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Acute Lung Infections in Normal and Immunocompromised Hosts

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Pulmonary infections are among the most common causes of morbidity and mortality worldwide and contribute substantially to annual medical expenditures in the United States. Despite the availability of antimicrobial agents, pneumonia constitutes the sixth most common cause of death and the number one cause of death from infection [1]. Pneumonia can be particularly life-threatening in the elderly, in individuals who have pre-existing heart and lung conditions, in patients who have suppressed or weakened immunity, and in pregnant women. Many of these patients present for emergency care, and radiologic imaging is critical in making the appropriate diagnosis, suggesting an etiologic microorganism, and monitoring response to therapy.

Microorganisms gain access to the respiratory system and cause infection in a variety of ways. The most common route of entry is inoculation of the tracheobronchial tree by the inhalation of aerosolized respiratory droplets. Other routes include aspiration of oropharyngeal secretions; hematogenous dissemination, such as in endocarditis; and contiguous extension of infection from adjacent areas, such as the abdomen [2].

Knowledge of the patient's underlying immune status is critical in arriving at an appropriate radiographic differential, and in some cases, suggesting a specific etiology. This article discusses some of the important causes of acute lung infections in normal and immunocompromised hosts.

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Pneumonia

Community acquired

Community-acquired pneumonia (CAP) is the most common cause of acute lung infection in immunocompromised and immunocompetent patients. Despite being common and potentially lethal, its importance is often underappreciated. Estimates of the incidence of CAP range from 4 to 5 million cases per year [3,4]. Eighty percent of patients are treated as outpatients, and their mortality is less than 1%. The remaining 20% of patients require inpatient management, and the overall mortality is approximately 12%. Risk factors for CAP include advanced age, chronic obstructive pulmonary disease, renal insufficiency, congestive heart failure, malignancy, diabetes, and alcoholism [5]. The etiologic organism in CAP is undetermined in 50% of cases [6]. Some of the more common organisms that cause CAP and the radiographic appearances are discussed below.

Streptococcus pneumoniae, a gram-positive coccus, is the most common bacterial cause of CAP. Classically, it causes a lobar pattern of consolidation that is characterized by the initial development of a peripheral opacity that rapidly becomes confluent. Air-bronchograms are common. Inflammation occurs predominantly at the level of the alveolar sac when the organism is inhaled. There is alveolar spread and the inflammatory response spreads throughout the lung through small channels—the canals of Lambert and the pores of Kohn. The spread of this process through collateral channels, rather than bronchioles, explains why this pattern of pneumonia often does not follow a segmental distribution. The infection easily crosses pulmonary segments and inflammation is limited by

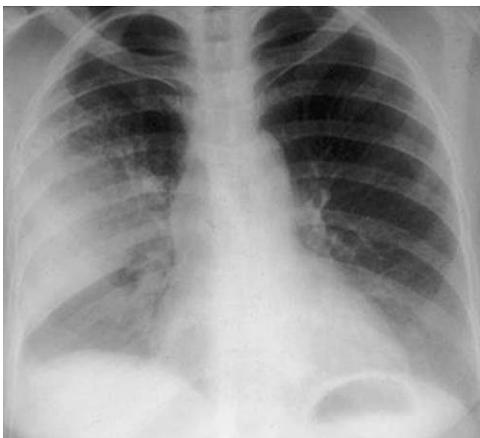


Fig. 1. *Streptococcus pneumoniae*. Chest radiograph demonstrates classic lobar pneumonia in the right upper lobe. Air space disease is homogeneous and confluent and there is no evidence of volume loss.

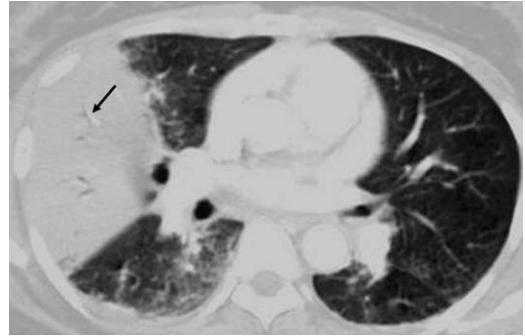


Fig. 2. *Streptococcus pneumoniae*. CT scan of the chest in another patient demonstrates a classic appearance of lobar pneumonia with confluent homogenous opacification of the right middle lobe. Air-bronchograms are noted (arrow).

pleural boundaries. In addition to localized lobar consolidation, *Streptococcus pneumoniae*-associated pneumonia also has atypical appearances, such as bronchopneumonia or an interstitial pattern [2]. One study that investigated the radiographic appearances in 81 in-patients with culture-documented pneumococcal pneumonia demonstrated a lobar pattern of consolidation in 81% of the patients. Lobar consolidation was focal in 48% of patients and multifocal in 33%. A bronchopneumonia/lobular pattern of consolidation, often with peribronchial thickening, occurred in 19%. A bronchopneumonia pattern results when infections begin in bronchi and bronchioles and then extend into the contiguous airspace. It usually is patchy, multifocal, bilateral, heterogeneous, and nonconfluent. The radiographic pattern is not influenced by HIV status. Pleural effusions are uncommon, and in this study, were found in 11% of patients [Figs. 1 and 2] [7].

Staphylococcus aureus, another gram-positive coccus, is a less common cause of CAP and more often is acquired in the hospital. The frequency of *Staphylococcus aureus* infection ranges from 1% to more than 22% in severe CAP cases, and up to 5% of all CAP cases. Risk factors include intravenous drug abuse, diabetes, renal failure, and recent infection with viral influenza [5]. It usually causes a bronchopneumonia pattern that often predominates in the lower lobes. Volume loss is common. Pneumatoceles may occur and may contain air–fluid levels. Pleural effusions are found in more than 50% of cases, and can become superinfected [Figs. 3–5]. Abscesses are another common complication of bronchopneumonia [Fig. 6].

Haemophilus influenzae, a gram-negative coccobacillus, is another recognized cause of CAP. This organism frequently colonizes the upper respiratory tracts of individuals who have predisposing conditions, such as chronic obstructive pulmonary disease

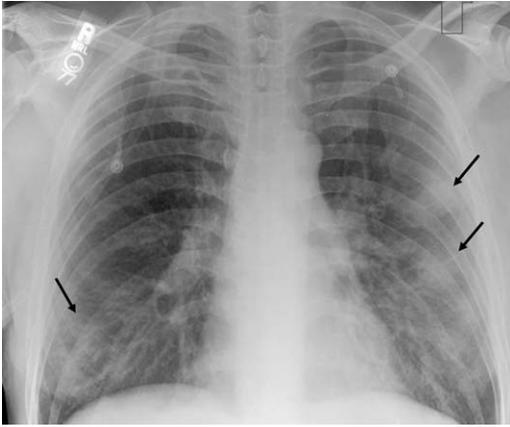


Fig. 3. *Staphylococcus aureus* pneumonia. Chest radiograph demonstrates multifocal opacities (arrows) predominantly in the left lung.

[5], and typically causes bronchitis. It usually produces a nonspecific bronchopneumonia pattern. Pleural and pericardial involvement is said to be common and affects up to 50% of patients [8].

Klebsiella pneumoniae, a gram-negative rod, is an important pathogen in nursing home-acquired pneumonia and in alcoholics. It is known for production of exudates that cause lobar consolidation and volume expansion that occasionally results in bowing of the fissures, although this appearance is seen less commonly with antibiotic use.

Atypical pneumonia

The term “atypical pneumonia” was coined in 1938 to describe cases of pneumonia without an obvious etiologic agent and with atypical signs and symptoms that failed to respond to standard treatments of that era [9]. *Mycoplasma pneumoniae* is the most common pathogen of this group. It also is one of the most commonly identified agents in CAP and



Fig. 4. *Staphylococcus aureus* bronchopneumonia. CT scan of the chest in another patient demonstrates bilateral multifocal opacities. Bronchopneumonia often is associated with pleural effusions as seen in this patient.



Fig. 5. *Staphylococcus pneumoniae*. CT scan of the chest demonstrates multifocal inhomogeneous opacities consistent with bronchopneumonia (arrows) in addition to bilateral pleural effusions and secondary relaxation atelectasis.

causes 20% to 30% of infections [6]. *Mycoplasma* is the smallest free-living culturable organism and shares some similarities with bacteria; however, it lacks a cell wall. It causes infection by cytotoxicity and damage that is incurred from the host inflammatory response. Upper respiratory tract symptoms may precede overt *M pneumoniae* infection. Patients classically develop nonproductive cough, headache, malaise, fever, rhinorrhea, and chest pain.

Mycoplasma pneumoniae has been known to produce segmental consolidation, sometimes with air trapping and mosaic perfusion. Pleural effusion and lymphadenopathy are uncommon. Using CT, Reittner and colleagues [10] demonstrated that 79% of patients who had mycoplasma pneumoniae had consolidation and 86% had centrilobular nodules (as compared with 17% in bacterial pneu-



Fig. 6. *Staphylococcus pneumoniae*. CT scan of the chest through the upper lobes of the same patient as in Fig. 5 demonstrates dense consolidation in the left upper lobe containing a focal region of low attenuation and gas (arrow) that is consistent with necrosis and abscess formation.

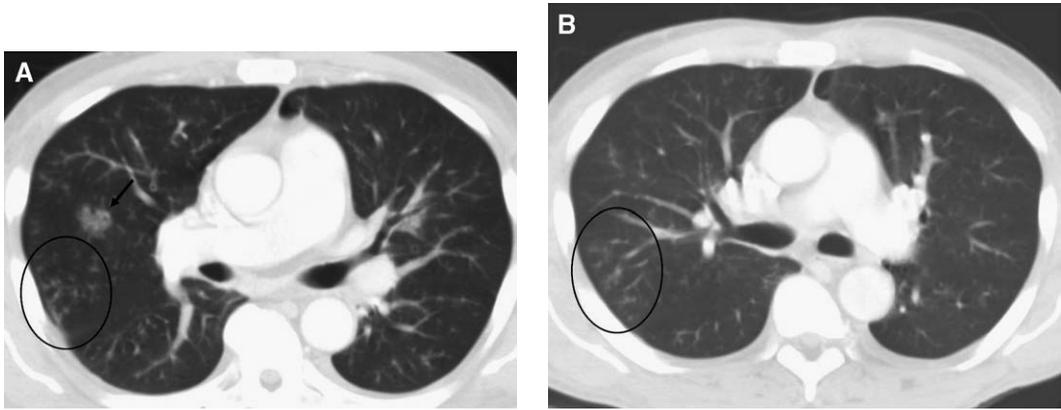


Fig. 7. *Mycoplasma pneumoniae*. CT scan of the chest demonstrates foci of ground glass attenuation (arrow, A). More inferiorly, CT scan of the chest demonstrates centrilobular nodules in a “tree-in-bud” pattern (circles, A and B).

monias). Focal areas of ground glass attenuation often were seen in association with these nodules [1,10]. Another retrospective study by Tomiyama and colleagues [11], using CT imaging, demonstrated centrilobular nodules in a patchy distribution in 96% of 13 patients who had mycoplasma infections versus 61% of patients who had bacterial pneumonia. Among patients in this study, 88% of patients had airspace consolidation, 100% had areas of ground glass attenuation, and 69% had centrilobular branching “tree-in-bud” structures compared with 34% in bacterial pneumonia. The “tree-in-bud” appearance represents dilated and fluid-filled (pus/mucus/inflammatory exudates) centrilobular bronchioles. It is characterized by a knobby bulbous appearance (the “bud”) at the tip of branching impacted bronchioles (the “tree”). Overall, the combination of airspace consolidation, centrilobular nodules, and heterogeneous segmen-

tal distribution was found in 85% of patients who had mycoplasma pneumonia [Fig. 7] [11].

Chlamydia pneumoniae, another atypical pathogen, is an obligate intracellular parasite that is the etiologic agent in 2% to 16% of cases of CAP [6]. The illness usually is self-limited and rarely is fatal. It has the highest prevalence in the elderly, whereas *M pneumoniae* has the highest prevalence in the young [5]. The imaging appearance is nonspecific and includes a combination of consolidation and linear opacities. The radiographic appearance may progress to a multilobar distribution over time [2].

Legionella pneumophila resides in natural water sources and is indigenous to freshwater lakes and streams. Infection can occur when *Legionella* contaminates water systems such as air conditioners and condensers. Infections tend to be more severe than most infections with mycoplasma and *Chlamydia pneumoniae*, and it is estimated that

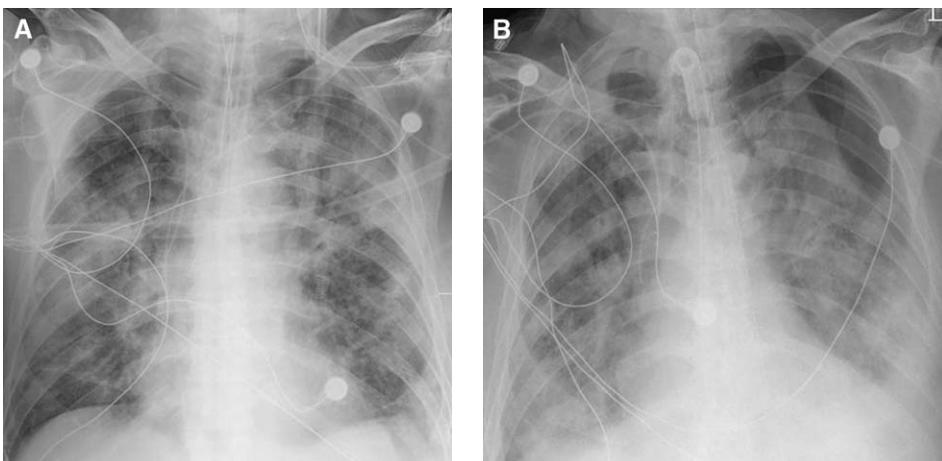


Fig. 8. *Legionella pneumoniae* in a patient who presented with severe respiratory distress. (A) Chest radiograph demonstrates multifocal bilateral air space disease. (B) Within 2 weeks, the patient’s respiratory status continued to decline and he developed a left-sided pneumothorax.

L pneumophila accounts for up to 6% of pneumonia that requires in-hospital management. The overall mortality in CAP that is attributed to *Legionella* is 14% [5]. *Legionella* often causes peripheral focal consolidation that rapidly progresses to involve an entire lobe or several lobes ipsilateral to the initial presenting site. Consolidation becomes bilateral in most patients, even with appropriate therapy. Pleural effusion occurs in 30% to 60% of patients and clears slowly compared with other bacterial pneumonias. Cavitation is common in immunocompromised patients [Fig. 8].

Aspiration pneumonia

Aspiration pneumonia is another important cause of consolidation in patients who present for emergency care. It characteristically occurs in dependent portions of the lung and is frequently bilateral. Material that is aspirated while the patient is upright tends to

localize to the right lower lobe. In supine patients, aspirated material collects in the posterior segments of the upper lobes. Alcoholic patients and persons who have poor oral hygiene are at increased risk and these patients are particularly prone to develop infections after aspiration. Anaerobic organisms cause 90% of aspiration pneumonias. Radiologic findings vary depending on the material aspirated and the causative organism. Aspiration of infectious material often manifests as necrotizing consolidation and abscess formation [Fig. 9].

Viral pneumonia

Viral pneumonias are another important cause of lower respiratory tract infections in adults that may present acutely. Responsible viruses include influenza, adenovirus, measles, varicella zoster, and cytomegalovirus (CMV). Influenza viruses types A and B account for most viral pneumonias in immunocom-

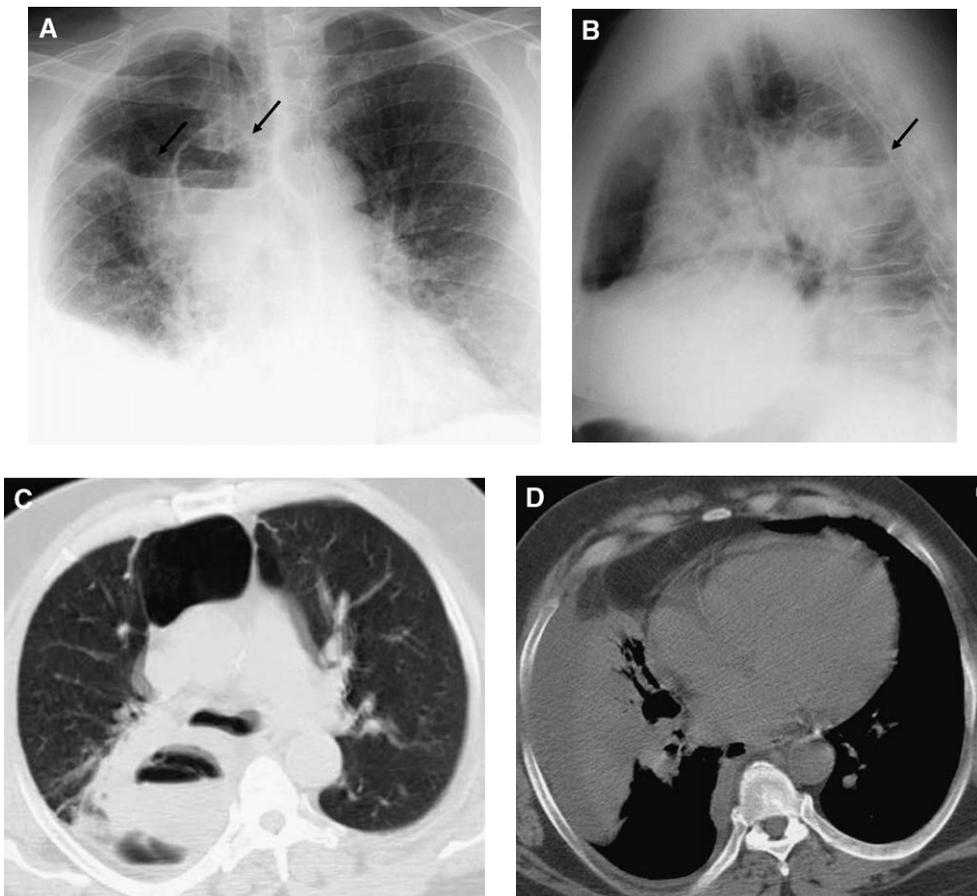


Fig. 9. Aspiration pneumonia in a 65-year-old alcoholic who had respiratory distress. (A) Admission chest radiograph demonstrates a right pleural effusion and multiple cavities containing air–fluid levels in the medial aspect of the right middle lung zone (arrows). (B) Lateral view localizes the cavities to the superior segment of the right lower lobe (arrow). (C) CT scan of the chest demonstrates multiple cavities in a dependent location in the medial aspect of the superior segment of the right upper lobe. (D) Images through the lung bases demonstrate right middle lobe consolidation and nondependent parapneumonic effusion.

petent adults. Immunocompromised patients are susceptible to CMV and other herpesvirus. Viruses can result in several forms of lower respiratory tract infections, including tracheobronchitis, bronchiolitis, and pneumonia.

Viral pneumonia is particularly severe in elderly and immunocompromised patients. Overall, patients who have viral pneumonia tend to have less severe illness than patients who have bacterial pneumonia, and they may complain of a dry hacking cough with minimal radiographic findings. Cultures often are necessary to make a definitive diagnosis.

The radiographic findings of viral pneumonia are nonspecific. Chest radiograph (CXR) can demonstrate reticular opacities that often are bilateral and diffuse in distribution. CT scan may show poorly defined air space nodules, patchy areas of peribronchial ground glass opacity, and consolidation. Hyperinflation commonly is present secondary to bronchiolitis. Uncommonly, viral pneumonias can be associated with thickened interlobular septa that results in Kerley B lines on CXR. Viral infections rarely are associated with complications or pleural effusion, but can lead to secondary bacterial pneumonia [Figs. 10–12] [12,13].

Fungal pneumonia

The endemic fungi, *Histoplasma capsulatum*, *Blastomyces dermatitidis*, and *Coccidioides immitis*, are regionally common causes of CAP in healthy individuals. These fungi reside in the soil where organic nitrogen allows optimum growth. Following inhalation of the infecting particles, a small area of pneumonitis develops. Only a minority of patients becomes symptomatic, and only a small fraction of symptomatic individuals visits a physician or requires treatment. The natural history of endemic

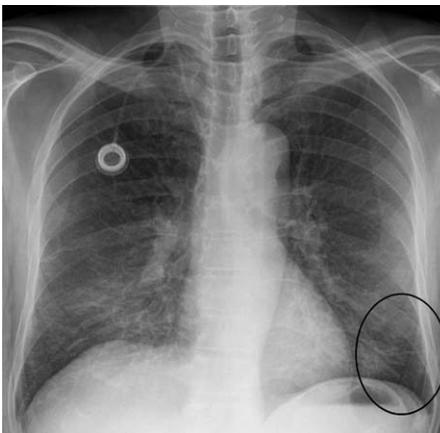


Fig. 10. Viral pneumonia. CXR demonstrates a diffuse bilateral reticular pattern consistent with viral infection. Note the presence of Kerley lines (circle), an uncommon feature in viral pneumonia.

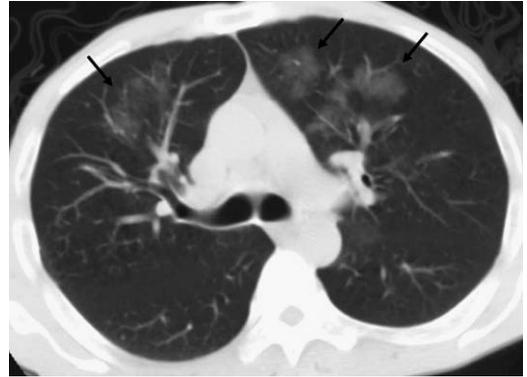


Fig. 11. Influenzae pneumonia. CT scan of the chest demonstrates patchy multifocal ground glass attenuation opacities (arrows).

fungal pneumonia is spontaneous resolution unless the inhaled infective dose is overwhelming or the patient is an abnormal host. Immunocompromised patients who present with the acute form of the disease require immediate treatment because of the high risk of progression that leads to ventilatory compromise and extrapulmonary dissemination.

Histoplasma capsulatum normally lives in soil that is contaminated with guano from bats or birds. Infection is endemic in the Ohio and Mississippi River valleys, and more than 70% of the population shows positive skin tests [2]. The initial polymorpholeukocytic response to the inhaled organism is ineffective in killing it, and lymphocytes and macrophages are recruited. Early in the disease, spread to lymph nodes is common and extrathoracic spread is frequent. Healing with formation of a fibrous capsule around the inflammatory focus frequently occurs with calcification. Symptomatic patients often present with respiratory problems, pulmonary opacities, hilar lymphadenopathy, and possibly,



Fig. 12. Influenzae pneumonia. CT scan of another patient who has influenza pneumonia demonstrates areas of bronchial wall thickening (arrow) and airway disease.

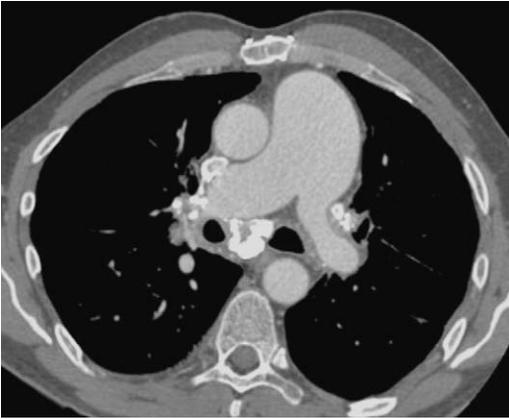


Fig. 13. Fibrosing mediastinitis in a 54-year-old man who had chronic histoplasmosis. CT scan of the chest demonstrates calcified mediastinal and hilar adenopathy. Note the narrowing of the left main pulmonary artery. The right main pulmonary artery is truncated and no right pulmonary veins are patent on imaging (incompletely seen).

organomegaly. In severe cases, the organism may cause overwhelming infection with hemoptysis, pericarditis, acute respiratory distress syndrome (ARDS), and death.

In most patients with histoplasma infection, the CXR is normal. It can manifest with a nonspecific pattern of multifocal air space consolidation or as multiple small nodules. Another pattern is that of a discrete pulmonary nodule, a histoplasma, which mimics carcinoma. These nodules can be large (≤ 3 cm). Adjacent “satellite” nodules are common, as is adenopathy that can be calcified. Occasionally, adenopathy may be the only finding which may cause atelectasis by compression of adjacent bronchi.

Chronic histoplasmosis can cause upper lobe linear opacities and fibrocavitary consolidation that

resemble postprimary tuberculosis (TB). Infection of mediastinal lymph nodes can result in necrosis and fibrosis of the affected lymph nodes—“fibrosing mediastinitis”—with subsequent venous obstruction, bronchial stenosis, and narrowing of the pulmonary arteries. Fibrosing mediastinitis probably occurs most often in a genetically susceptible population [Fig. 13] [14]. The disseminated form of histoplasmosis usually occurs in very young children or in severely immunocompromised individuals, such as patients who have AIDS or transplant recipients. The radiographic appearance is a miliary pattern that can affect extrathoracic organs.

Coccidiomyces immitis is a fungus that is endemic in the southwestern United States. Inhalation of the organism can produce varied appearances, including multifocal consolidation and multiple pulmonary nodules, sometimes with cavitation. Disseminated coccidiomycosis also can occur, which manifests in the chest as a miliary pattern that usually is associated with adenopathy [Fig. 14].

Blastomyces dermatitidis is an endemic fungus in the central and southeastern United States. As with the other endemic fungi, initial infection may be asymptomatic; symptomatic infection presents as a flu-like illness. Infection can be rapidly progressive with the development of multifocal bilateral air space opacities or even ARDS. Miliary disease also has been reported.

Pneumonia in immunocompromised patients

Immunocompromised patients frequently present to the emergency department with pneumonia. The etiologic agents that cause infections in immunocompromised hosts often are different from those that are found in immunocompetent individuals. Furthermore, the pattern of disease with the same organism often varies, depending on the immune

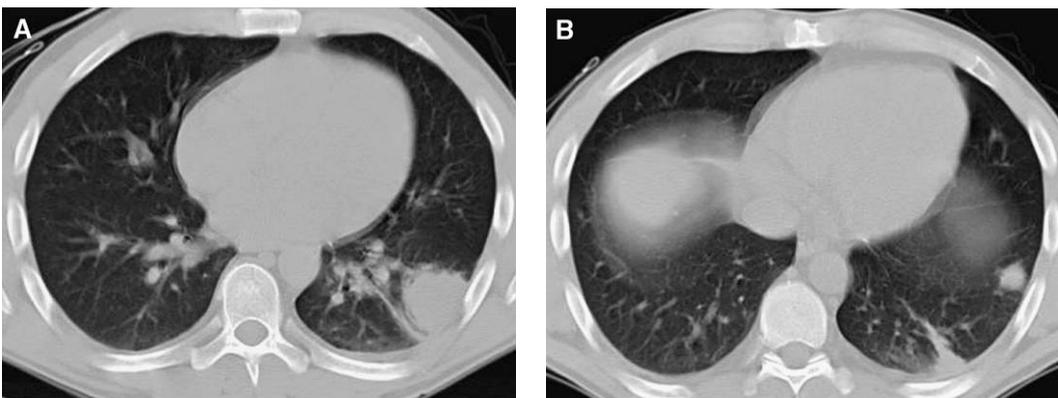


Fig. 14. *Coccidioides immitis* was isolated at bronchoscopy in a 34-year-old Mexican patient who presented to the emergency department with mild respiratory symptoms. (A and B) CT scan at two levels through the bases demonstrates multiple nodular areas of consolidation in the left lower lobe.

status of the infected individual. An organized approach to the imaging evaluation of immunocompromised patients is critical to ensure an accurate and timely diagnosis. In patients who have AIDS, the pattern and progression of abnormality should be correlated with the clinical scenario, including the CD4 count; in patients who have undergone transplants, the amount of time that has elapsed since institution of chemotherapy or transplant is important.

Imaging of immunosuppressed patients usually starts with chest radiography. Although radiographic findings often are nonspecific, they play an important role in triage. Follow-up radiography can help to monitor response to treatment. Recognizing basic patterns may help to establish the differential diagnosis.

Imaging patterns of infection

Infected immunosuppressed patients with focal air space opacities are most likely to have a bacterial infection. TB also should be a consideration in patients who have low CD4 levels. Multifocal air space opacities have a broader differential diagnosis and include bacterial infections, *Pneumocystis jiroveci* (PCP), and fungi (eg, *Cryptococcus* and *Aspergillus*). Mycobacterial infection is less likely. A pattern of nodular densities suggests fungal or mycobacterial infections. Cavitation usually is not found in viral infections. Franquet and colleagues [15] analyzed high-resolution CT (HRCT) scans in 78 immunocompromised patients with nodules and found that only 15% of the patients with nodules had a viral infection. Nodules were always multiple, 83% were less than 1 cm, and none was cavitory [15]. A diffuse or interstitial pattern is particularly concerning for viral infections and PCP. Less frequently can appear in this fashion bacterial infections, mycobacterium, or fungi [16].

AIDS

Respiratory disease is an important cause of morbidity and mortality in HIV-infected individuals; most patients encounter a pulmonary complication during the course of their illness. A variety of these infections has been classified as AIDS-defining illnesses, including cryptococcus, CMV, PCP, non-TB mycobacterium, mycobacterium TB, recurrent pneumonia, and disseminated histoplasmosis [17]. The epidemiology of thoracic manifestations of AIDS has changed because of antibiotics, with a reduction in the number of cases of PCP and an increase in the number of cases of *Mycobacterium avium* complex (MAC) and CMV. Because there is considerable overlap between the radiologic findings of numerous infections and neoplastic entities that are known to occur with increased frequency in

patients who have AIDS; clinical information, including the acuity of the illness, CD4 count, and current drug therapy, is valuable in limiting the differential diagnosis.

Regardless of the radiologic appearance, opportunistic infections generally do not occur before a decrease in the CD4⁺ count to less than 200×10^6 cells/L. Several other disease processes tend to be encountered only when the CD4⁺ count decreases to less than certain threshold levels as listed below [17]:

CD4⁺ greater than 200×10^6 cells/L: bacterial pneumonia, TB (reinfection)

CD4⁺ 50 to 200×10^6 cells/L: bacterial pneumonia, primary TB, PCP, fungal infections

CD4⁺ less than 50×10^6 cells/L: bacterial pneumonia, atypical appearances of TB, PCP, fungal infections, MAC, CMV

Pneumocystis jiroveci

Pneumocystis jiroveci, previously known as *P carinii*, was initially classified as a protozoan but is now believed to be a fungus. The prevalence of PCP has been decreasing with antibiotic prophylaxis. The diagnosis is suggested strongly by typical history, low CD4 count, and hypoxia. Induced sputum can establish the diagnosis, or alternatively, bronchoscopy with bronchoalveolar lavage can be used in patients who are at risk but who have a negative sputum induction result.

The radiographic appearance of PCP demonstrates considerable variation. The CXR can be normal; typical radiographic findings include bilateral perihilar air space disease or reticular markings [Fig. 15]. On CT, acute infection classically results in perihilar ground glass opacification, often in a geographic distribution with areas of affected lung interspersed by normal lung parenchyma. A linear or reticular pattern is demonstrated frequently with thickening of the interlobular septa causing a "crazy paving" pattern [Fig. 16] [18–20]. Some patients develop thin-walled cystic areas (pneumatocoles) that have an upper lobe distribution. Typically, these cysts do not contain fluid or other material. The exact etiology of pneumatocoles is unclear although a variety of mechanisms has been suggested, including check valve obstruction of small airways, pulmonary infarction, and production of proteases or elastases with lung digestion. Pneumatocoles may predispose to pneumothorax or pneumomediastinum [Fig. 17]. Atypical manifestations of PCP include focal consolidation, mass lesions, cavitation, and adenopathy [Fig. 18]. Multifocal air space consolidation can be seen if the patient has been ill for some time. Characteristically, pleural effusions are absent [2]. HRCT is highly sen-



Fig. 15. PCP pneumonia in a young HIV-positive patient. CXR demonstrates predominantly central air-space disease with peripheral sparing.

sitive and in a study by Hidalgo and colleagues [21], 10% of HIV-positive patients who had PCP and a normal CXR had an abnormal HRCT. Ground glass areas were found in all of the patients. A normal HRCT is said to rule out PCP pneumonia [22].

Bacterial pneumonia in AIDS patients

Although the major immune deficiency in AIDS patients impacts T-cell function, B-cell and antibody production are also affected and increase the susceptibility to pyogenic organisms. Bacterial pneumonia tends to occur throughout the course of HIV illness and becomes increasingly common with a decreasing CD4⁺ count. Two or more episodes of bacterial pneumonia within a 1-year period constitute an AIDS-defining illness. The prevalence of bacterial pneumonia is six times greater than in the general population, and the development of pneumococcal septicemia is 100-fold greater [23]. Similar to that in the general population, bacterial pneumonia in HIV-infected individuals is usu-



Fig. 16. PCP pneumonia in another young HIV-positive patient. CT scan demonstrates a mixed pattern of ground glass attenuation and superimposed prominent septal lines in a "crazy-paving" pattern.

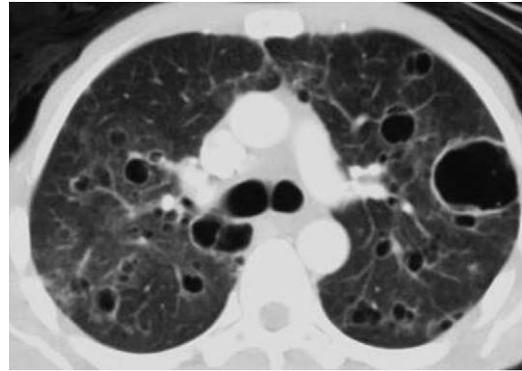


Fig. 17. PCP pneumonia. CT scan of the chest demonstrates cystic air spaces of varying sizes that are consistent with pneumatoceles.

ally community acquired. *Streptococcus pneumoniae* is the most common infecting organism; *Haemophilus influenzae*, *Staphylococcus aureus*, *Escherichia coli*, and *Pseudomonas* account for the majority of remaining cases. The clinical presentation of pneumonia is generally the same as in the HIV-negative population; however, there is an increased tendency for rapid progression, cavitation, parapneumonic effusion, and empyema formation.

The most common radiographic finding in bacterial pneumonia in AIDS patients is focal consolidation, and the combination of focal consolidation and clinical symptoms of fewer than 7 days' duration is highly specific for the diagnosis of bacterial pneumonia. Almost one half of cases demonstrate a radiographic pattern other than focal consolidation that can mimic infections by nonbacterial pathogens such as PCP [23]. Bacterial infections also can present as nodules that can cavitate. A study of cavitory nodules in HIV patients by Aviram and colleagues [24], found a bacterial cause in 85% of the cases; more than one pathogen was

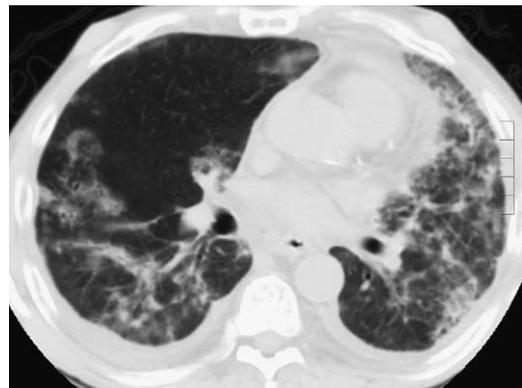


Fig. 18. PCP pneumonia in an HIV-positive patient who had hypoxia. CT scan of the chest demonstrates an atypical pattern with scattered irregular heterogeneous densities and areas of bronchial wall thickening.

identified in most patients. The most frequently identified organisms were *Pseudomonas aeruginosa* and *Staphylococcus aureus*. In most bacterial infections, mildly enlarged lymph nodes are seen frequently on CT imaging but usually not on CXR. Visibly enlarged nodes on CXR in HIV-positive patients with CD4 counts of less than 200×10^6 cells/L suggests TB. Pleural effusions are uncommon in patients who have PCP, but are seen more typically in patients who have pyogenic bacterial infections.

Pyogenic airway disease in AIDS

HIV-infected patients are at an increased risk for developing airway disease such as bacterial tracheobronchitis, in addition to pneumonia. The most common infectious organisms include *Haemophilus influenzae*, *Pseudomonas aeruginosa*, and *Streptococcus pneumoniae*. Airway infection leads to inflammation with subsequent bronchial wall thickening and dilatation. These changes can be irreversible if they are not treated early with antimicrobial agents. Bronchiolitis may create an interstitial pattern of reticulonodular opacities that represent impacted bronchioles; however, the CXR can be normal. The characteristic findings of infectious bronchiolitis are centrilobular nodules and "tree-in-bud" structures. Focal regions of air trapping may be evident on expiratory CT scans [17,23].

Cryptococcus

Cryptococcus is the most common fungal pulmonary infection in patients who have AIDS, and it usually coexists with cryptococcal meningitis. Infection may be asymptomatic, but clinically apparent

pneumonia occurs in approximately 30% of patients. It tends to affect patients who have CD4 counts that are less than 100×10^6 cells/L [17]. In healthy patients, cryptococcal infection usually manifests as one or more peripheral circumscribed nodules, usually without cavitation [25]. In patients who have AIDS, cryptococcal pneumonia may have a variety of appearances. It has been known to demonstrate a diffuse reticular or reticulonodular pattern that resembles PCP, lobar or segmental consolidation, or multiple nodules that have a propensity to cavitate [26]. Disseminated disease can occur and manifests as a miliary pattern that may be associated with lymphadenopathy or pleural effusion [Fig. 19] [2].

Mycobacterial infections

Mycobacteria are aerobic, nonspore-forming rods with unusually long doubling times. Two broad groups cause human disease: TB complex and the non-TB/atypical mycobacteria complex (NTMB).

Tuberculosis

TB has been an infection of importance throughout human history and can be a serious diagnostic dilemma in the emergency department setting. It has become increasingly important with the emergence of HIV and is one of the leading causes of death among HIV-infected individuals. Numerous factors influence the likelihood of contracting TB. Homeless individuals, intravenous drug users, and immunocompromised patients are at an increased risk compared with the rest of the population. TB becomes increasingly common in patients toward the later stages of immunosuppression, but as with

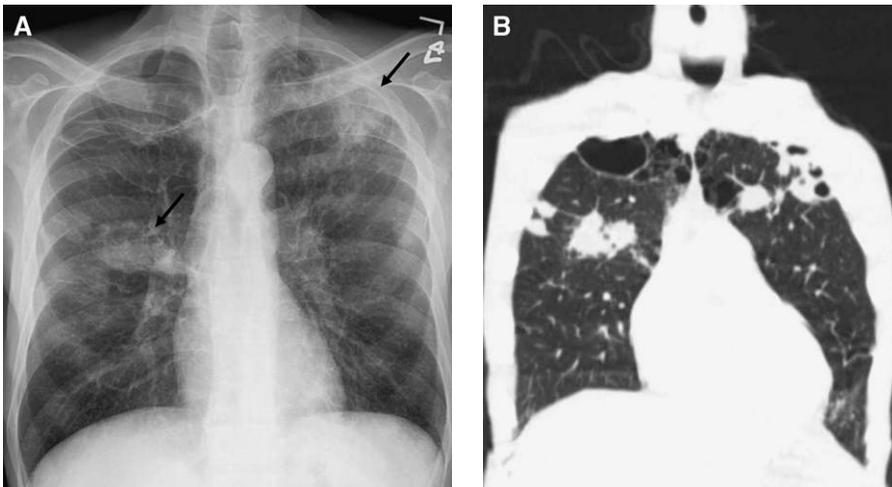


Fig. 19. (A) Cryptococcus infection in an HIV-positive patient who had respiratory distress. CXR demonstrates multiple bilateral foci of consolidation (arrows), some of which appear nodular and cavitary. Emphysematous changes are identified at the apices, especially on the right. (B) Accompanying CT coronal image demonstrates upper lobe cystic air space disease. Bilateral upper lobe nodules, cavitation in the left upper lobe, are demonstrated.

bacterial pneumonia, infection may occur at relatively high CD4 counts. Very young and elderly patients also are at higher risk of infection. Infection begins with the inhalation of airborne respiratory droplets that contain the organisms. Person-to-person contact is more likely if exposure occurs in a poorly ventilated area, or if contact with the infected person is prolonged.

Primary tuberculosis Primary TB is said to occur when clinical infection occurs after the first exposure to the organism. TB is able to survive dormant within host macrophages for long periods of time and incite a delayed hypersensitivity response by the infected host. Under normal circumstances, the host sequesters the organism by forming caseating granulomas. This initial infection has been termed the "Ghon focus" and usually heals by developing a fibrous capsule around the focus of infection which often calcifies. Organisms may spread through the lymphatics to hilar and mediastinal lymph nodes where a similar reaction occurs; the combination of lung and hilar infection is called the "Ranke complex." Usually, host defenses are sufficient to prevent overt infection. Organisms remain viable and may serve as the nidus for reactivation when conditions become more favorable [2].

Most often, patients who have primary TB show no radiologic abnormalities. If there is overt infection, the pattern is one of air space consolidation with no zonal predominance. Cavitation is uncommon. Adenopathy is common in children and can be striking; occasionally, it causes atelectasis by airway compression. Usually, hilar lymph nodes are involved, and mediastinal lymph nodes, particularly in the right paratracheal region, may be enlarged as well. Unilateral adenopathy is more common than bilateral disease. After administra-

tion of intravenous contrast, enlarged lymph nodes may have central areas of low attenuation with peripheral enhancement, which reflect the presence of necrosis [Fig. 20]. Unilateral pleural effusion is another less common presentation and these effusions can be large [27].

Progressive and postprimary tuberculosis Primary TB infection can progress rapidly and cause extensive consolidation and cavitation at the site of the initial pulmonary parenchymal focus of infection or in the apical and posterior segments of the upper lobes. This pattern of progression of primary TB is called *progressive TB* and radiographically resembles postprimary TB infection.

Postprimary (reactivation) TB occurs as a result of previously latent infection. During the initial infection, organisms may be transported by the bloodstream to the apical and posterior segments of the upper lobes and to the superior segments of the lower lobes. Reactivation in these regions may be favored by high oxygen tension and tends to occur when host defenses become impaired. Latent organisms become active and overt infection develops. Unlike the healing that commonly occurs with primary *Mycobacterium tuberculosis* (MTB) infection, postprimary TB infection is often associated with progressive disease. As inflammation mounts, tissue destruction occurs, caseous material liquefies, and communication with the tracheobronchial tissue can ensue. This produces cavitation, the characteristic pathologic and radiologic finding of postprimary MTB. Cavitation creates the opportunity for endobronchial spread of infection and communication to other individuals. If host defenses triumph, these cavities usually heal by scar formation with bronchiectasis, volume loss, and areas of emphysema. Chronic thin-walled cavities may persist. Typical clinical

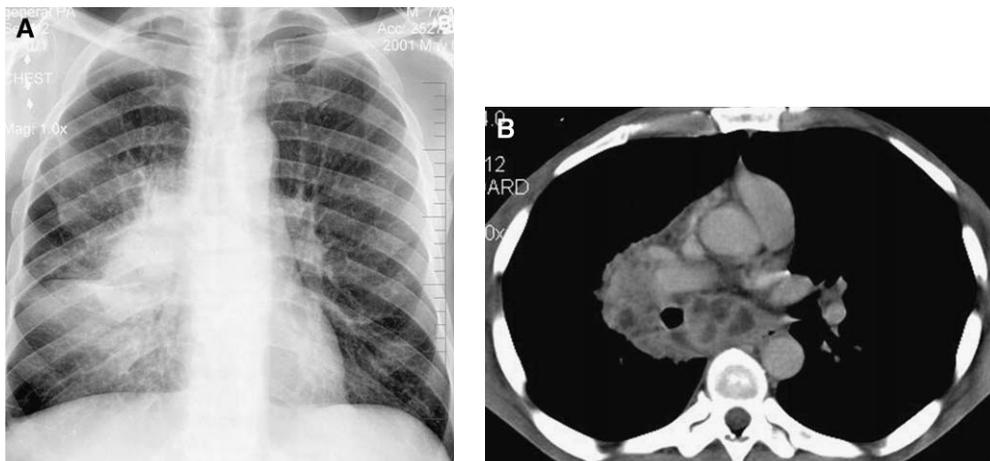


Fig. 20. Primary TB. (A) CXR demonstrates prominent unilateral right hilar adenopathy. (B) CT scan demonstrates necrotic subcarinal and right hilar adenopathy.

cal manifestations of postprimary TB include failure to thrive, fatigue, night sweats, weight loss, and low-grade fever. Bronchiectasis may result in hemoptysis [2].

Radiographic findings of postprimary TB include consolidation in apical and posterior segments of the upper lobes, and, to a lesser extent, the superior segments of the lower lobes. Areas of cavitation develop in 20% to 45% of patients. Often small, poorly defined "satellite" nodules are seen at the periphery of the dominant foci of consolidation. Commonly there are poorly defined nodules in a centrilobular location and branching structures in a "tree-in-bud" pattern. Lymphadenopathy and effusions are uncommon [Fig. 21].

Miliary tuberculosis In fewer than 5% of patients who have TB, the mycobacterial infection spreads hematogenously and causes a "miliary" pattern of nodularity on CXR. It can occur with primary or postprimary TB infection. HIV-positive individuals have a higher frequency of miliary and extrapulmonary disease [28]. The characteristic radiographic findings of miliary TB consist of innumerable 1- to 3-mm noncalcified nodules that are scattered throughout both lungs. Associated radiographic findings, which may suggest the diagnosis of TB and are present in up to 30% of affected persons, include consolidation, cavitation, calcified lymph nodes, and lymphadenopathy. On thin-section CT nodules are found in a diffuse, random fashion. After acute infection, the radiograph may return to normal rapidly or scattered residua of the nodules may persist [Fig. 22].

In general, previous radiographs are needed for comparison to determine disease activity. Stability for longer than 6 months suggests inactivity. Other

findings that are associated with inactive disease include bronchiectasis, linear opacities, and calcified nodules [28]. Consolidation, endobronchial spread, a miliary pattern, and cavities suggest active disease. The "tree-in-bud" pattern is the most characteristic CT feature of active endobronchial spread and can be found in 72% of patients who have active disease. In a study of patients who had active TB (based on acid-fast bacilli in sputum), Im and colleagues [29] found centrilobular lesions (nodules or a "tree-in-bud" pattern) in 95% of patients. Most of these nodules disappeared with treatment.

Tuberculosis in AIDS patients The radiographic manifestation of TB in AIDS patients depends on the patient's CD4 count. Patients who have preserved immunity and CD4 counts greater than 200×10^6 cells/L usually present with a pattern of disease that resembles postprimary MTB infection. Patients with CD4 counts that are less than 200×10^6 cells/L present with a pattern of disease that resembles primary MTB infection with lymphadenopathy, pleural disease, and a tendency for dissemination [17]. Culture-positive pulmonary TB with a normal CXR is not uncommon and in a study by Greenberg and colleagues [30], 21% of 48 patients with active TB and CD4 counts less than 200×10^6 cells/L had a normal CXR. Extrapulmonary dissemination is more frequent in immunocompromised patients than in immunocompetent patients.

Nontuberculosis mycobacterial pneumonia

NTMB includes at least 20 organisms, of which only a fraction is important in causing lung infection. They are classified by pigment production and growth rate. NTMB pulmonary infections in immu-

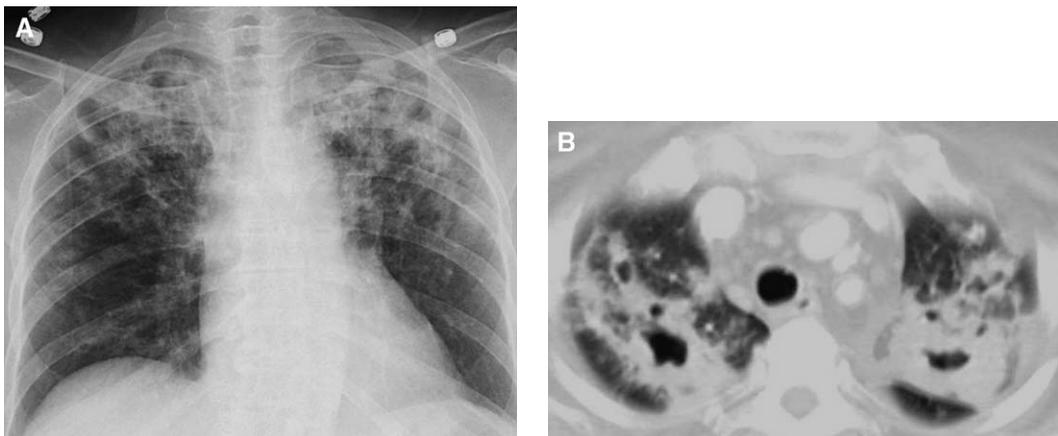


Fig. 21. Postprimary TB in an immunocompromised patient who had weight loss and night sweats. (A) CXR demonstrates biapical cavitary consolidation. (B) CT scan confirms the cavitary nature of upper lobe opacities.

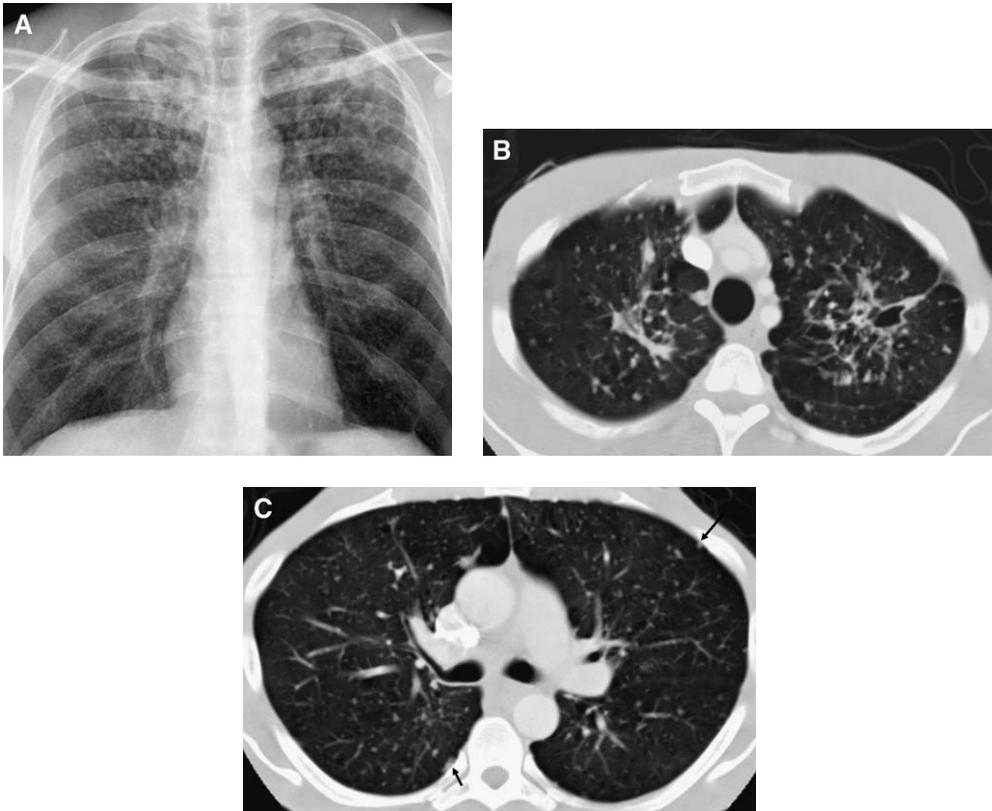


Fig. 22. Miliary TB. Culture proven miliary TB in an HIV-positive patient with several weeks' duration of constitutional symptoms, fever, and weight loss. (A) CXR demonstrates biapical cavitory lesions and superimposed innumerable diffuse well-defined subcentimeter nodules. (B and C) CT scan confirms presence of upper lobe consolidation and innumerable randomly distributed subcentimeter nodules consistent with a miliary distribution. Some nodules (arrows, C) are on pleural surfaces, an important differentiation from airway nodules which are separate from the pleura.

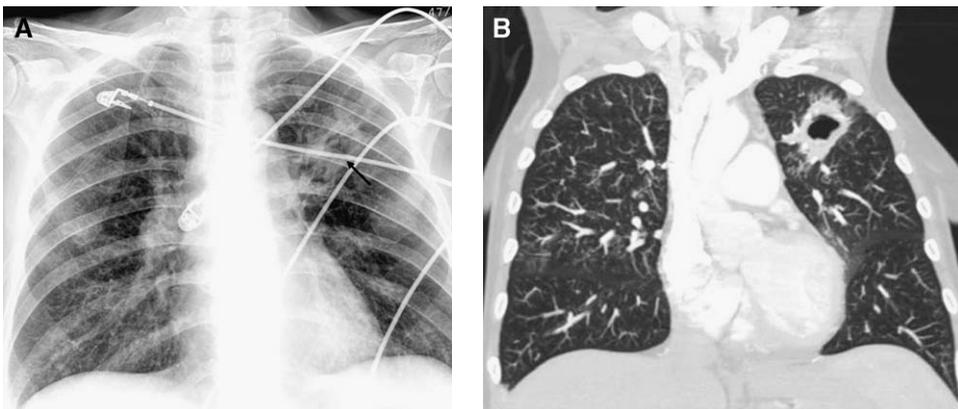


Fig. 23. *Mycobacterium avium-intracellulare* pneumonia in a middle-aged man who had fever. (A) CXR demonstrates cavitory consolidation in the left upper lung zone (arrow). (B) Coronal CT confirms the presence of a thick-walled cavitory lesion in the left upper lobe. Imaging is indistinguishable from postprimary TB.

nocompetent hosts have two distinct radiologic manifestations: an upper lobe cavitory form and a nodular bronchiectatic form.

The characteristic findings of the upper lobe cavitory form are heterogeneous nodular and cavitory opacities. Often there is a combination of consolidation, cavities, and scar formation that is indistinguishable from postprimary TB. This form is encountered most often in older men who have mild immunocompromised states, such as chronic obstructive pulmonary disease, and is seen most often in infection by *M avium-intracellulare* complex [Fig. 23].

The second pattern is a nodular bronchiectatic form which often occurs in middle-aged women who do not have underlying lung disease called "Lady Windemere syndrome." This pattern consists of bronchiectasis and centrilobular nodules that predominate in the right middle lobe and lingula. A study by Jeong and colleagues [31], of 22 patients who had NTMB pulmonary infection, found that 87% had nodules that were smaller than 10 mm, 58% had a branching centrilobular "tree-in-bud" pattern, and 81% had cylindrical bronchiectasis. Large nodules (>1 cm) were seen in some patients. Findings often can be extensive and a study by Koh and colleagues [32] demonstrated that 34% of 105 HIV-negative patients who had a combination of bilateral multifocal bronchitis (centrilobular nodules and "tree-in-bud" structures) and bronchiectasis had a subsequent positive diagnostic work-up for NTMB [Figs. 24 and 25].

The prevalence of NTMB infection increases as the CD4 count decreases and most patients who have clinically overt infection have CD4 cell counts that are less than 50 cells/ μ L. The immunocompromised patient who has NTMB presents in a

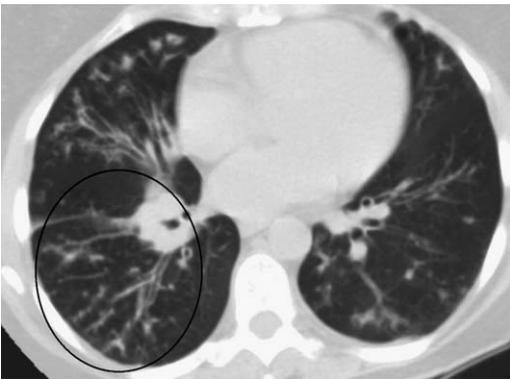


Fig. 24. *Mycobacterium avium-intracellulare* pneumonia in a middle-aged woman. CT scan demonstrates evidence of small airway disease with scattered bilateral centrilobular "tree-in-bud" structures (circle). Bronchial wall thickening is seen in the right middle lobe.

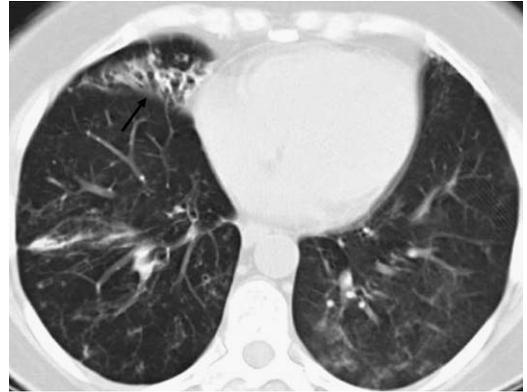


Fig. 25. *Mycobacterium avium-intracellulare* pneumonia in another patient. CT scan of the chest demonstrates bronchiectasis and bronchial wall thickening in the right middle lobe (arrow) and "tree-in-bud" structures in the lower lobes.

manner that is entirely different from the patterns described above. They may have no radiographic abnormalities, presumably because of inadequate inflammatory response. When present, radiographic findings include small, usually centrilobular, nodules combined with air space consolidation. Lymphadenopathy and pleural effusions may be the only abnormalities with no evidence of parenchymal disease. Mediastinal lymph node enlargement may show central areas of low attenuation, although this finding is seen more commonly in patients who have TB [33].

Atypical organisms, such as *Nocardia*, always should be considered in HIV-infected individuals who have advanced immune suppression. Cavitating masses, consolidation, and pleural effusions are common features [17].

Non-HIV immunocompromised patients

Bone marrow transplant

Patients who are immunocompromised secondary to chemotherapy and bone marrow transplant recipients are susceptible to different organisms than are HIV-infected patients. Bone marrow transplant (BMT) or hematopoietic stem cell transplantation involves the intravenous infusion of hematopoietic progenitor cells to replace the malignant or ablated bone marrow cells. It is used in the treatment of hematologic malignancies and certain solid tumors. Allogeneic transplantation refers to the transfer of marrow from a donor to a recipient who is not an identical twin, whereas autologous transplantation involves the use of the patient's own marrow. Pulmonary complications occur in 40% to 60% of patients who undergo BMT and are a common cause of morbidity and mortality [34].

There is a predictable time course of neutropenia, immunosuppression, and recovery that allows for the development of a post-BMT timeline in patients who receive allogeneic transplants. Knowledge of this timeline is of critical importance when confronted with an abnormal CXR in a patient who has undergone BMT. This issue is especially important as the prognosis is grim for immunosuppressed patients who have pulmonary complications. The mortality in immunosuppressed patients who require mechanical ventilation exceeded 80% [35]. A study of 200 non-HIV immunocompromised patients demonstrated that a delay of greater than 5 days in identifying the etiology of infectious “infiltrates” was associated with a more than threefold risk of death [36]. The radiologist’s role in helping to narrow the differential diagnosis in these patients is critical. Pulmonary complications can be classified chronologically as occurring in the neutropenic or pre-engraftment period (0–30 days after BMT), in the early post-engraftment period (31–100 days after BMT), or in the late post-engraftment period (>100 days after BMT). CMV and *Aspergillus* were the most common pathogens overall in one study [37].

Neutropenic phase complications after bone marrow transplant

During the neutropenic phase, patients are particularly susceptible to bacterial and candidal infections and invasive aspergillosis [37]. Bacterial infections during this time period are related to severe granulopenia and often are caused by gram-negative bacteria. Usually the appearance is similar to that in an immunocompetent patient, with focal or multifocal consolidation. Candida pneumonia manifests as a focal or multilobar consolidation

occasionally with a linear interstitial component. Cavitation and adenopathy are not features. Patients also may have multiple nodules with areas of ground glass opacity [2].

Aspergillus pneumonia

Aspergillus is a ubiquitous fungus, found throughout nature which may cause disease in susceptible hosts when inhaled. The risk groups for invasive aspergillosis are patients who have severe, prolonged granulocytopenia secondary to hematologic malignancy; hematopoietic stem cell/solid organ transplant recipients; and patients who are taking high-dose corticosteroids. Rarely, persons who have HIV infection develop aspergillosis. *Aspergillus fumigatus* is the most important species that causes infection in humans.

Angioinvasive aspergillosis results when *Aspergillus* invades the pulmonary vasculature and causes thrombosis, pulmonary hemorrhage, and infarction. It is characterized at histologic analysis by the invasion and occlusion of small- to medium-sized pulmonary arteries by fungal hyphae that lead to the formation of necrotic hemorrhagic nodules or pleural-based, wedge-shaped, hemorrhagic infarcts [38]. CXRs often are abnormal, but nonspecific, and reveal patchy segmental or lobar consolidation or multiple, ill-defined nodular opacities. Characteristic CT findings consist of nodules that are surrounded by a halo of ground glass attenuation (“halo sign”) or pleural-based, wedge-shaped areas of consolidation. These findings correspond to hemorrhagic infarcts. In severely neutropenic patients, the halo sign is highly suggestive of angioinvasive aspergillosis; however, a similar appearance has been described in several other conditions, such as candida, mucor, herpes simplex, CMV, and Kaposi’s sarcoma [Fig. 26] [39].

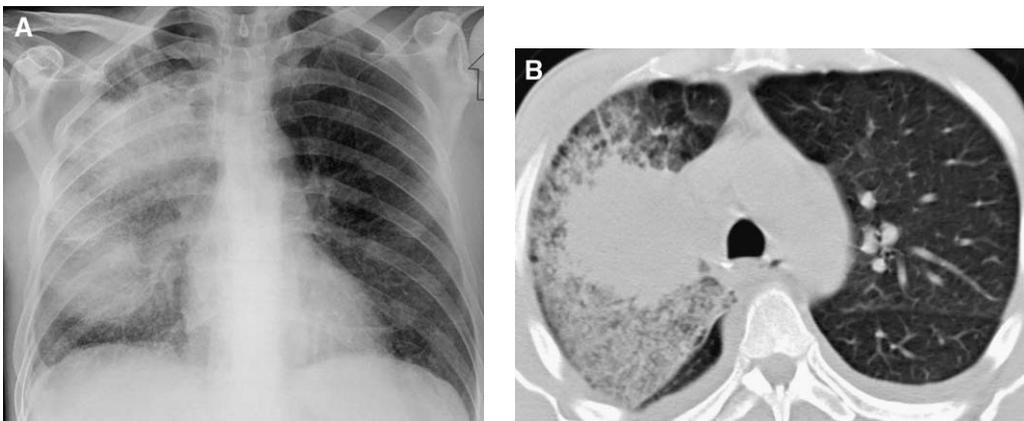


Fig. 26. Acute aspergillus infection in a neutropenic patient. (A) CXR demonstrates large foci of nodular consolidation with “shaggy” borders in the right lung. (B) Corresponding CT scan confirms large nodular consolidation in the right upper lobe with surrounding heterogeneous ground glass attenuation. Findings are consistent with a “halo” sign.

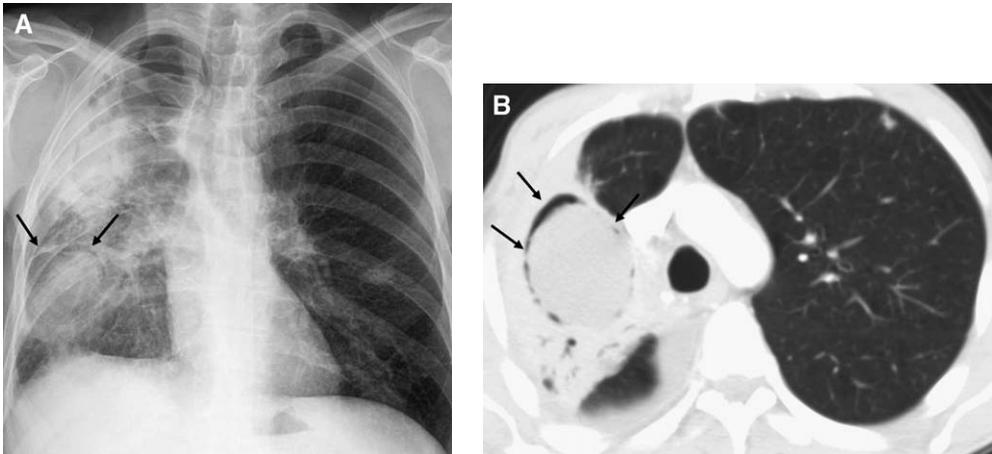


Fig. 27. (A) CXR of the patient in Fig. 26 a couple of weeks later demonstrates that the previously identified nodules are better defined and have developed a peripheral crescent of air (arrows). (B) Corresponding CT scan demonstrates cavitary consolidation containing air-bronchograms and an “air crescent” sign (arrow). The “air crescent sign” results when air fills the space between devitalized tissue and surrounding parenchyma. In the appropriate clinical setting, this finding is specific for aspergillus infection.

As the patient’s immune system recovers, about 2 weeks after the onset of infection, CXR or CT may demonstrate an “air crescent sign,” corresponding to necrotic lung around retracted infarcted lung. Although this finding is not specific for angioinvasive aspergillosis, it is highly characteristic in the proper clinical setting, especially when the initial lesion is consolidation or a mass [38]. Air crescent formation was shown to be associated with improved survival [Fig. 27] [40].

Predominant airway involvement by *Aspergillus* organisms, termed “airway-invasive aspergillosis,” occurs most commonly in immunocompromised neutropenic patients and in patients who have AIDS [38,41]. Radiologic findings include patchy centrilobular nodules, “tree-in-bud” centrilobular structures, and a bronchopneumonia pattern. Bronchial wall thickening also may occur [38].

Early-phase complications after bone marrow transplant

Later, in the postengraftment or early phase, the predominant infectious risk is viral, most commonly from CMV. Respiratory syncytial virus and parainfluenza commonly cause upper respiratory symptoms during this time as well and progress to clinically significant pneumonia in 30% to 40% of cases [34,42]. CMV pneumonia occurs in approximately 15%–30% of patients who receive allogeneic BMT, usually between 6 and 12 weeks after transplantation [34]. Infection most commonly occurs from reactivation of latent endogenous virus [34,43]. It is uniformly fatal if not treated [43].

The radiographic manifestations of CMV are non-specific and can be normal. CT may reveal multifocal, bilateral ground glass opacities and foci of air space consolidation accompanied occasionally by small centrilobular nodules. Franquet and colleagues [44] demonstrated areas of ground glass opacities on CT in 66% of 32 HIV-negative immunocompromised patients who had CMV pneumonia. Multiple, subcentimeter nodules were identified in 59% of the cases, and a halo of ground glass attenuation was seen in 37% of the cases. Fifty-nine percent of the patients also had areas of air space consolidation. A study by Gasparetto and colleagues [45], of 13 patients who had undergone BMT and who had CMV pneumonia, similarly demonstrated ground glass opacities as the predominant abnormality in 69% of patients. Small centrilobular nodules were found in 69% of patients and air space opacities were found in 54% of patients. In both studies, findings were almost always bilateral [Fig. 28].

Late-phase complications after bone marrow transplant

Late-phase complications occur 100 days or more after BMT, and the patient’s immune system is near normal by 1 year. The most common infections in this phase are bacterial, although mycobacterial infections also should be considered.

Solid organ transplant infections

Solid organ transplant recipients are susceptible to infections similar to those following BMT. In organ transplant patients there are three important periods. In the first month, infections are second-

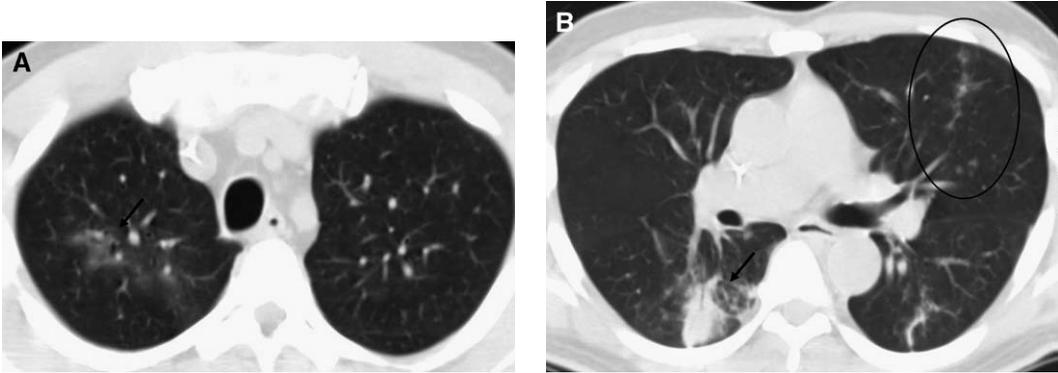


Fig. 28. CMV pneumonia in a bone marrow transplant recipient. CT scan of the chest demonstrates ground glass attenuation and consolidation (arrow, A and B). Centrilobular air space nodule consistent with an airway distribution is identified in the lingula (circle, B). CMV was isolated at bronchoscopy.

ary to nosocomial bacteria. At 1 to 6 months after transplantation, viruses, such as CMV, Epstein-Barr virus, and herpes simplex, become more important potential causes of lung infection. In addition, because these viruses can impair immunity, they can predispose the host to opportunistic pneumonia by PCP or *Aspergillus fumigatus*. Beyond 6 months after transplantation, patients with adequate graft function develop infection only occasionally, and the infecting organisms tend to be those of the non-transplant population [16].

New/emerging infections

Anthrax and severe respiratory syndrome (SARS) cause acute respiratory distress and are emerging conditions the emergency radiologist needs to recognize in order to assist referring clinicians in making an appropriate diagnosis.

Anthrax

Anthrax is caused by the bacterium *Bacillus anthracis*. It is a gram-positive aerobic spore-forming microorganism. Infection occurs by three different portals of entry: the skin, the gastrointestinal tract, and the lungs. The inhalational form has the highest mortality. When dispersed in the air and inhaled, anthrax spores are deposited into the alveolar ducts or alveoli where they are engulfed by macrophages that carry them to peribronchial and mediastinal lymph nodes. They germinate in the lymph nodes and cause a large amount of toxin production and secondary edema, necrotizing lymphadenitis, hemorrhagic mediastinitis, mediastinal enlargement, and bacteremia [46,47]. The bacillus does not cause a true pneumonia in most cases; however, retrograde migration through lymphatics can occur resulting in an interstitial perihilar pneumonia [47].

Anthrax was largely unknown in the United States until shortly after the terrorist attacks on the World Trade Center and Pentagon on September 11, 2001. In late 2001, 23 cases of anthrax were reported, 11 of which were inhalational. Five of the patients who had the inhalational form died [46]. The possibility of terrorism still exists and, it is important for health care providers to consider anthrax in the appropriate differential diagnosis because the clinical manifestations of early disease are nonspecific and the predicted case fatality of inhalational anthrax, based on historical data, is approximately 90% [48]. Timely diagnosis can reduce mortality substantially and initiate public health and law enforcement measures.

All recent patients who had inhalational anthrax had abnormal findings on CXR. Manifestations include mediastinal widening due to bulky lymphadenopathy and pleural effusions. Hilar adenopathy also may be present. Consolidation can be present often secondary to pulmonary hemorrhage [49]. CT findings include high attenuation mediastinal and hilar adenopathy, pleural effusions that can be hemorrhagic, and mediastinal widening. Ring-like nodal enhancement also is described [Fig. 29] [47,49].

Anthrax should be considered in the differential diagnosis of a patient with possible exposure and the above radiographic findings in the absence of trauma, dissection, or bleeding diathesis.

Severe acute respiratory syndrome

SARS is an infectious pulmonary disease that seems to have originated in southern China in the fall of 2002. Sophisticated isolation methods demonstrated that the causative agent is a coronavirus that is spread by respiratory droplets. It spread to other parts of Asia, Europe, and North America; more than 8422 cases were reported from November

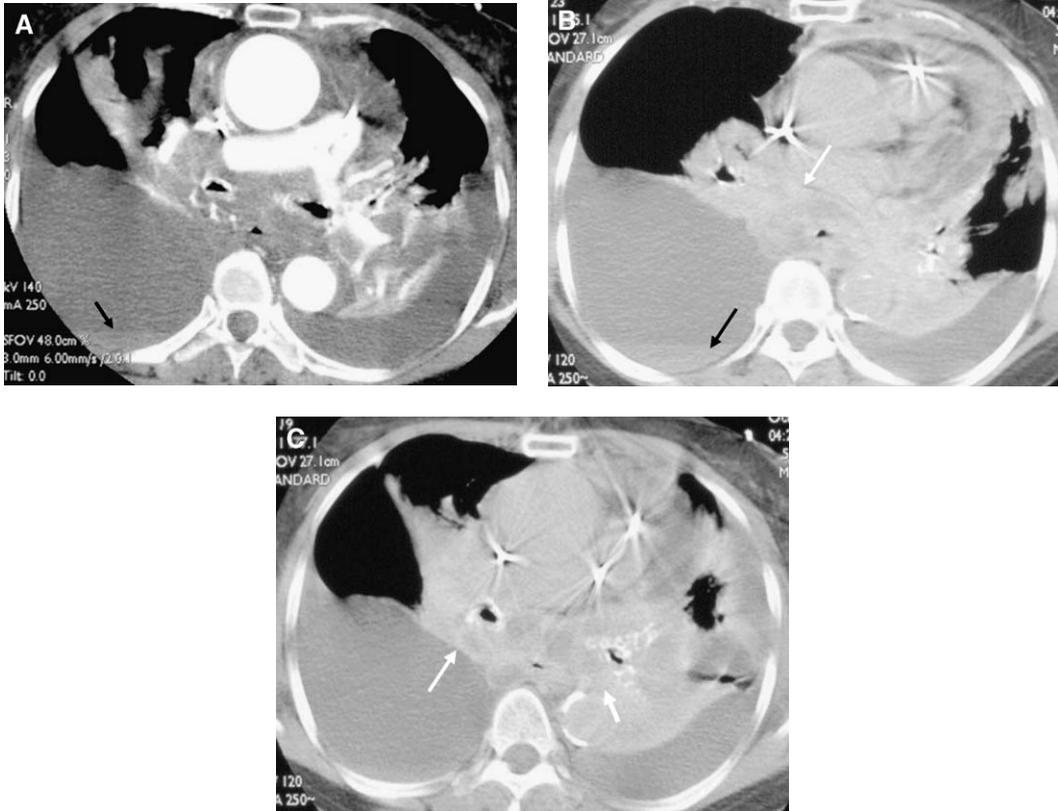


Fig. 29. Anthrax. Blood culture confirmed case of inhalational anthrax in a 61-year-old postal worker who presented to the emergency room after 3 days of experiencing general malaise and chills. (A) Contrast-enhanced CT scan demonstrated diffuse mediastinal infiltration and large bilateral pleural effusions. Right pleural effusion has a fluid-fluid level with layering high attenuation fluid; consistent with hemorrhage (*black arrows, A and B*). (B and C) Delayed CT scan of the chest demonstrates high attenuation mediastinal and hilar adenopathy; consistent with hemorrhage (*white arrow, C*). Anthrax infection should be considered in cases with high-attenuation adenopathy without intravenous contrast administration. (Courtesy of Jeffrey Galvin, MD, Baltimore, MD and the Armed Forces Institute of Pathology).

2002 to August 2003 and the death toll reached 916 (11%) individuals [50]. As of this writing, the world is in an interepidemic period and the last human chain of transmission has been broken [51].

The clinical presentation of SARS includes fever, dyspnea, nonproductive cough, chills or rigors, malaise, and myalgias. The natural clinical history ranges from febrile respiratory symptoms without hypoxemia to fatal respiratory distress. The World Health Organization defines SARS as “suspect” or “probable.” Clinical presentation and the patient’s level of contact with a SARS person who has SARS define a “suspect” case [52]. A “probable” case involves a “suspect” case with the additional finding of “infiltrates” on radiography.

Radiographically, abnormalities appear approximately 12 days after viral exposure or 5 days after the onset of fever. In a study of 40 patients in Canada, Grinblat and colleagues [52] found that 40% of patients initially had a normal CXR. In a report by Hui and colleagues [50], 78.3% of

138 patients presented with consolidation. In both series, all patients ultimately developed consolidation. Usually consolidation is peripheral and distributed in the lower lung zones. Hui and colleagues [50] found that patients who had more extensive consolidation, including bilateral distribution at presentation, were more likely to have an adverse outcome, including death and ICU admission, than were those who had unilateral pneumonia. The disease can progress rapidly. SARS is not associated with adenopathy or pleural effusion.

In one CT study of patients who had SARS, an area of ground glass opacification with or without consolidation was seen in 83.2% of patients. Consolidation without ground glass opacity was uncommon (16.8%). Affected segments were predominantly in the lower lobes (61.1%). Consolidation tended to be peripheral (71.8%) or central and peripheral (19.5%). Other findings included thickening of interlobular septa, which occurred only when superimposed on ground glass opacification

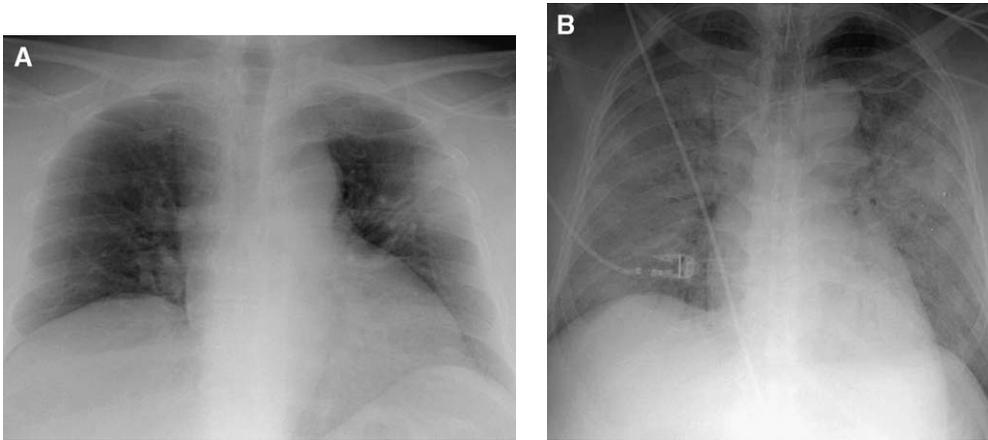


Fig. 30. SARS in a 54-year-old Asian physician who was living in Toronto, Canada. (A) Initial radiograph demonstrates foci of consolidation in the left upper lobe. (B) Within 3 days there was marked progression with diffuse bilateral air space disease, and the patient required mechanical ventilation. A rapid progression is typical of SARS pneumonia. (Courtesy of Jeffrey Galvin, MD, Baltimore, MD and the Armed Forces Institute of Pathology).

to produce a “crazy-paving pattern.” None of the CT features of SARS is diagnostic [Fig. 30] [53].

Summary

Although imaging in patients who have acute lung infections rarely is specific, the combination of clinical information and input regarding the radiographic appearance can help the emergency room physician to refine the differential diagnosis, and in some cases, suggest a specific etiology.

References

- [1] Reittner P, Ward S, Heyneman L, et al. Pneumonia: high-resolution CT findings in 114 patients. *Eur Radiol* 2003;13(3):515–21.
- [2] Webb WR, Higgins CB. *Thoracic imaging—pulmonary and cardiovascular radiology*. Philadelphia: Lippincott Williams and Wilkins; 2005.
- [3] American Thoracic Society. Guidelines for the initial management of adults with community acquired pneumonia: diagnosis, assessment of severity, and initial antimicrobial therapy. *Am J Respir Crit Care Med* 2001;163:1730–54.
- [4] National Center for Health Statistics. National hospital discharge survey: annual summary 1990. *Vital Health Stat* 1998;13:1–225.
- [5] Mandell LA. Epidemiology and etiology of community acquired pneumonia. *Infect Dis Clin North Am* 2004;18:761–76.
- [6] Marrie TJ. Empiric treatment of ambulatory community acquired pneumonia: always include treatment for atypical agents. *Infect Dis Clin North Am* 2004;18:829–41.
- [7] Shah RM, Gupta S, Angeid-Backman E, et al. Pneumococcal pneumonia in patients requiring hospitalization: effects of bacteremia and HIV seropositivity on radiographic appearance. *AJR Am J Roentgenol* 2000;175(6):1533–6.
- [8] Schleiss MR. *Haemophilus influenzae* infections. *eMedicine*. 2/18/2005. Available at: <http://www.emedicine.com>. Accessed June 1, 2005.
- [9] Reiman H. An acute infection of the respiratory tract with atypical pneumonia. *JAMA* 1938;26:2377–84.
- [10] Reittner P, Muller NL, Heyneman L, et al. *Mycoplasma pneumoniae* pneumonia: radiographic and high resolution CT features in 28 patients. *AJR Am J Roentgenol* 2000;174:37–41.
- [11] Tomiyama N, Müller N, Johkoh T, et al. Acute parenchymal lung disease in immunocompetent patients: diagnostic accuracy of high-resolution CT. *AJR Am J Roentgenol* 2000;174:1745–50.
- [12] Kim EA, Lee KS, Primack SL, et al. Viral pneumonias in adults: radiologic and pathologic findings. *Radiographics* 2002;22:S137–49.
- [13] Oikonomou A, Muller NL, Nantel S. Radiographic and high-resolution CT findings of influenza virus pneumonia in patients with hematologic malignancies. *AJR Am J Roentgenol* 2003;181(2):507–11.
- [14] Rossi S, Page McAdams H, Rosado-de-Christenson ML, et al. Fibrosing mediastinitis. *Radiographics* 2001;21:737–57.
- [15] Franquet T, Muller NL, Gimenez A, et al. Infectious pulmonary nodules in immunocompromised patients: usefulness of computed tomography in predicting their etiology. *J Comput Assist Tomogr* 2003;27(4):461–8.
- [16] Oh YW, Effmann EL, Godwin JD. Pulmonary infections in immunocompromised hosts: the importance of correlating the conventional radiologic appearance with the clinical setting. *Radiology* 2000;217(3):647–56.
- [17] King LJ, Padley SPG. Imaging of the thorax in AIDS. *Imaging* 2002;14:60–76.
- [18] Kuhlman JE, Kavuru M, Fishman EK, et al.

- Pneumocystis carinii* pneumonia: spectrum of parenchymal CT findings. *Radiology* 1990;175:711-4.
- [19] Bergin CJ, Wirth RL, Berry GJ, et al. *Pneumocystis carinii* pneumonia: CT and HRCT observations. *J Comput Assist Tomogr* 1990;14(5):756-9.
 - [20] Richards PJ, Riddell L, Reznick RH, et al. High resolution computed tomography in HIV patients with suspected *Pneumocystis carinii* pneumonia and a normal chest radiograph. *Clin Radiol* 1996;51(10):689-93.
 - [21] Hidalgo A, Falco V, Mauleon S, et al. Accuracy of high-resolution CT in distinguishing between *Pneumocystis carinii* pneumonia and non-*Pneumocystis carinii* pneumonia in AIDS patients. *Eur Radiol* 2003;13(5):1179-84.
 - [22] Raoof S, Raoof S, Naidich DP. Imaging of unusual diffuse lung diseases. *Curr Opin Pulm Med* 2004;10(5):383-9.
 - [23] Brecher CW, Aviram G, Boisselle PM. CT and radiography of bacterial respiratory infections in AIDS patients. *AJR Am J Roentgenol* 2003;180(5):1203-9.
 - [24] Aviram G, Fishman JE, Sagar M. Cavitary lung disease in AIDS: etiologies and correlation with immune status. *AIDS Patient Care STDS* 2001;15(7):353-61.
 - [25] Murayama S, Sakai S, Soeda H, et al. Pulmonary cryptococcosis in immunocompetent patients: HRCT characteristics. *Clin Imaging* 2004;28(3):191-5.
 - [26] McGuinness G. Changing trends in the pulmonary manifestations of AIDS. *Radiol Clin North Am* 1997;35(5):1029-82.
 - [27] Stern EJ, White CS. *Chest radiology companion*. Philadelphia: Lippincott Williams & Wilkins; 1999.
 - [28] Leung AN, Brauner MW, Gamsu G, et al. Pulmonary tuberculosis: comparison of CT findings in HIV-seropositive and HIV-seronegative patients. *Radiology* 1996;198(3):687-91.
 - [29] Im JG, Itoh H, Shim YS, et al. Pulmonary tuberculosis: CT findings—early active disease and sequential change with antituberculous therapy. *Radiology* 1993;186(3):653-60.
 - [30] Greenberg SD, Frager D, Suster B, et al. Active pulmonary tuberculosis in patients with AIDS: spectrum of radiographic findings (including a normal appearance). *Radiology* 1994;193(1):115-9.
 - [31] Jeong YJ, Lee KS, Koh WJ, et al. Nontuberculous mycobacterial pulmonary infection in immunocompetent patients: comparison of thin-section CT and histopathologic findings. *Radiology* 2004;231(3):880-6.
 - [32] Koh WJ, Lee KS, Kwon OJ, et al. Bilateral bronchiectasis and bronchiolitis at thin-section CT: diagnostic implications in nontuberculous mycobacterial pulmonary infection. *Radiology* 2005;235:282-8.
 - [33] Agrawal A. Lung, nontuberculous mycobacterial infections. Available at: <http://www.emedicine.com/radio/topic413.htm>.
 - [34] Gosselin MV, Adams RH. Pulmonary complications in bone marrow transplantation. *J Thorac Imaging* 2002;17(2):132-44.
 - [35] Shorr AF, Kollef MH. The quick and the dead: the importance of rapid evaluation of infiltrates in the immunocompromised patient. *Chest* 2002;122(1):9-12.
 - [36] Rano A, Agusti C, Benito N, et al. Prognostic factors of non-HIV immunocompromised patients with pulmonary infiltrates. *Chest* 2002;122(1):253-61.
 - [37] Leung AN, Gosselin MV, Napper CH, et al. Pulmonary infections after bone marrow transplantation: clinical and radiographic findings. *Radiology* 1999;210(3):699-710.
 - [38] Franquet T, Muller NL, Gimenez A, et al. Spectrum of pulmonary aspergillosis: histologic, clinical, and radiologic findings. *Radiographics* 2001;21(4):825-37.
 - [39] Primack SL, Hartman TE, Lee KS, et al. Pulmonary nodules and the CT halo sign. *Radiology* 1994;190(2):513-5.
 - [40] Gefter WB, Albelda SM, Talbot GH, et al. Invasive pulmonary aspergillosis and acute leukemia. Limitations in the diagnostic utility of the air crescent sign. *Radiology* 1985;157(3):605-10.
 - [41] Collins J, Blankenbaker D, Stern EJ. CT patterns of bronchiolar disease: what is "tree-in-bud"? *AJR Am J Roentgenol* 1998;171(2):365-70.
 - [42] Ghosh S, Champlin RE, Englund J, et al. Respiratory syncytial virus upper respiratory tract illnesses in adult blood and marrow transplant recipients: combination therapy with aerosolized ribavirin and intravenous immunoglobulin. *Bone Marrow Transplant* 2000;25(7):751-5.
 - [43] McGuinness G, Gruden JF. Viral and *Pneumocystis carinii* infections of the lung in the immunocompromised host. *J Thorac Imaging* 1999;14(1):25-36.
 - [44] Franquet T, Lee KS, Muller NL. Thin-section CT findings in 32 immunocompromised patients with cytomegalovirus pneumonia who do not have AIDS. *AJR Am J Roentgenol* 2003;181(4):1059-63.
 - [45] Gasparetto EL, Ono SE, Escuissato D, et al. Cytomegalovirus pneumonia after bone marrow transplantation: high resolution CT findings. *Br J Radiol* 2004;77(921):724-7.
 - [46] Mina B, Dym JP, Kuepper F, et al. Fatal inhalational anthrax with unknown source of exposure in a 61-year-old woman in New York City. *JAMA* 2002;287(7):858-62.
 - [47] Krol CM, Uszynski M, Dillon EH, et al. Dynamic CT features of inhalational anthrax infection. *AJR Am J Roentgenol* 2002;178(5):1063-6.
 - [48] Inglesby TV, O'Toole T, Henderson DA, et al. Working Group on Civilian Biodefense. Anthrax as a biological weapon, 2002: updated recommendations for management. *JAMA* 2002;287(17):2236-52.
 - [49] Wood BJ, DeFranco B, Ripple M, et al. Inhala-

- tional anthrax: radiologic and pathologic findings in two cases. *AJR Am J Roentgenol* 2003; 181(4):1071–8.
- [50] Hui DS, Wong KT, Antonio GE, et al. Severe acute respiratory syndrome: correlation between clinical outcome and radiologic features. *Radiology* 2004;233(2):579–85.
- [51] WHO guidelines for the global surveillance of severe acute respiratory syndrome (SARS). Updated recommendations, October 2004. Available at: http://www.who.int/csr/resources/publications/en/WHO_CDS_CSR_ARO_2004_1.pdf.
- [52] Grinblat L, Shulman H, Glickman A, et al. Severe acute respiratory syndrome: radiographic review of 40 probable cases in Toronto, Canada. *Radiology* 2003;228(3):802–9.
- [53] Wong KT, Antonio GE, Hui DS, et al. Thin-section CT of severe acute respiratory syndrome: evaluation of 73 patients exposed to or with the disease. *Radiology* 2003;228(2):395–400.