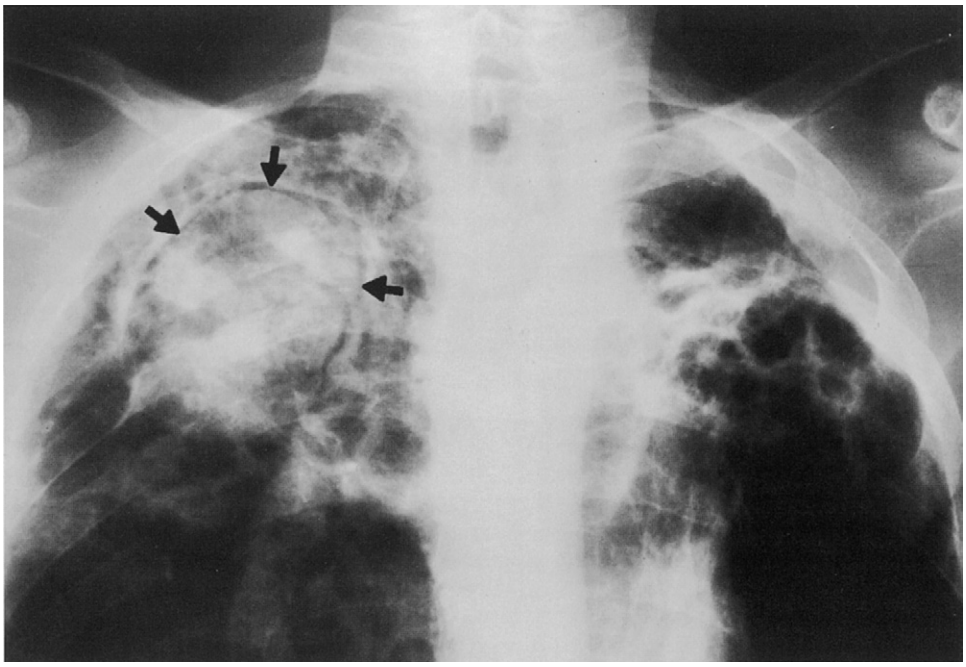


FIGURE 3-40. Fungus ball or mycetoma due to *Aspergillus*. Coned-down posteroanterior view shows the chest of a patient with biapical, fibrocavitary tuberculosis accompanied by volume loss. There is a mass in a large, right upper lobe cavity, with air dissecting into the cavity producing air crescents *(arrows)*.

are several therapeutic options. One is an interventional radiologic technique that consists of embolization of bronchial arteries that supply the cavity. Direct installation of amphotericin B in the form of a paste inserted through a percutaneous catheter into the cavity has been successful in some cases.

Semi-invasive Aspergillosis

Characteristics

Semi-invasive aspergillosis occurs in mildly immunosuppressed patients, such as those with alcoholism, chronic debilitating illness, or advanced malignancy. The lesion usually begins as a focal consolidation in the apex of one or both lungs that progresses over a period of months to become cavitary. It may form a crescent of air (i.e., air crescent sign) similar to that seen in a mycetoma. A thick-walled cavity, which later becomes thin walled and contains a fungus ball, is then formed.

Radiographic Features

The appearance may be identical to that of a mycetoma. It consists of a cavity with or without a fungus ball and air crescent, or it may be a localized area of consolidation. Extensive pleural thickening can be identified.

Invasive Aspergillosis

The features of invasive aspergillosis are described in Chapter 4, which discusses pulmonary infections in the immunocompromised patient.

Allergic Bronchopulmonary Aspergillosis

Characteristics

Allergic bronchopulmonary aspergillosis (see Chapter 13) occurs almost exclusively in asthmatic individuals. *Aspergillus* spores contained within mucous plugs in the tracheobronchial tree incite an allergic reaction. The syndrome consists of blood eosinophilia with positive precipitins and marked elevation of IgE antibodies. Large masses of mucus and *Aspergillus* hyphae can become trapped in the airways, producing mucoid impaction of the bronchi.

Radiographic Features

The most characteristic pattern is that of mucoid impaction of the bronchus. Central branching opacities, which sometimes are referred to as a finger-in-glove or V pattern, are identified. A more extensive description is provided in Chapter 13. Atelectasis distal to the areas of mucoid impaction usually does not occur because of collateral air drift. Air trapping may be identified, and lobar consolidation may be present. As the mucous plugs are expectorated, areas of central bronchiectasis can be identified, particularly on CT scans. Patients usually respond to steroids, but in the chronic form of the disease, scarring and upper lobe bronchiectasis are prominent features.

Mucormycosis

Mucormycosis, almost exclusively a disease in immunocompromised patients, is discussed in Chapter 4.

Pneumocystis jiroveci

Pneumocystis jiroveci (formerly called *Pneumocystis carinii*) is discussed in Chapter 4.

PROTOZOAN AND OTHER PARASITIC INFECTIONS

In the United States, parasitic infection of the lung is rare. Pneumonia is caused by a hypersensitivity reaction to the organisms, or it results from systemic invasion of the lungs and pleura.

Toxoplasmosis

Toxoplasma gondii pulmonary involvement usually develops as part of a more generalized disease. The congenital variety is the most common, and it results from transmission of the organism from mother to fetus. It is associated with a consolidative and hemorrhagic pneumonia in neonates. In adults, toxoplasmosis, like pneumocystosis, occurs in patients who are immunocompromised. The radiographic appearance is that of fairly diffuse reticulonodular opacities.

Echinococcal Disease

Characteristics

Echinococcus granulosus (Box 3-26), the cause of most cases of human hydatid disease, occurs in two forms: pastoral and sylvatic, which differ in definitive and intermediate hosts and in geographic distribution. The pastoral variety is more common and occurs in sheep, cows, or pigs as the intermediate hosts, and in dogs as the definitive host. It is particularly common in sheep-raising areas. The sylvatic variety has as the definitive host the dog, wolf, or arctic fox.

Approximately 65% to 70% of *Echinococcus* cysts occur in the liver, and 15% to 30% occur in the lungs. The hydatid cyst is composed of two layers, an exocyst and an endocyst. Daughter cysts may be formed within the endocyst. Cysts may rupture in the lung parenchyma, with resulting intense inflammation. Rupture into the bronchus may result in severe hypotensive shock.

Radiographic Features

Echinococcal cysts are usually well-circumscribed, spherical or oval masses that may be single or multiple (Fig. 3-41). They are usually located in the lower lobes. If communication develops between the cysts and the bronchial tree, air may enter between the pericyst and exocyst, producing the appearance of a thin crescent of air around the periphery of the cyst, sometimes called the *meniscus* or *crescent sign*. Bronchial communication occurs directly into the endocyst. Occasionally, an air crescent sign and air-fluid level can be identified. The membrane of the cyst, which has ruptured into the bronchial tree, may float on the fluid within the cyst, giving rise to the classic water lily sign. CT can differentiate cystic from solid lesions and may identify the pathognomonic features in ruptured or complicated hydatid cysts, such as the presence of daughter cysts and endocyst membranes. Calcification of a pulmonary hydatid cyst is rare.

Box 3-26. **Echinococcus**

CHARACTERISTICS
Pastoral form
- Sheep, cows, or pigs (intermediate hosts)
- Dogs (definitive host)

Sylvatic form
- Dog, wolf, arctic fox (definitive hosts)

Sites of involvement
- Liver (65% to 70%)
- Lung (15% to 30%)

Cystic structure
- Endocyst
- Exocyst
- Daughter cysts

Complications
- Rupture (local inflammation)
- Anaphylaxis

RADIOGRAPHIC FEATURES
Single or multiple lesions
Spherical lesions
Affects lower lobes
Meniscus or crescent sign
Air-fluid level (water lily sign)
No calcification

Amebiasis

Characteristics

Pulmonary amebiasis is rare and is usually a sequela of hepatic or gastrointestinal involvement. Amebiasis is caused by the protozoan *Entamoeba histolytica*. This organism causes dysentery and has a worldwide distribution. Pleuropulmonary complications usually occur when the liver is involved. Patients present with right upper quadrant and right-sided pleuritic chest pain.

Radiographic Features

The common radiographic features are right-sided pleural effusion with basal consolidation. Involvement of the lung may result from rupture of an amebic abscess in the liver. Occasionally, areas of consolidation in the right lower lobe may progress to abscess formation with cavitation.

Schistosomiasis

Characteristics

Schistosomiasis is a common disease in many areas of the world, including Central and South America, the Middle East, and the Far East. The intermediate host of this parasite is the snail. Humans contact the parasites in water. The parasites penetrate the skin, reach the circulation, and eventually grow in the mesenteric or pelvic venous plexus, where they mature into adult worms and lay eggs. Pulmonary symptoms may occur during the larval migration phase in the lungs due to a hypersensitivity reaction. A progressive diffuse endarteritis and thrombosis may result from impaction of ova in the pulmonary circulation, with the eventual development of pulmonary arterial hypertension.

Pathology and Pathogenesis

Pathologic changes in the lungs result from deposition of eggs or ova, which are released directly into the systemic venous blood or occasionally into the portal system, where eggs can reach the lungs through anastomotic channels as the liver becomes cirrhotic. The embolized ova become impacted in pulmonary arterioles and then extruded into the surrounding tissue. This causes an obliterative arteriolitis, which can result in increased pulmonary artery pressure. The ova may mature into adult worms in the lungs and can cause lung damage.

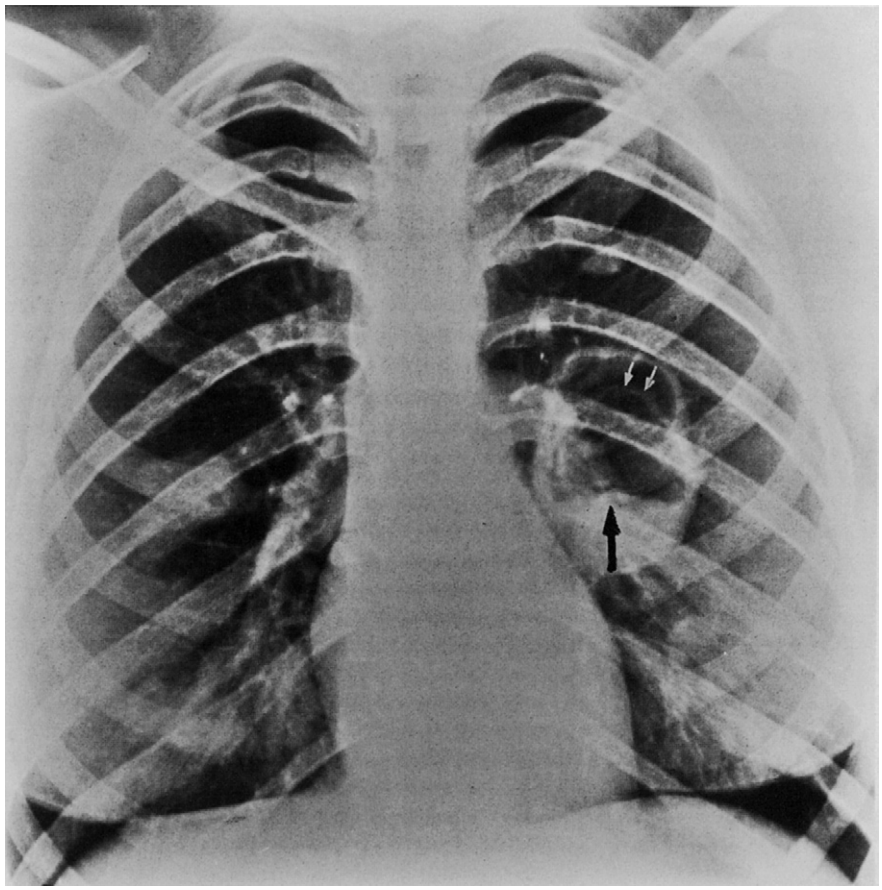


Figure 3-41. Echinococcal cysts. Both lungs contain multiple nodules, some of which are cavitated. A meniscus or crescent can be identified *(white arrows)* in the large cyst in the left lung, which also displays an air-fluid level and water lily sign *(black arrow)*.

Radiographic Features

Pulmonary arterial hypertension is the most common finding in patients with pulmonary schistosomiasis (Fig. 3-42). The appearance consists of dilation of the central pulmonary arteries with rapid tapering. The passage of larva through the pulmonary capillaries can cause a transitory eosinophilic pneumonia, simulating Loeffler's syndrome. This is characterized by the presence of peripheral areas of consolidation.

Other Metazoan Infections

The lungs may be infected by a number of worms, causing ascariasis, strongyloidiasis, trichinosis, ancylostomiasis (i.e., hookworm disease), and filariasis (i.e., tropical eosinophilia). Most of these organisms produce hypersensitivity reactions in the lungs, similar to Loeffler's syndrome (see Chapter 9).

EMERGING VIRAL INFECTIONS

Outbreaks of several newly recognized viral infections, including avian influenza, severe acute respiratory syndrome–associated coronavirus, and hantavirus, have been associated with high mortality rates. These infections have presented challenges to clinicians, radiologists, scientists, and public health officials.

H5N1 Avian Influenza

Avian influenza is caused by the H5N1 subtype of the influenza A virus. Human transmission occurs through close contact with infected birds, usually from ingestion of infected poultry. The first documented case occurred in 1997 in Hong Kong. In 2003, the virus resurfaced in Vietnam. Approximately 180 people throughout Southeast Asia have been infected, with a nearly 50% mortality rate. Affected patients present with a rapidly progressive pneumonia that may lead to respiratory failure and ARDS.

Chest radiographs usually show abnormalities at the time of presentation. The most common finding is multifocal consolidation (Fig 3-43), which is bilateral in 80% of cases. Consolidation may infrequently be complicated by areas of cavitation. Bilateral pleural effusions occur in about one third of cases.

Severe Acute Respiratory Syndrome–Associated Coronavirus

Severe acute respiratory syndrome (SARS) is caused by the SARS-associated coronavirus. It results in a systemic infection that is manifested clinically as a progressive pneumonia. The first reported case in humans occurred in China in 2002. In 2003, SARS spread to Hong Kong and subsequently to Canada, Singapore, and Vietnam. Before the

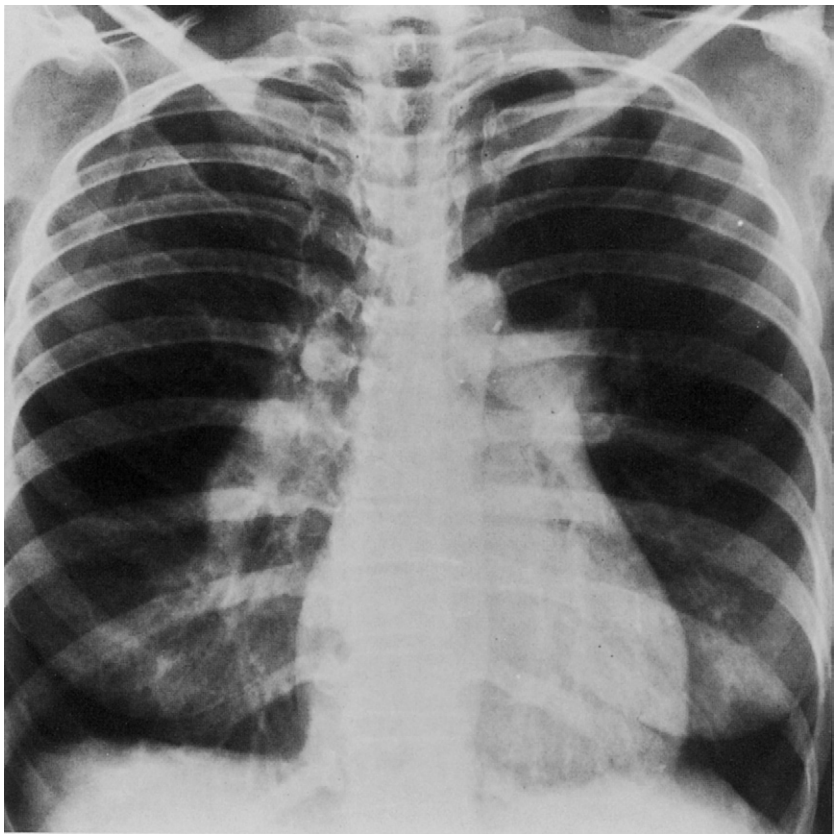


FIGURE 3-42. Pulmonary arterial hypertension in pulmonary schistosomiasis is characterized by dilation of the central pulmonary arteries. The patient was a 48-year-old Puerto Rican woman with proven schistosomiasis, cirrhosis, and portal hypertension.

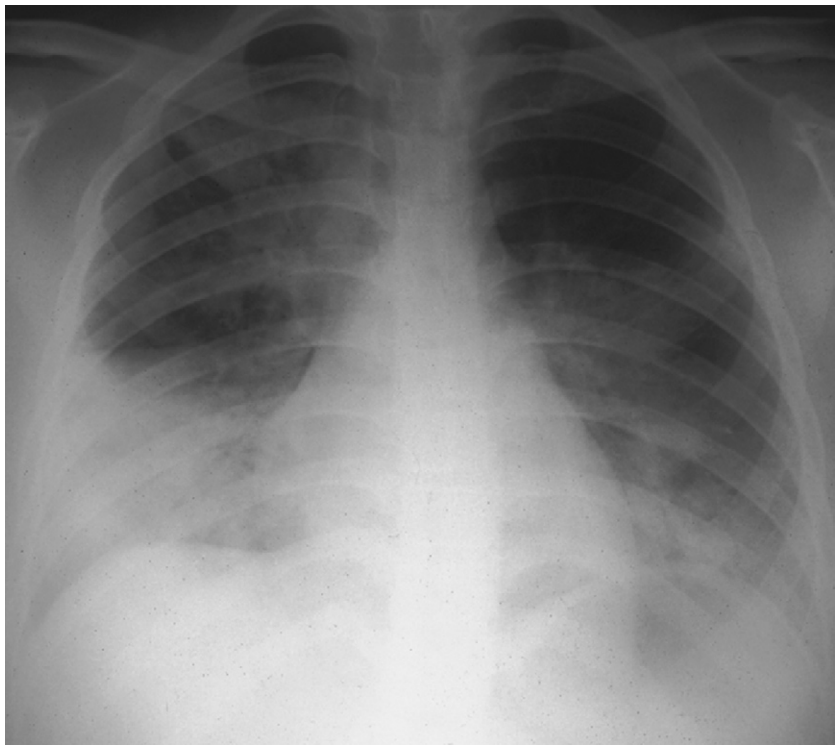


FIGURE 3-43. H5N1 avian influenza. The chest radiograph demonstrates bilateral, multifocal airspace consolidation. (From Ketai L, Paul NS, Wong KT: Radiology of severe acute respiratory syndrome [SARS]: the emerging pathologic-radiologic correlates of an emerging disease. J Thorac Imaging 21:276–283, 2006).

infection could be contained by vigorous public health measures, more than 8000 persons were infected, with a nearly 10% fatality rate. No additional human infections have been reported since 2003. After an initial incubation period of 2 to 10 days (mean, 6 days), affected patients typically present with headache, malaise, fever, and nonproductive cough.

Chest radiographs show abnormalities at the time of clinical presentation in about 80% of cases. The most common radiographic finding is poorly defined airspace consolidation. Although about one half of cases appear to have a focal distribution at the time of presentation, progression to multifocal involvement is common. Areas of consolidation have a predilection for the lower lobes and lung periphery. CT shows abnormalities at the time of clinical presentation, even when chest radiographs do not. The most common CT finding is ground-glass opacification (Fig 3-44), which is often accompanied by small foci of consolidation and interlobular and intralobular thickening. Severe SARS may progress to diffuse alveolar damage.

Overall, 20% of patients with SARS require mechanical ventilation, and 10% of patients do not survive the infection. Survivors often have residual abnormalities seen on CT, reflecting interstitial fibrosis and small airways disease.

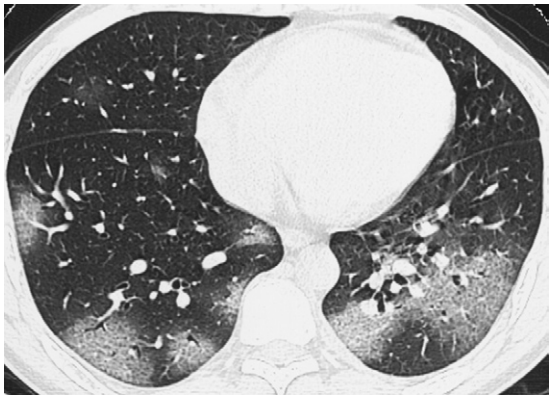


Figure 3-44. Severe acute respiratory syndrome (SARS). CT shows multifocal, peripheral foci of ground-glass attenuation with superimposed reticular opacities. (From Ketai L, Paul NS, Wong KT: Radiology of severe acute respiratory syndrome [SARS]: the emerging pathologic-radiologic correlates of an emerging disease. J Thorac Imaging 21:276–283, 2006).

Hantavirus

Hantaviruses are carried by rodent vectors. Human infection occurs after inhalation of aerosolized rodent feces or urine. The Sin Nombre hantavirus (translated as "the nameless virus") was initially discovered in the southwestern United States in 1993 as a cause of pulmonary edema and respiratory failure accompanied by hematologic abnormalities. This clinical entity is referred to as the hantavirus pulmonary syndrome (HPS).

HPS is caused by endothelial damage to the lung. The initial interstitial edema manifests radiographically as Kerley lines, bronchial wall thickening, and subpleural edema. Although some patients recover fully from the initial stage of infection, many progress to diffuse alveolar edema, which is manifested by symmetric perihilar and basilar airspace consolidation (Fig 3-45). This phase of illness requires mechanical ventilation and is associated with a high mortality rate. As the disease progresses, it may be accompanied by myocardial depression, which worsens tissue hypoxia and contributes to the high mortality rate associated with this syndrome.

INFECTIONS RELATED TO BIOTERRORISM

The Centers for Disease Control and Prevention (CDC) lists several infectious agents as a category A threats, denoting the highest potential for public health impact. These agents include inhalational anthrax *(Bacillus anthracis)*, plague *(Y. pestis)*, smallpox (variola major), botulism *(Clostridium, botulinum)*, tularemia *(Francisella tularensis)*, and hemorrhagic fever (Ebola and Marburg filoviruses). Among these infections, anthrax has the unique distinction that imaging studies may allow prompt diagnosis and institution of life-saving therapy before organ damage is irreversible. For this reason, the discussion focuses on anthrax.

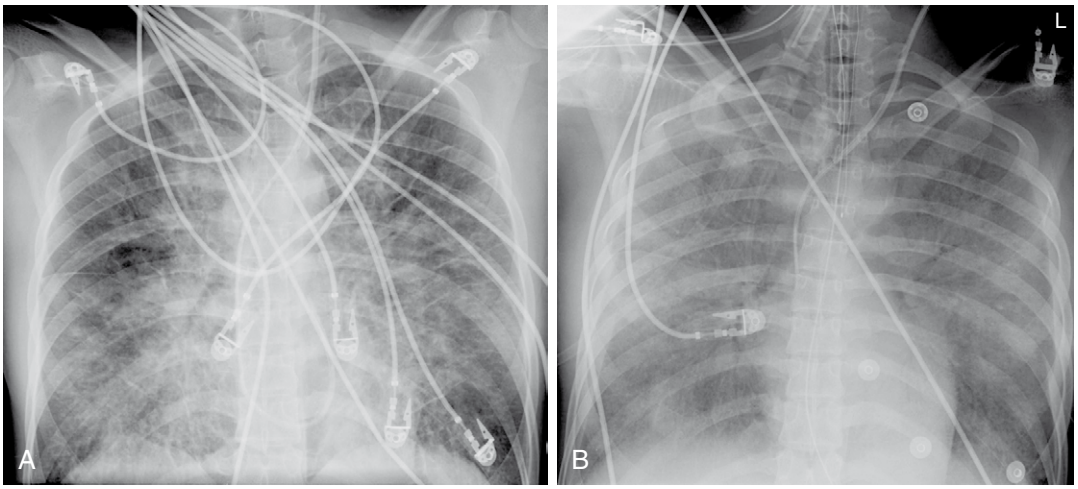


Figure 3-45. Hantavirus pulmonary syndrome. **A**, Portable chest radiograph shows bilateral central airspace opacities and diffuse Kerley lines due to combined alveolar and interstitial edema. **B**, Portable chest radiograph of same patient 1 day later shows progressive alveolar pulmonary edema and interval intubation. (Courtesy of Loren Ketai, MD, University of New Mexico, Albuquerque, NM.)

Anthrax

Anthrax has been used as a biologic weapon since World War II. The most recent episode occurred in 2001, when highly refined anthrax spores were placed in envelopes and mailed through the United States postal system. This act of bioterrorism resulted in 22 diagnosed cases of anthrax, which were evenly split between inhalational and cutaneous forms. Almost one half of those with the inhalational form died.

B. anthracis is a sporulating, gram-positive bacterium that may result in cutaneous, gastrointestinal, or pulmonary infection. The latter, which is also referred to as inhalational anthrax, is the deadliest form. The spores are 2 to 6μm, an ideal size for deposition in the distal respiratory tract after inhalation. Once inhaled, the spores are ingested by macrophages. Surviving spores are transported to mediastinal lymph nodes, where they germinate for 2 to 30 days (mean, 1 week).

Radiologic findings have not been identified before germination. After germination, the organisms synthesize a toxin, resulting in the prodromal phase of the disease. This is manifested by flulike symptoms of fever, chills, fatigue, and cough. The prodromal phase lasts about 4 days and is rapidly followed by the second phase of the illness, which is characterized by stridor, respiratory failure, and shock. In many cases, death occurs despite antibiotic therapy.

Imaging findings for anthrax reflect hemorrhagic lymphadenitis and mediastinitis caused by the release of anthrax toxin within the mediastinum. In the prodromal phase of the illness, the chest radiograph typically demonstrates mediastinal widening and unilateral or bilateral hilar enlargement. These findings are frequently accompanied by pleural effusions. Although limited peribronchovascular airspace opacities may be present, extensive consolidation is uncommon. Imaging findings of mediastinal widening and pleural effusions are helpful for differentiating inhalational anthrax from a community-acquired respiratory infection.

CT may provide convincing evidence of inhalational anthrax before confirmatory laboratory tests have returned (Fig 3-46). Unenhanced CT may show high-attenuation (46 to 62 Hounsfield units) mediastinal and hilar lymph nodes, which may rapidly enlarge over a period of days. These findings reflect the presence of hemorrhage and edema within lymph nodes. Because of this characteristic appearance, unenhanced CT is considered the imaging modality of choice for the diagnosis of inhalational anthrax.

After contrast administration, rim enhancement and central low attenuation of lymph nodes may be seen. Rapidly enlarging pleural effusions are commonly identified by CT, and they may contain dependently layering, high-attenuation fluid, reflecting serosanguineous exudates. Peribronchovascular thickening correlates with the presence of edema, hemorrhage, and necrosis of the airways and adjacent lymphatics. The constellation of these CT findings is almost pathognomonic for inhalational anthrax, but a variety of other causes of mediastinitis may produce similar findings in the appropriate clinical setting.

Inhalational anthrax is treated with an antibiotic regimen that includes ciprofloxacin or doxycycline combined with two other agents, usually rifampin and clindamycin. Early recognition of anthrax and prompt administration of antibiotics before the onset of fulminant illness can dramatically improve patient survival.

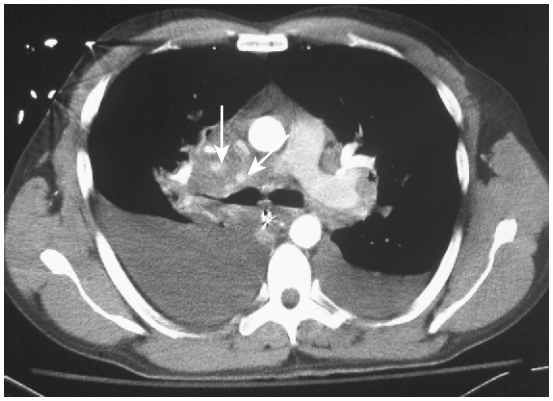


FIGURE 3-46. Inhalational anthrax. Contrast-enhanced CT scan of the chest shows diffuse widening of mediastinal and hilar regions due to a combination of widespread edema and enlarged lymph nodes. High-attenuation foci in the right paratracheal soft tissue *(arrows)* likely are caused by hemorrhagic foci in the lymph nodes. Notice the bilateral pleural effusions. (From Ketai L, Alrahji AA, Hart B, et al: Radiologic manifestations of potential bioterrorist agents of infection. AJR Am J Roentgenol 180:565–575, 2003.)

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