The advent of new prophylactic and treatment options has resulted in a considerable increase in the length of survival of HIV-infected patients. However, pulmonary parenchymal complications remain the main cause of morbidity and mortality in these patients [1]. Early diagnosis and treatment of these complications are important to improve survival.

The risk of developing specific pulmonary complications is influenced by the degree of immunosuppression [2]. Patients with fewer than 500 CD4 cells/mm³ are at increased risk for developing bacterial pne-
monia, pulmonary tuberculosis, and lymphoproliferative disorders. The risk for these complications increases further as the patients become more immunocompromised. When the CD4 cell count falls below 200 cells/mm³, the patients are also at increased risk for developing *Pneumocystis carinii* pneumonia and disseminated tuberculosis. Fungal infections, Cytomegalovirus pneumonia, AIDS-related lymphoma, and Kaposi’s sarcoma usually occur in severely immunocompromised patients (<100 CD4 cells/mm³) [2].

In most patients with AIDS, a confident diagnosis of the pulmonary complications can be made by a combination of clinical, radiographic, and laboratory findings. However, 5–10% of patients with AIDS and pulmonary disease have normal or nonspecific radiographic findings [3]. High-resolution CT is more sensitive than radiography for revealing parenchymal abnormalities in patients with AIDS and is superior to radiography in the differential diagnosis of the pulmonary complications seen in these patients [3].

Several studies have shown that the high-resolution CT findings of pulmonary disease seen in patients who do not have AIDS reflect the macroscopic pathologic findings. However, limited information is available about the correlation of the high-resolution CT and pathologic findings in patients with AIDS. The aim of this pictorial essay is to illustrate the high-resolution CT and pathologic findings of the most common pulmonary complications in patients with AIDS.

**P. Carinii Pneumonia**

The most common high-resolution CT manifestation of *P. carinii* pneumonia consists of patchy or confluent, symmetric, bilateral ground-glass opacities. Less common manifestations include bilateral areas of consolidation, interlobular septal thickening, intralobular linear opacities, cystic lesions, and nodules [1, 3]. The combination of ground-glass opacities and superimposed intralobular linear opacities results in a pattern commonly referred to as crazy paving (Fig. 1A).

The ground-glass opacities and areas of consolidation reflect the presence of alveolar filling by a foamy exudate, constituted mainly of surfactant, fibrin, and cellular debris [1] (Fig. 1B). The organisms are typically seen within this foamy exudate as small bubbles [4]. Interlobular septal thickening and intralobular linear opacities can result from interstitial edema or cellular infiltration. The nodules reflect the presence of granulomatous inflammation consisting of clusters of epithelioid histiocytes and multinucleated giant cells [4]. Rarely, granulomas secondary to *P. carinii* pneumonia may undergo necrosis and cavitate.

Cystic lesions are seen on high-resolution CT in 10–30% of AIDS patients with *P. carinii* pneumonia. They can reflect the presence of bullae, intraparenchymal cysts, or, occasionally, necrotizing granulomas. Some of the cysts have been shown to be secondary to tissue invasion by *P. carinii* followed by necrosis. The cysts are usually bilateral and involve mainly the upper lobes. Patients with cysts have an increased propensity to develop pneumothorax [4].

Occasionally, *P. carinii* pneumonia may result in interstitial fibrosis that can be mild or severe. The fibrosis is manifested on CT by the presence of irregular linear opacities, traction bronchiectasis, and architectural distortion [1, 4].

**Tuberculosis**

Patients with AIDS are at increased risk of developing tuberculosis. The manifestations of tuberculosis in HIV-positive patients are influenced by the degree of cellular immune compromise [5]. In patients who have CD4 cell counts greater than 200 cells/mm³, the findings tend to be similar to those seen in reactivation tuberculosis in the normal host. In these patients, the most common high-resolution CT manifestations consist of a single or, less commonly, multiple 1- to 3-cm-diameter nodules; consolidation; cavitation involving mainly the upper lobes; and centrilobular nodular and branching linear opacities resulting in a tree-in-bud pattern. The characteristic histologic lesion of tuberculosis is a necrotiz-
ing granuloma that can expand, resulting in consolidation and typically cavitation. Endobronchial spread to the bronchioles results in centrilobular nodular opacities and a tree-in-bud pattern.

In more severely immunocompromised patients, the radiologic manifestations tend to resemble those of primary disease and consist predominantly of areas of consolidation, miliary disease (Fig. 2), pleural effusion, and lymph node enlargement [4, 5]. Lymph node enlargement results from inflammation of the lymphatic vessels within the nodes and of the nodes themselves. The enlarged nodes typically contain necrotizing granulomas. Up to

![Image](https://example.com/image1)

**Fig. 3.**—44-year-old woman with AIDS and bacterial pneumonia.  
**A,** High-resolution CT scan shows foci of air-space consolidation with adjacent ground-glass attenuation in dorsal lung regions. Also note branching linear and nodular opacities resulting in tree-in-bud pattern (arrows).  
**B,** Photomicrograph of histologic specimen shows bronchiolar bifurcation with inflammatory infiltrate in lumen (straight arrow) and in peribronchiolar region (curved arrows), corresponding to tree-in-bud pattern shown on high-resolution CT. (H and E, ×40)

![Image](https://example.com/image2)

**Fig. 4.**—19-year-old man with AIDS and miliary histoplasmosis.  
**A,** High-resolution CT scan shows numerous small nodules in random distribution.  
**B,** Photomicrograph of histologic section reveals granulomas, some of which are confluent in parenchymal interstitium. (H and E, ×40)
20% of severely immunocompromised AIDS patients with pulmonary tuberculosis have radiographs that show normal findings [2]. High-resolution CT in these patients usually shows small nodules and lymph node enlargement [2].

**Bacterial Pneumonia**

The imaging findings of bacterial pneumonia in patients with AIDS are similar to those observed in immunocompetent patients and consist predominantly of single or multifocal areas of consolidation [2]. Lobar pneumonia is characterized by the spread of bacteria and inflammatory exudates between the alveolar air spaces, a pattern seen most commonly in *Streptococcus pneumoniae* pneumonia. A lobular distribution is characterized by centrilobular inflammation that is concentrated around respiratory bronchioles (Fig. 3), with spread to the surrounding alveolar ducts and alveolar spaces. Bronchopneumonia can result from a variety of gram-positive and gram-negative bacteria, most commonly those in the *Staphylococcus, Streptococcus, Pseudomonas, Klebsiella, Enterobacter,* and *Haemophilus* genera.

**Histoplasmosis and Coccidioidomycosis**

Patients with AIDS who are exposed to histoplasmosis and coccidioidomycosis are at increased risk of developing disseminated disease. The high-resolution CT findings consist of a miliary pattern (Fig. 4A), or, less commonly, diffuse air-space consolidation [4]. The miliary lesions result from hematogenous dissemination and consist of small foci of acute in-

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**Fig. 5.—** 62-year-old man with AIDS and invasive pulmonary aspergillosis.  
A, High-resolution CT scan obtained at level of upper lobes shows nodule with surrounding halo of ground-glass attenuation (arrows) in right upper lobe.  
B, High-resolution CT scan obtained at level of middle and lower lobes shows small nodules in lingula and left lower lobe (arrows) and localized scarring in right lower lobe.  
C, Photomicrograph of histologic specimen of one of small nodules shows necrotic center (straight arrows) surrounded by leukocytic infiltrate (curved arrows) and more peripherally by alveolar hemorrhage (arrowheads). (H and E, ×40)  
D, Photomicrograph of histologic specimen, black of Grocott-Gomori methenamine–silver nitrate stain reveals hyphae of *Aspergillus* organisms with radial distribution inside nodule from center to periphery. (×40)
CT and Pathologic Findings of Pulmonary Disease in AIDS

flammation with neutrophils, macrophages, and granulomas. Diffuse air-space consolidation is typically associated with large numbers of organisms in the alveoli and an inflammatory response consisting of neutrophils with a mixture of fibrin, RBCs, and macrophages.

Invasive Pulmonary Aspergillosis
The most common high-resolution CT finding of invasive pulmonary aspergillosis in patients with AIDS is the presence of thick-walled cavitary lesions. The predominant histologic abnormalities consist of tissue invasion, abscess formation, and angioinvasion with or without infarction. The cavitary lesions reflect the presence of pulmonary infarction and abscess formation [6]. Less common CT findings include single or multiple nodules, patchy areas of consolidation, and pleural effusions [6]. The nodules may have a surrounding halo of ground-glass attenuation. The nodules reflect the presence of infarction and histologically display coagulating necrosis and fungus hyphae; the halo is due to surrounding hemorrhage (Fig. 5).

Cryptococcosis
Cryptococcosis in patients with AIDS usually manifests as disseminated disease, the main clinical manifestation being meningitis. The pulmonary manifestations are variable and include bilateral nodular or reticular opacities, bilateral consolidation, or miliary nodules [1] (Fig. 6A). The histologic response to cryptococcal infection depends on the immune status of the patient. In patients with normal or nearly normal immune response, the organisms result in nodular granulomas similar to those seen in other fungal pulmonary infections [4] (Fig. 6B). In severely immunosuppressed patients, there may be extensive tissue infiltration by organisms in a pneumonic fashion, with little tissue response.

Cytomegalovirus Pneumonia
Cytomegalovirus is commonly detected on bronchoalveolar lavage fluid in AIDS patients. In most cases, it is an incidental finding, there being no associated pulmonary complication. In a small number of patients, however, Cytomegalovirus organisms can result in disseminated infection and pneumonia. The high-resolution CT findings are heterogeneous and include bilateral ground-glass opacities, patchy bilateral consolidation, and multiple nodules or masslike areas of consolidation [1] (Fig. 7).

Kaposi's Sarcoma
The characteristic high-resolution CT manifestations of Kaposi's sarcoma consist of peribronchovascular interstitial thickening and irregular or ill-defined nodules in a predominantly peribronchovascular distribution (Fig. 8). These findings reflect the propensity of Ka-
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Kaposi’s sarcoma cells to infiltrate predominately the perihilar peribronchovascular interstitium [7] (Fig. 8). Other common findings include thickening of the interlobular septa, lymphadenopathy, and pleural effusion. The interlobular septal thickening can result from infiltration by tumor cells or edema (Fig. 8).

Lymphoma

AIDS-related lymphoma is typically a high-grade B-cell non-Hodgkin’s lymphoma. It most commonly originates in extranodal locations in the lungs, bone marrow, central nervous system, and bowel.

The most common pulmonary manifestation consists of multiple nodules or masses measuring 1–5 cm in diameter. The nodules reflect the presence of a dense focal monomorphic cellular infiltrate. Less common findings include localized or multiple areas of consolidation, interlobular septal thickening, centrilobular nodules, and, occasionally, reticular infiltrates that may have a peribronchovascular distribution (Fig. 9A). The air-space consolidation results from the filling of the alveoli by tumor cells. The peribronchovascular thickening is secondary to the infiltration of the peribronchovascular bundles by neoplastic cells. Extension to the interstitium along the bronchioles results in centrilobular nodules (Fig. 9B). The thickening of the interlobular septa and the pleural surface reflects the presence of infiltration of these regions by tumor cells [8].

Fig. 8.—34-year-old man with AIDS and Kaposi’s sarcoma.
A, High-resolution CT scan shows marked peribronchial thickening, perivascular nodularity (straight arrows), nodules along interlobar fissures (curved arrows), and thickening of interlobular septa.
B, High-resolution CT scan obtained at more caudal level than A shows extensive interlobular septal thickening and centrilobular nodules (arrows).
C, Photomicrograph of histologic specimen shows edema and tumor cells, which produce thickening of interlobular septa (arrows). (H and E, ×40)
D, Photomicrograph of histologic specimen shows tumor cells infiltrating peribronchial connective tissue, which results in centrilobular nodules seen on high-resolution CT. (H and E, ×40)
Lymphocytic Interstitial Pneumonia

Lymphocytic interstitial pneumonia is a lymphoproliferative disorder seen with increased frequency in patients with AIDS, particularly children. In most of these patients, the disorder is benign and regresses spontaneously or with treatment. Rarely, it evolves into lymphoma [4]. The most common high-resolution CT manifestations consist of poorly defined bilateral centrilobular nodules, smooth or nodular thickening of the bronchovascular bundles, and ground-glass opacities [2] (Fig. 10A). Histologically, lymphocytic interstitial pneumonia is characterized by an interstitial infiltrate of lymphocytes and plasma cells that involves the perilymphatic interstitium along the bronchovascular bundles, resulting in bronchial wall thickening and centrilobular nodules (Fig. 10B). Interlobular septal thickening and small subpleural nodules are also commonly present. The cellular infiltrate typically extends diffusely along the alveolar

Fig. 9.—52-year-old man with AIDS and non-Hodgkin’s lymphoma.
A, High-resolution CT scan shows bilateral consolidation in predominantly peribronchial distribution, nodule in lingula (straight arrow), and few centrilobular nodules (curved arrows).
B, Photomicrograph of histologic section shows infiltration around bronchiole and arteriole by tumor cells. Such infiltration results in centrilobular nodular opacities seen on high-resolution CT. (H and E, ×40)

Fig. 10.—24-year-old woman with AIDS and lymphocytic interstitial pneumonia.
A, High-resolution CT scan shows patchy bilateral ground-glass opacities, small foci of consolidation, mild septal thickening (straight arrow), and few small nodules (curved arrows).
B, Photomicrograph of histologic specimen shows lymphocyte aggregates resulting in nodular appearance (straight arrows). In some areas, lesions are abundant (curved arrows) and result in collapse of alveolar spaces, which results in ground-glass opacities and air-space consolidation seen on high-resolution CT. (H and E, ×40)
septa, resulting in ground-glass opacities visible on high-resolution CT [4, 8].

Nonspecific Interstitial Pneumonia

Nonspecific interstitial pneumonia is a relatively common abnormality in patients with AIDS characterized histologically by mild to moderate lymphocytic and plasma cell infiltration of the peribronchiolar, perivascular, and interlobular septal interstitial tissue [2]. It is distinguished from lymphocytic interstitial pneumonia by the lack of involvement of the alveolar interstitium [2, 4]. The clinical and radiologic findings mimic those of P. carinii pneumonia (Fig. 11). However, nonspecific interstitial pneumonia typically is seen early in AIDS patients with normal CD4 cell counts, whereas P. carinii pneumonia occurs mainly in patients with CD4 cell counts of less than 200 cells/mm$^3$ [2]. Nonspecific interstitial pneumonia has a good prognosis, typically stabilizing or resolving spontaneously or with treatment.

References


Fig. 11.—7-year-old boy with AIDS and nonspecific interstitial pneumonia. High-resolution CT scan shows patchy bilateral ground-glass opacities, small foci of consolidation, and poorly defined centrilobular nodular opacities (arrows).
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