susceptible patients include those with hematologic malignancies, those undergoing chemotherapy for malignancy, and those undergoing long-term corticosteroid therapy for inflammatory and connective tissue diseases such as Wegener granulomatosis and systemic lupus erythematosus [1].

Chest radiography is usually the initial imaging examination performed for patients with suspected pneumonia. However, the radiographic findings of PJP are nonspecific, and as many as one third of infected patients may have normal radiographic findings [3, 4]. Volumetric high-resolution (HRCT) may be indicated in the evaluation of immunocompromised patients with normal or near-normal chest radiographic findings, and the results can be suggestive of PJP in the correct clinical situation. This pictorial essay describes the clinical circumstances in which PJP should be considered and illustrates the spectrum of HRCT manifestations of PJP.

Clinical Presentation

Pneumocystis jiroveci is an atypical fungus that causes pneumonia in immunocompromised human hosts, particularly those with deficiency in cell-mediated immunity. P. jiroveci lives almost exclusively in the pulmonary alveoli, adhering to the alveolar epithelium. Intraalveolar macrophages serve as the primary host defense against P. jiroveci, and macrophage deficiency or dysfunction can lead to infection [1]. CD4+ T lymphocytes, the count of which decreases in HIV infection, are essential to eradicating P. jiroveci infection and contribute to inflammatory lung damage [2].

Bacterial pneumonia is the most common pulmonary infection among persons with AIDS, but despite widespread use of highly active antiretroviral therapy (HAART) and chemoprophylaxis, P. jiroveci pneumonia (PJP) is the most common opportunistic infection among persons with AIDS in the United States. PJP occurs primarily among persons unaware that they have HIV infection [1] and is an AIDS-defining illness. In industrialized countries, the incidence of PJP among persons without HIV infection exceeds that associated with HIV infection [1]. Nevertheless, the incidence of PJP in solid organ and blood stem cell transplant recipients remains low because of widespread chemoprophylaxis. Most transplant-related PJP infections occur in the early posttransplant period. Other susceptible patients include those with hematologic malignancies, those undergoing chemotherapy for malignancy, and those undergoing long-term corticosteroid therapy for inflammatory and connective tissue diseases such as Wegener granulomatosis and systemic lupus erythematosus [1].

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**Keywords:** high-resolution CT, HIV, immunocompromise, pneumonia, transplant

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**OBJECTIVE.** The purpose of this essay is to review the spectrum of high-resolution CT findings of Pneumocystis jiroveci pneumonia in immunocompromised patients with and without HIV infection.

**CONCLUSION.** Pneumocystis jiroveci pneumonia is a common opportunistic infection affecting immunosuppressed patients. High-resolution CT may be indicated for evaluation of immunosuppressed patients with suspected pneumonia and normal chest radiographic findings. The most common high-resolution CT finding of Pneumocystis jiroveci pneumonia is diffuse ground-glass opacity. Consolidation, nodules, cysts, and spontaneous pneumothorax also can develop.

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**Clinical Presentation**

PJP usually develops in HIV-infected patients when the CD4+ cell count decreases to fewer than 200 cells/mm³ and particularly to fewer than 100 cells/mm³. Nevertheless, HIV-infected patients with CD4+ counts greater than 200 cells/mm³ account for 10–15% of cases of PJP [5]. The presentation of PJP in a patient with HIV infection typically is subacute, characterized by a gradual on-
set of dry cough and dyspnea; in many cases, the onset period lasts as long as 1 month. Pulmonary auscultation is often unrevealing, but patients have signs of respiratory compromise, including tachypnea, tachycardia, and cyanosis. Elevated serum lactate dehydrogenase levels are highly sensitive but not specific for PJP. Because of the accompanying severe inflammatory response, PJP in patients without HIV infection presents as an acute illness associated with severe hypoxia and results in rapid respiratory deterioration and respiratory failure requiring mechanical ventilation [6, 7].

**High-Resolution CT Findings**

At HRCT, extensive ground-glass opacity is the principal finding in PJP, reflecting accumulation of intraalveolar fibrin, debris, and organisms (Figs. 1–4). A study involving 32 patients with AIDS-related PJP showed a central distribution of ground-glass opacity with relative peripheral sparing in 41% of patients, a mosaic pattern in 29%, and a diffuse distribution in 24% [8]. A predilection for the upper lobes has also been described [3, 9]. In patients without HIV infection, the extent of ground-glass opacity is often greater [6].

With more advanced disease, septal lines (Fig. 5) with or without intralobular lines superimposed on ground-glass opacity (crazy paving) [8] (Fig. 6) and consolidation (Figs. 7 and 8) may develop [9, 10]. Lung consolidation is more common in patients without HIV infection and tends to develop more rapidly, reflecting pulmonary damage from the host immune response [11].

With widespread use of chemoprophylaxis, other HRCT manifestations of AIDS-related PJP are more commonly reported. Pulmonary cysts (Figs. 9–12) of varying shape, size, and wall thickness occur in as many as one third of patients with PJP [3, 8, 9]. Cysts are associated with an increased frequency of spontaneous pneumothorax (Fig. 13), although spontaneous pneumothorax can occur in the absence of definable lung cysts [12]. Cysts may resolve after treatment and clearing of infection [9]. The incidence of pulmonary cysts has been reported to be lower in patients without HIV infection than in HIV-infected patients [6, 13].

Granulomatous inflammation occurs in approximately 5% of patients, usually early in the course of HIV infection while immunodeficiency is more limited, and can become evident at HRCT as a solitary nodule or mass mimicking lung carcinoma or as multiple nodules ranging from a few millimeters to more than 1 cm [10] (Fig. 14). However, small nodules and tree-in-bud opacities are uncommon in patients with AIDS and PIP and usually indicate the presence of infectious bronchiolitis from other organisms [14]. Patients recovering from PJP may have residual interstitial fibrosis [4, 9, 10, 15]. In addition, although rare, interstitial fibrosis can occur in AIDS patients with low-grade chronic PJP, a condition termed chronic *Pneumocystis* pneumonia [16].

**Diagnosis**

Culturing *P. jiroveci* is extremely difficult. Confirmation of the diagnosis requires identification of organisms in sputum or bronchoalveolar lavage fluid (Fig. 15). Monoclonal antibodies for detecting *P. jiroveci* are available and have a sensitivity greater than 90% for detecting *P. jiroveci* in induced sputum from HIV-infected patients. Confirmation of PJP can be difficult in patients without HIV infection because of the much lower burden of organisms [1]. Several polymerase chain reaction methods have been developed. PCR has low sensitivity for confirming PJP but has a high negative predictive value. Currently, PCR is an investigative tool [1].

**Treatment and Prognosis**

Oral trimethoprim-sulfamethoxazole (TMP-SMX) is first-line treatment of patients with PJP. Second-line therapy for mild to moderate infection in patients who cannot tolerate TMP-SMX includes dapsone and trimethoprim, atovaquone, and clindamycin and primaquine. IV pentamidine can be used to treat patients with moderate to severe PJP who cannot tolerate TMP-SMX. By reducing inflammatory lung injury, corticosteroids have been found to improve survival among HIV-infected patients when administered in the first 72 hours of treatment. The role of corticosteroids in the care of patients without HIV infection remains unclear. Despite therapy, the mortality of PJP remains high, especially among patients without HIV infection. Patients with HIV infection have higher survival rates, ranging from 86% to 92%; patients without HIV infection have survival rates ranging from 51% to 80% [1].

**Conclusion**

Despite widespread use of HAART and chemoprophylaxis in industrialized countries, *P. jiroveci* remains a potentially life-threatening cause of pneumonia among immunocompromised persons because of prolonged survival of patients with hematologic malignancies, solid organ and blood stem cell transplant recipients, and patients undergoing chemotherapy and prolonged corticosteroid therapy. Furthermore, PJP can be the initial manifestation of AIDS in patients who do not have access to HAART or patients in whom HAART fails. HRCT plays a central role in evaluating immunocompromised patients with new-onset lung disease. PJP should be strongly suspected when any immunocompromised patient has respiratory tract signs and systems and extensive, patchy, upper-lobe-predominant ground-glass opacity on HRCT images.

**References**

6. Hardak E, Brook O, Yigla M. Radiological features of *Pneumocystis jiroveci* pneumonia in immunocompromised patients with and without AIDS. Lung 2010; 188:159–163


**CT of Pneumocystis jiroveci Pneumonia**

**Fig. 1**—38-year-old man with AIDS and *Pneumocystis jiroveci* pneumonia. High-resolution CT image shows patchy but extensive ground-glass opacity throughout both lungs.

**Fig. 2**—81-year-old man with acute myelogenous leukemia and *Pneumocystis jiroveci* pneumonia. **A** and **B**, Transverse (**A**) and coronal (**B**) high-resolution CT images show diffuse ground-glass opacity with relative peripheral sparing. Note the "black bronchus" sign (**arrow, A**), reflecting a background of diffuse ground-glass opacity.

**Fig. 3**—58-year-old woman with *Pneumocystis jiroveci* pneumonia who has undergone renal transplant. High-resolution CT image shows diffuse centrilobular nodules with ground-glass attenuation.
Fig. 4—58-year-old woman with *Pneumocystis jiroveci* pneumonia and dermatomyositis and undergoing immunosuppressive therapy. A and B, Transverse (A) and coronal (B) high-resolution CT images show patchy ground-glass opacity with mid and lower lung predominance.

Fig. 5—29-year-old man with AIDS and *Pneumocystis jiroveci* pneumonia. A and B, Transverse (A) and coronal (B) high-resolution CT images show patchy ground-glass opacity and smooth interlobular septal thickening (arrows).

Fig. 6—50-year-old woman with *Pneumocystis jiroveci* pneumonia receiving gemcitabine and docetaxel for metastatic uterine leiomyosarcoma. High-resolution CT image shows crazy paving characterized by extensive ground-glass opacity with superimposed interlobular septal thickening and intralobular lines. Relative subpleural sparing is evident.

Fig. 7—27-year-old man with *Pneumocystis jiroveci* pneumonia receiving bleomycin for testicular carcinoma. High-resolution CT image shows patchy peribronchial consolidation in lower lobes and lingula. Organizing pneumonia type of drug reaction can have similar appearance.
CT of *Pneumocystis jiroveci* Pneumonia

Fig. 8—67-year-old man with AIDS and *Pneumocystis jiroveci* pneumonia (PJP).  
A, High-resolution CT image shows patchy ground-glass opacity, greater in left lung.  
B, High-resolution CT image 17 days after A shows development of superimposed reticulation and formation of dense consolidation (arrow). Small pleural effusions (arrowheads) are not common finding in PJP and may be related to fluid resuscitation.

Fig. 9—41-year-old man with AIDS and *Pneumocystis jiroveci* pneumonia. High-resolution CT image shows scattered small foci of ground-glass opacity and consolidation with scattered small cysts (arrows).

Fig. 10—37-year-old man with AIDS and *Pneumocystis jiroveci* pneumonia. High-resolution CT image shows numerous thin-walled cysts (arrows) on background of patchy ground-glass opacity. Mild focal consolidation (arrowhead) is present in left lower lobe. (Courtesy of Sirajuddin A, Northwestern Memorial Hospital, Chicago, IL)

Fig. 11—54-year-old man with AIDS and *Pneumocystis jiroveci* pneumonia. High-resolution CT image shows extensive bilateral ground-glass opacity and single thin-walled cyst (arrow) in right upper lobe.
Fig. 12—48-year-old man with AIDS and Pneumocystis jiroveci pneumonia (PJP). A and B, Transverse (A) and coronal (B) high-resolution CT images show diffuse ground-glass opacity with numerous tiny thin-walled cysts (arrowheads). Large cavity (arrow) containing gas-liquid level is evident in left upper lobe. Finding is uncommon manifestation of PJP and should raise question of superimposed infection, although this patient did not have such infection.

Fig. 13—37-year-old man with AIDS and Pneumocystis jiroveci pneumonia. High-resolution CT image shows multiple cysts of varying size, scattered nodules (arrowheads), and mild patchy ground-glass opacity. Left pneumothorax (arrow) has developed.

Fig. 14—56-year-old man with chronic kidney disease and Pneumocystis jiroveci pneumonia. A and B, High-resolution CT images show multiple nodules (arrows) of varying size, mild patchy ground-glass opacity, and mild interlobular septal thickening (arrowheads).
CT of *Pneumocystis jiroveci* Pneumonia

**Fig. 15**—Patient with *Pneumocystis jiroveci* pneumonia. Photomicrograph of lung biopsy specimen (Gomori methenamine silver, ×600) shows multiple small black organisms (arrowheads) typical of *P. jiroveci*. (Courtesy of Torrealba J, University of Wisconsin, Madison, WI)

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