Pneumocystis Carnii Pneumonia Infections: Disease, Diagnosis, and Treatment Options

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Abstract By reading this chapter, readers will be able to understand what is *Pneumocystis carinii* pneumonia (PCP) infection, how it affects immunocompromised patients, and on prior treatment different diagnostic parameters are performed for sampling and afterwards treatment is recommended by a physican. Readers will be able to distinguish PCP patients infected with HIV/AIDS and PCP patients infected without HIV/AIDS. Also, by going through this chapter, readers will be able to distinguish between pneumonia, PCP fungal infection and the compatibility of COVID-19 with PCP fungal infection. Different treatment strategies are discussed in this chapter in order to treat PCP-infected patients and risk factors are also considered so that by keeping in view these risk factors preventive measures are adopted to treat PCP fungal-infected patients. Epidemiology of PCP infection is elaborated so that reader will be able to understand whether it is endemic or pandemic infectious disease. In addition, the pathophysiology of PCP is discussed so that reader should come to know its mode of transmission in lungs where this fungal infection starts replicating. Importantly, different case studies are discussed in this chapter for the purpose of understanding that more than one infection also affects

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PCP-infected patients and different antibiotic therapies are performed along with adjunctive corticosteroids therapy for better recovery of the patient. It is the expected responsibility of readers after studying this chapter to provide awareness of PCP infection among health care professionals and people.

Keywords *Pneumocystis carinii* pneumonia · Epidemiology · Diagnosis · Treatment · Case studies

1 Background

It is commonly called as *Pneumocystis carinii* pneumonia (PCP)/*Pneumocystis jirovecii* pneumonia (PJP). PCP is a fungal infection that can affect one or both of the lungs and its causative agent is *Pneumocystis jirovecii*, which is also called as *Pneumocystis carinii* [1]. It mostly affects individuals who are infected with HIV infections [2]. In 1980, this case was first reported in the USA and it occurred in an individual infected with HIV. In the beginning, scientists were confused about whether PCP is caused by protozoa or fungus so they classified it as protozoan but with the passage of time and advancement in medical knowledge they classified it as fungus [3]. Today, PJP is considered one of the several fungal infections which can cause severe life-threatening problems in individuals suffering with AIDS/HIV infections [4]. In the USA, the first decade of HIV epidemic cases associated with PJP were reported approximately to be 100,000, but today with current antiretroviral therapy (ART), individuals with HIV/AIDS are less likely to be infected with PCP infection [5]. PCP is a fungal infection that affects the lungs of individuals with weakened immune system and it is usually caused by *Pneumocystis jirovecii*. There are several reasons for a weakened immune system such as cancer, HIV infection, AIDS, high dose corticosteroids, or medicine taken after having bone marrow or organ transplant. This fungal infection mostly attacks individuals suffering from HIV/AIDS infection but seems to rarely occur in healthy individuals who do not acquire AIDS/HIV infections [6]. Nearly, all the individuals suffering from PCP either have low oxygen levels in their blood (hypoxemia) at rest or an increase in their alveolar-arterial oxygen tension gradient, which causes difficulty for the individual to breathe [7].

2 Microbiology

PJP occurs in the respiratory tracts of humans and mammals and it belongs to unicellular fungi group. Distinct species flexibility is present between members of host-specific genus. In 1909, Chagas first introduced this organism and then few years later Dr. Carni isolated it from infected rats and proposed this organism's name as *Pneumocystis carinii* and some years later Dr. Otto Jirovec and his group members found that this organism was also present in humans, later, they isolated

this organism and renamed it as *Pneumocystis jirovecii*. Because of that reason, this organism has dual names i.e., PCP and PJP. There was a clash among the scientists whether *Pneumocystis jirovecii* pneumonia belongs to protozoa group or trypanosome group, further nucleic acid biochemical analysis suggest that *Pneumocystis* RNA and mitochondrial DNA considered the organism as a fungus which is unicellular rather than a protozoa [8]. Later on, scientists found that these organisms exist in three structural forms, namely, trophozoite, sporozoite, and cyst. The trophozoite is sometimes called as trophic form due to its existence in clusters arrangement. While sporozoite is also ranked as a precystic form in which it lays down the resting phase, and the cyst is a kind of form containing several spores which are sometimes called as intracystic bodies.

3 Epidemiology

PJP diagnosis is difficult because modern medical facilities are not present in underdeveloped regions of the world. In Africa, its frequency is found to occur at the rate of 80% in infants suffering with pneumonia and other HIV infections [9]. In sub-Saharan Africa, individuals suffering from tuberculosis, which is a serious lungs infection, also have a chance to be infected with PJP pneumonia [10]. Similarly in Pakistan, PCP pneumonia prevalence rate is 16% and different antibiotic therapies are performed to prevent form PCP infection [11]. According to latest research prevalence rate of PCP infection seems to be 32–38% in India [10]. In USA, 75% overall PCP cases were reported [5] and in China PCP prevalence rate is 40% according to latest research [12]. In Malaysia, PCP prevalence rate is 60% and in Europe PCP detection ratio is 18% [13]. In Mozambique, PCP occurs at the incidence of 6.8% and a specimen study was performed via nasopharyngeal aspirates through polymerase chain reaction (PCR) test to confirm the presence of infection.

In Malawi, 5% PCP detection ratio was observed and sample specimen was taken via lung aspiration through a PCR detection technique [5]. Similarly in Namibia, PCP detection ratio is 5%, but sample specimen was taken via sputum induction through Grocott's Methenamine Silver stain (GMS) and PCR detection ratios [14]. In France, PCP occurs at the incidence of 26.1% and in Brazil 20% PCP detection rate was observed [5, 15]. In Uganda, 4% PCP detection ratio was noticed and a specimen study was performed through BAL test, and a modified Giemsa detection method was used in this regard [16]. In Vietnam and Tanzania, the PCP detection rate were found to be 3% and 1.5%, respectively, when sample specimens were taken via oral route using a PCP detection technique [17]. In Poland, 21% PCP detection rate was observed, and in Malawi, PCP occurs at incidence rate of 9% and specimen study was performed via BAL test and detection methods used in this technique were IF and PCP [18]. These are the different regions of the world where different studies and techniques are performed for PCP detection. By covering the epidemiological factors of PCP fungal infection, it was found that PCP infectious disease is a pandemic disease because it is present in different regions of the world.

4 Etiology

The causative agent of PCP is the fungus *Pneumocystis jirovecii* pneumonia [19]. Individuals with healthy immune system do not get infected with this organism, but those individuals who have weakened immune system may easily be affected by this fungus organism named as PCP. The immune system may be weakened due to several reasons such as in the case of cancer therapy, organ transplant, and using medicines (steroids) that suppress your immune system [20]. If PCP is not treated in the appropriate manner the patient's condition may worsen. So, it is recommended to boost up your immune system in the case of PCP infection.

5 Pathophysiology

Pneumocystis pneumonia is a worldwide infectious fungal disease and it occurs mostly in children who are 3 to 4 years of age [21]. Furthermore, preclinical studies have suggested that PCP transmission is airborne and clinical trials on humans has also been reported due to depressed immunity in individuals [22]. PCP occurs due to defective humoral and cellular immunity. Once PCP spores are inhaled via alveoli, the host organism starts replicating and ultimately causes disease. The role of immunity in the case of PCP infection is attributed due to the reasons such as (1) defects in cellular or humoral immunity, (2) CD4+ production is low, (3) CD4+ T-cell count is >200 cells/μL, and (4) development of PCP infection [9].

6 Risk Factors

It is most likely to develop in those individuals in which HIV/AIDS infection has been reported. It also occurs in individuals who are immunodeficient. In this regard, patients receive long-term immunosuppressive therapy. It can also occur in individuals who are at risk of malnutrition [22]. Patients, whose organ transplantation is performed by providing corticosteroids therapy for suppressing immune system, the chances of PCP fungal infection began to increase in such cases. PCP fungal infection is more susceptible in those patients whose are hematologic and nonhematologic malignant including solid tumors and cancerous cells [23].

7 Pneumonia & *Pneumocystis Carinii* Pneumonia

Pneumonia is an infection of lungs affecting one or both lung parts [24]. In this infection, alveoli are filled with fluid and pus. Its causative agent is *Streptococcus pneumoniae*. Pneumonia affects mainly patients with 65 years of age or more and

children about 2 years of age [25]. The signs and symptoms of pneumonia in adults are clearly observed but in case of children signs and symptoms are monitored carefully. They may have fever, cough, or they may have difficulty in breathing and eating. Pneumonia classification is based according to infectious agent or place from where infection spread. Community acquired pneumonia is caused by viruses, bacteria, or fungi. Hospital acquired pneumonia is caused when a patient is admitted for another illness but after recovering from particular illness got infectious pneumonia disease. It is more severe because bacteria are more resistant to antibiotic therapies and patients who acquire this infection are already immunosuppressed. Hospital acquired pneumonia develops when people are visiting to attend the patient for longer times, it is also more resistant to antibiotics, and can also be caused by visiting out-patient clinics. Aspiration pneumonia is caused when patient inhaled food, drink, saliva, or vomit and disturbs body's normal reflux mechanism. This can also be spread by excessive intake of alcohol.

Pneumocystis carinii pneumonia is caused by fungal infection and can affect one or both lungs [26]. It is usually spread through individuals who are either immunocompromised or have already been infected with HIV/AIDS. Before adopting treatment strategy, its diagnosis is performed based on PCP patient infected with or without PCP. Factors that increase the risk of PCP fungal infections include smoking, alcohol consumption, dyspnea, and malnutrition. From above discussion, the difference of pneumonia and PCP fungal infection is clearly observed. Further basic details of pneumonia and PCP fungal infection are given below to summarize our findings and by observing these findings, it can easily diagnose whether patient is infected with pneumonia or PCP fungal infection (Table 1).

Table 1 Difference between pneumonia and PCP

Pneumonia	*Pneumocystis carinii* pneumonia
Inflammation of lungs in one or both parts.	PCP is a fungal infection that may affect one or both parts of lungs.
Alveoli are filled with fluid and pus.	Before opting treatment strategy, diagnosis is performed to rule out PCP.
Streptococcus pneumoniae is the most causative agent which causes inflammation in alveoli.	Its causative agent is *pneumocystis jirovecii*.
Pneumonia develops when body immune system is weak.	It lowers infected patient's immune system and CD4+ level, and different antibiotics along with adjunctive corticosteroids are given to treat PCP infection.
Factors that may lead to pneumonia are pre-existing lungs disease, recent influenza infections, smoking, and upper respiratory tract infections.	Factors that may lead to PCP are smoking, alcohol intake, and malnutrition. These conditions may trigger PCP infection.
Vaccines are available	No vaccines are currently available

8 Differential Diagnosis of COVID 19 and PCP Infection

Clinical conditions of coronavirus disease 2019 (COVID-19) and pneumocystis pneumonia (PCP) have similarities and are clinically indistinguishable at the early stages in HIV-positive patients [27]. Differential diagnosis should be performed to rule out similar clinical manifestations. Diagnostic parameters should be performed on priority basis to determine whether underlying disease is COVID-19 or PCP fungal infection. Similarities and differences based on COVID-19 and PCP fungal infection can be better described and explained with the help of case studies. Fewer such cases have been discussed in this context to understand the pathological condition and suspected diseased condition.

8.1 Case Study 1

During the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) pandemic, a 25-year-old patient presented with significant hypoxemia despite using a non-rebreather mask. A massive right pneumothorax and severe interstitial illness were discovered on a chest X-ray. Despite the installation of a chest tube, hypoxemia persisted, prompting emergency intubation. A CT scan of the chest was performed, and the nasopharyngeal SARS-CoV-2 PCR was positive. His absolute CD4+ count was 32 cells/Mm^3 and his HIV serology was positive. Because of his severe acquired immunodeficiency, radiographic results suggested a life-threatening co-infection with *Pneumocystis jirovecii*, prompting therapy with trimethoprim–sulfamethoxazole, prednisolone, and remdesivir. Pneumocystis pneumonia (PCP) was confirmed 4 days later by bronchoscopic pneumocystis antigen. Clinically, the patient recovered and was discharged from hospital successfully 21 days later [28] (Fig. 1).

In both PCP and SARS-CoV-2 infection, widespread ground-glass nodules are the most common finding, making radiographic distinction challenging, especially in immunosuppressed patients. One-third of patients with serious PCP may develop cystic tumors [29, 30]. The identification of *Pneumocystis jirovecii* co-infection would have been difficult without these cystic radiographic features. As a result, in the present SARS-CoV-2 pandemic, knowledge of co-infections is vital in order to correctly diagnose and treat these co-infections, decreasing morbidity and mortality rates [31].

8.2 Case Study 2

With a three-week history of cough, myalgia, fever, and increasing dyspnea, a 54-year-old man was taken to a medical center. The BMI of patient was normal. However, patient had an 8-year history of hypertension and type 2 diabetes as well

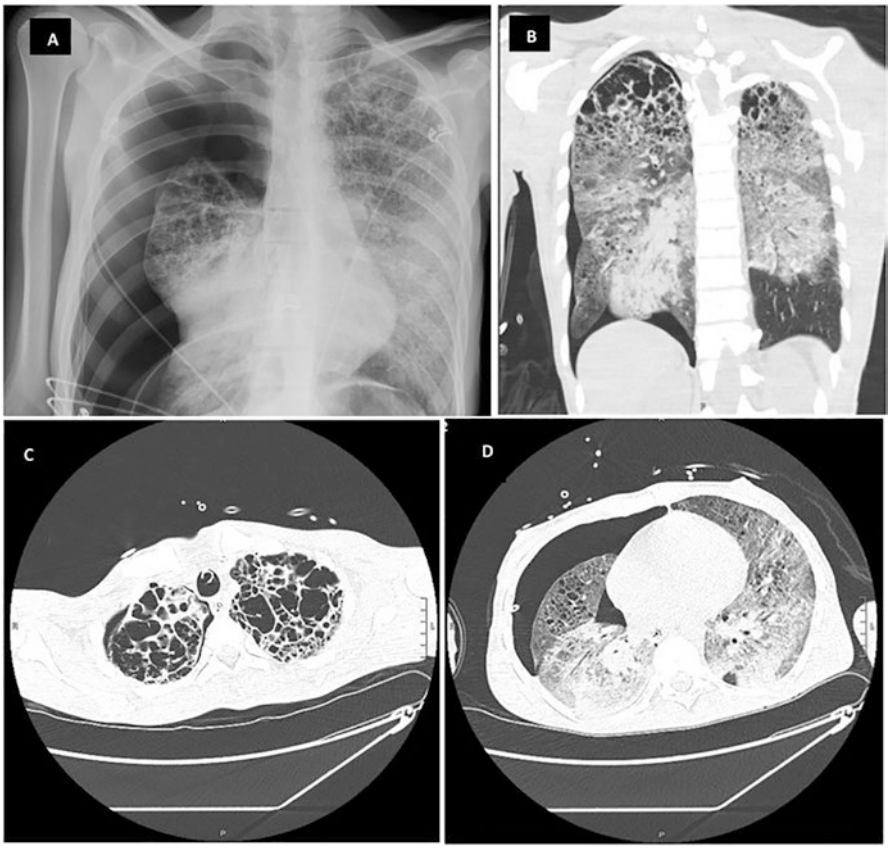

Fig. 1 Depicting a chest X-ray and a CT scan of the chest at the time of presentation, (**a**) X-ray of the chest reveals a massive right pneumothorax and severe interstitial illness, (**b**) Coronal CT chest picture demonstrating apical cystic alterations, diffuse ground-glass opacities, thick consolidation, and pneumothorax, (**c**) An axial image of the most prominent apical cystic alterations, and (**d**) Axial image with the chest tube revealing diffuse ground-glass opacities and a right pneumothorax, reproduced with permission [28]. (continue directly)

as electrocardiographic signs of left ventricular hypertrophy. The patient previously had two bouts of drug-sensitive pulmonary tuberculosis, both of which the subject had successfully treated. The patient was HIV positive at the time of admission, with a CD4+ count of 26 cells/L and a viral load of 2,447,646 copies/mL. His SARS-CoV-2 polymerase chain reaction (PCR) nasopharyngeal swab was likewise positive. He was moved to a field hospital for coronavirus illness (COVID), where the subject needed nasal prong oxygen to keep his oxygen saturation (SpO_2) at 96%. His oxygen needs increased within 24 h of transfer, therefore the patient was transferred to our intensive care unit (ICU) for high-flow nasal cannula (HFNC) oxygen (Figs. 2 and 3).

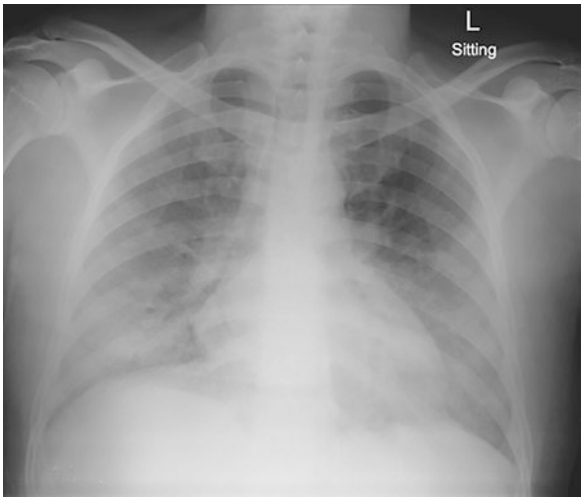

Fig. 2 The above figure shows that on arrival, the patient's chest radiograph revealed bilateral ground-glass opacifications, mostly in the lower zone. The patient was started on empiric dexamethasone and therapeutic co-trimoxazole after a working diagnosis of COVID-19 and/or PCP. On the third day of hospitalization, however, persistent fever, hemodynamic instability, increased oxygen needs with worsening pulmonary infiltrates on chest X-ray, and growing inflammatory markers led to a diagnosis of nosocomial pneumonia. In the absence of culture findings, empiric meropenem and fluconazole were started, reproduced with permission [28]

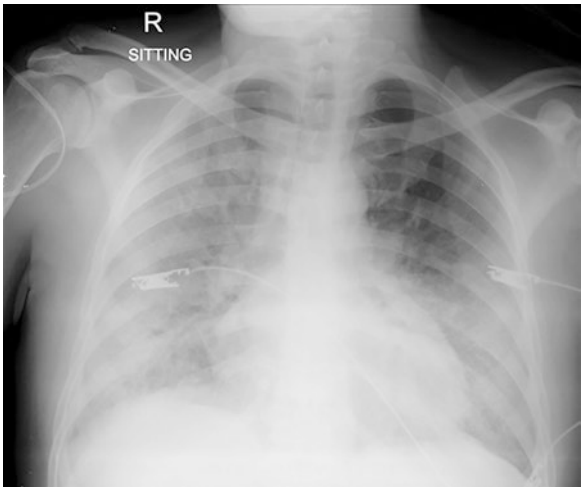

Fig. 3 The above figure shows the consolidation including all but the left upper zone shown on this chest radiograph, indicating a severe deterioration. Sputum DFAT confirmed PCP, which was backed up by a β-D-glucan level of >500 pg/mL (normal 60). *Acinetobacter baumannii* was also found in blood cultures, for which colistin was started pending sensitivity. Legionella species were not found in the urine. On the eighth day, after admission to the ICU, the patient died of increasing respiratory failure. (Image reproduced with permission from [28])

8.3 Case Study 3

A middle-aged man with shortness of breath, nocturnal sweats, and weight loss came to community care in England in March 2020. The subject was administered oral antibiotics after the chest X-ray, however, revealed nothing unusual. The subject was brought to emergency treatment a week later. In the absence of laboratory testing, the subject was discharged with a suspected mild COVID-19 diagnosis after a chest X-ray revealed bilateral apical ground glass alterations (Fig. 1a). The patient was clinically stable without severe hypoxia and was thus discharged with a suspected light COVID-19 diagnosis. Four days later with substantial hypoxia, increasing bilateral upper lobe airspace shadowing on chest X-ray, anemia (hemoglobin of 87 g/dL), lymphopenia (0.14 cells/Mm^3), and increased C-reactive protein (212 mg/L), as well as yeast infections were observed.

COVID-19 was initially regarded the most likely diagnosis in the emergency department, may be due to the relative frequency of COVID-19 during the peak of the epidemic and the resulting limitations in clinical reasoning. The diagnoses explored on the second presentation, 4 days later, were community acquired pneumonia (CAP) and moderate/severe COVID-19. Although the lymphopenia and bilateral chest X-ray alterations were consistent with COVID-19, the patient also had several unusual characteristics, such as oral thrush, weight loss, and a long clinical history. Following admission and a negative SARS-CoV-2 polymerase chain reaction test (PCR) result, *Pneumocystis jirovecii* pneumonia (PCP) was evaluated initially (Fig. 4).

The patient's condition worsened on day 5 of hospitalization, and was moved to the critical care unit for mechanical ventilation. SARS-CoV-2, influenza, parainfluenza, rhinovirus, adenovirus, respiratory syncytial virus, human metapneumovirus, and *Pneumocystis jirovecii* were all found to be negative by PCR, and acid-fast bacilli (AFB) staining was negative. Co-trimoxazole was switched to IV pentamidine on the ninth day of admission due to bone marrow suppression and hyperkalemia. A bronchial alveolar lavage on day 10 revealed *Pneumocystis jirovecii* confirming the diagnosis. CMV and herpes simplex type 1 (HSV-1) were also found in the lavage, but not SARS-CoV-2, respiratory viruses, or AFB. On day 15, a right tension pneumothorax occurred, as well as an intractable bronchopleural fistula. The patient died on the 17th day of his hospital stay, around 29 days after his first appearance in the community.

A lengthier clinical history previous to admission to emergency care is normal with COVID-19, oral thrush, and radiographic indications of apical alterations with basal sparing were among the clinical signals that may have prompted an earlier HIV test in the patient presented. Adding an HIV test to the order panel for all COVID-19 admissions, as well as educating and being attentive about potential differential illnesses like PCP, is one low-cost technique of enabling a differential diagnosis [33]. This will help determine how HIV-positive persons with and without COVID-19 should be treated, including cohort nursing and a focused therapy approach.

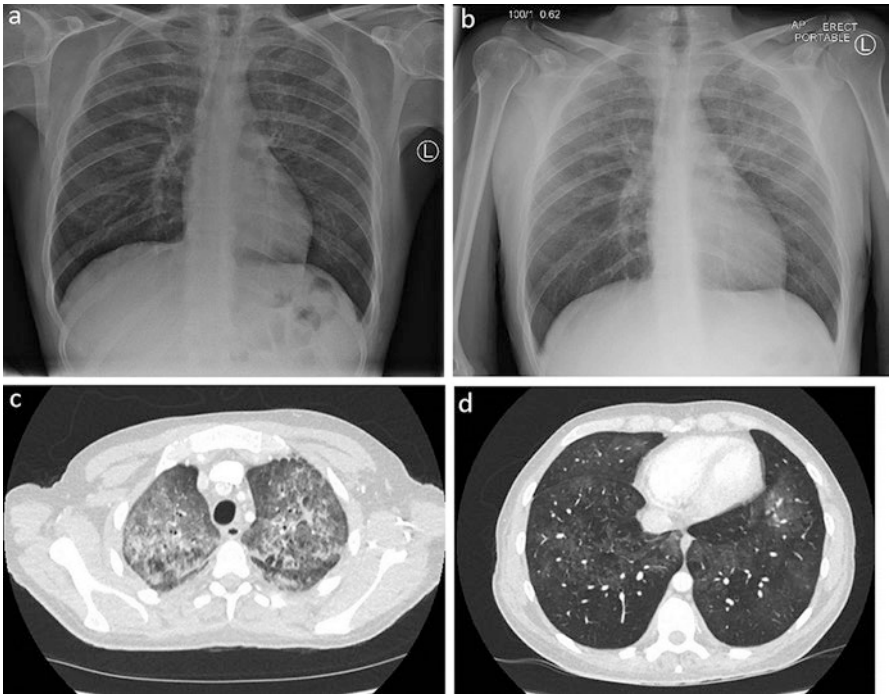

Fig. 4 (**a**) X-ray of the chest revealing bilateral apical ground glass alterations. (**b**) An X-ray of the chest reveals increasing bilateral upper lobe airspace shadowing, (**c** and **d**) chest computed CT demonstrating extensive ground glass alterations with basal sparing, reprinted with permission [32]

8.4 Case Study 4

During prednisolone therapy for autoimmune hepatitis, a 76-year-old lady got pneumocystis pneumonia (PCP) (AIH). A hematological test performed by patient's family physician revealed that the lady had excessive levels of hepatobiliary enzymes. The patient was sent to the hospital for further testing and was admitted to the hospital. The subject was diagnosed with autoimmune hepatitis (AIH) and began treatment on 40 mg of prednisolone per day. The transaminase levels of patient were improved due to which the dose of prednisolone was tailored downwards every 2 weeks. Fever of 38 °C was noted during the fourth week of medication. The chest X-ray revealed ground glass opacities, related to cough complaint. An induced sputum cytodiagnosis was conducted since the respiratory illness was suspected. The respiratory condition was followed after she was diagnosed with PCP.

Cotrimoxazole [trimethoprim/sulfamethoxazole] was begun after the patient's fever was managed symptomatically. The subject had acute exhaustion, hyponatremia, and a drop in platelets. ADRs were thought to be the cause of these signs and symptoms. The cough was suppressed once hyponatremia was cured. Eventually, the fever subsided, and the pneumonia began to recover. Prednisolone was not

lowered in dosage throughout this time and was kept at 15 mg/day for the whole 4-week period. Cotrimoxazole was added as a preventive measure, and AIH therapy was continued. As a result, multiple stomach ulcers and oral candidiasis was developed. The subject received treatment and was released on a daily dose of oral prednisolone of 10 mg. The IgG and transaminase values were both in the normal range when the patient was taking prednisolone 10 mg every other day at the time of the previous follow-up.

8.5 Case Study 5

On day 7 of the fifth chemotherapy session, a 69-year-old lady receiving biweekly pirarubicin hydrochloride, oncovin, cyclophosphamide, and prednisolone for mycosis fungoides developed a fever. The first chest CT pictures were unremarkable, and serum procalcitonin and -D-glucan levels were normal. Meropenem and amphotericin B were used to treat a bacterial or fungal illness, but was useless. A contrast-enhanced CT was performed around 10 days following the initial chest CT. Apart from two mass lesions in S6 and S10 in the right lower lobe, no source of fever was discovered (Fig. 5).

Compared to HIV-positive individuals, *Pneumocystis jirovecii* is particularly difficult to identify in specimens from HIV-negative patients, who have a higher immune response to pneumocystis but fewer pathogens. *Pneumocystis jirovecii* can be detected using a polymerase chain reaction based on bronchoalveolar lavage fluid. Because the tumors were confined, biopsy and Grocott's staining proved to be the most crucial measures for a correct diagnosis in this case. Because the chest CT results were abnormal and the patient's blood -D-glucan level was within normal ranges, PCP was excluded from the differential diagnosis in this case. In a retrospective investigation of patients with PCP identified via bronchoalveolar lavage, Tasaka et al. found that blood -D-glucan level was the most accurate PCP predictor among serum levels of lactate dehydrogenase, -D-glucan, Krebs von den Lungen-6

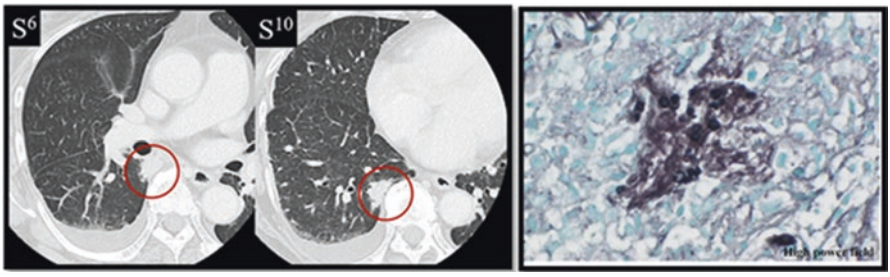

Fig. 5 In the right lung, pleural effusion can be observed, which might be impacted by inflammation. The SpO_2 level was within normal range, and was asymptomatic. Bronchoscopy was conducted, and bronchial biopsy specimens stained with Grocott's staining indicated cysts of *Pneumocystis jirovecii*, reproduced with permission [28]

(KL-6), and C-reactive protein. The threshold value for D-glucan concentration for PCP in the above-mentioned study was 31.1 pg/mL, with a sensitivity and specificity of 92.3% and 86.1% respectively. The reference range for -D-glucan, on the other hand, varies depending on the test technique used. Although the -D-glucan concentration was within normal ranges in this case, which might be due to the limited number of infections, there was insufficient data to evaluate if the D-glucan concentration represents the pneumocystis load in the lungs.

Depending on the patient's immunological state, PCP might appear with a variety of chest CT abnormalities. PCP is more frequent in immunocompromised persons and can be fatal. Even when chest CT images are abnormal, such as many lesions, PCP should be examined, and bronchoscopy should be attempted to diagnosis PCP if the patient's health allows. In suspected PCP cases, quick diagnosis and anti-PCP therapy are essential.

9 PCP Prognosis

The prognosis of PCP is worst due to its late diagnosis and it is a major cause of death in the US due to AIDS. It is most likely to occur in those patients who develop pneumothorax, and in this case patients receive mechanical ventilation. Currently, 20–50% cases have been reported due to large-scale studies.

10 Clinical Manifestations

These are basically signs and symptoms which distinguish and tell the medical expert whether infection is caused by *Streptococcus pneumoniae* and *Pneumocystis jirovecii*. By keeping in view these findings diagnostic parameters are performed prior to treatment. PCP signs & symptoms and different findings are discussed in below section for further observations and understanding (Table 2).

Table 2 Signs and symptoms for diagnosis of PCP

Symptoms	Signs	CXR Findings
Fever	Hypoxia	Diffuse, bilateral, hazy infiltrates
Dyspnea	Tachypnea, tachycardia	Pneumothorax
Dry cough	Inspiratory crackles	Pleural effusion, lobar infiltrate, nodules less common
Pleuritic chest pain	Elevated A-a gradient	CXR normal in 25%
Malaise	Chest exam normal in 50%	

Table 3 Differential diagnostic parameters of PCP infected patient

Acute respiratory distress syndrome (ARDS)	Cytomegalovirus	Lymphocytic interstitial pneumonia
Mycoplasma infections	Viral pneumonia	Pulmonary embolism
Legionellosis	Tuberculosis	Mycobacterium avium complex (MAC) infection

11 Differential Diagnosis of PCP

Patients who are PCP infected may also be infected with other pneumonia diseases [34]. This condition is not necessary in this regard that PCP patient is infected with fungal disease only. PCP patient may also be infected with other fungal disease, that's why differential diagnosis is performed to ensure whether patient is infected with PCP or multiple viral, bacterial, or fungal diseases are involved. Table 3 tells us about the differential diagnostic parameters of PCP-infected patient.

12 Laboratory Studies

A lactic dehydrogenase (LDH) test is performed to detect the degree of lung injury [35]. Individuals who are infected with HIV are at great risk of PCP and it is uplifted in 90% patients. There exists an alternative to invasive testing procedure names as sputum *P. jirovecii* PCR, which is a time-consuming method for sample collection and it is done in case of patient's respiratory failure. For PCP detection a sensitive test known as β-D-Glucan (BDG) is preferred which is comprised of Aspergillus, Candida, and Pneumocystis, but zygomycetes are excluded. The accuracy of this test is determined with Quantitative studies.

13 Chest Radiography

Those patients with defective immune system and other symptoms such as fever or respiratory signs are observed then in this regard chest radiography is performed. These results may be normal in patients with early mild disease. Common signs and symptoms include asymmetric infiltrates, pneumothorax, and pneumatoceles. In this overall process, a small amount of radiation is placed on the targeted organs such as lungs and then the image is detected in x-ray form.

14 Computed Tomography

For the detection and imaging of PJP infection high-resolution computed tomography (HRCT) is used rather than CT scan because it can easily detect PJP patients infected with HIV infection. This process is monitored by the radiologist and after obtaining HRCT of the patients with the help of specified computers, concluded results are sent to the physician for treatment purposes.

15 Other Noninvasive Tests

15.1 Pulmonary Function Tests

This test is performed on the basis of DLCO which stands for decreased diffusion capacity of carbon monoxide; patients whose DLCO value is normal are less likely to be susceptible with PCP infection. Decreased DLCO value indicates higher risk of PCP infection (89–100%). When this test is compared with HRCT, then it is used to distinguish whether the PCP patient is infected with HIV/AIDS or the patient is infected with PCP infection only. In such type of tests, patient's observation is made on regular basis.

15.2 Pulse Oximetry

It should be calculated in all the patients at room temperature [36]. It should be calculated at rest or after some activity in specified patients. If hypoxemia is detected in which oxygen saturation is less than 90%, then arterial blood gas level should be attained along with corticosteroids.

15.3 HIV Testing

In case of possible HIV testing in PCP patients, observations and results made before the test and after the test should be evaluated carefully [37].

15.4 Laboratory Testing

In laboratory testing, the blood sample of the affected patient is evaluated according to LDH level.

16 Sputum Induction

Another method of detecting the PCP infection is via sputum induction [38]. In this process, the patient is nebulized with 3% hypertonic saline and the specified patient is provided with a box for sputum collection. The nebulization sputum is sent to the laboratory to detect if the PCP infection is caused by HIV or it is caused by only pneumonia. The sensitivity of this test is usually based on the effective technique applied in laboratory and its specificity varies from 99% to 100%.

17 Bronchoalveolar Lavage (BAL) Test

BAL test is performed if the sputum induction is negative and this test has higher diagnostic sensitivity, this test is performed on the recommendation of pulmonologist when the patient mental status is altered and the patient is unable to give sample by sputum induction. This test gives more sensitivity to detect PCP infection than sputum induction [39].

18 Lungs Biopsy

This test is performed to detect higher sensitivity and specificity, in which the results obtained are 100%. In this test, tissue samples are obtained from infected PCP patient's lungs for diagnostic purposes [40].

19 Histologic Evaluation

P. jiroveci cannot grow in vitro, therefore, histologic findings are observed before patient diagnosis. Several staining techniques are applied for PCP detection. (1) Crystal violet, (2) Giemsa, (3) Diff-Quik, and (4) Wright stain [41]. For trophozoite and cyst form identification, mostly these staining methods are used.

20 Treatment of PCP

Although PCP is declared as fungal pneumonia, it does not respond to anti-fungal drugs. It is treated via TMP-SMX and other second line agents such as pentamidine and dapsone which are mostly along with pyrimethamine or atovaquone. A few successful case studies indicate that caspofungin can also treat PCP infection [42].

Treatment of PCP depends upon degree of illness and there are different parameters for tackling with PCP fungal infection which involves different drug combinations via oral or IV route depending upon the diagnosis and severity of the infection. There are two types of PCP patients, the first one are those who do not acquire HIV/AIDS infection and recovers within 4–5 days and the second one are those who acquire PCP infection and recovers within 21 days or longer [43].

20.1 Antibiotic Therapy (Table 4)

20.2 Adjunctive Corticosteroids Therapy

In severe cases, corticosteroids therapy should be administered to the PCP patient because of suppression of immune response. Latest research indicates that patients who are infected with PCP fungal infection should not keep in contact with other immunocompromised patients (Table 5).

Table 4 Antibiotic Therapy for PCP

Mild to moderate PCP (oral route)	
First choice	Trimethoprim-sulfamethoxazole
Second choice	Trimethoprim (Proloprim) and dapsone Or Clindamycin (Cleocin) and primaquine
Third choice	Atovaquone (Mepron)
Moderate to severe PCP (IV regimens)	
First choice	Trimethoprim-sulfamethoxazole
Second choice	Trimetrexate/leucovorin and oral dapsone Or Clindamycin (Cleocin phosphate) and oral primaquine
Third choice	Pentamidine

Table 5 Adjunctive Corticosteroids Therapy for PCP

Schedule	Dosage
Days 1–5	40 mg of prednisone twice daily
Days 6–10	40 mg of prednisone once daily
Days 11–21	20 mg of prednisone once daily

21 PCP Prevention

Smokers are at a greater risk of getting PCP infection, so it is advisable to quit smoking in order to prevent lungs from PCP infections. Currently, no vaccine available for PCP as a preventive measure. If an individual is infected with PCP, avoid direct contact with the person and practice safety precautions. If the patient is immunocompromised and CD4+ level is low, the physicians recommend to take medications that boost immune response thereby maintaining CD4+ level.

22 Conclusion

By reading this chapter, readers can easily get to know about PCP infection and can easily distinguish between PCP patients infected with HIV or PCP patients infected without HIV. Hospitals should have separate wards for dealing with PCP patients for better patient care services and different tests are performed before diagnosis based on patient disease response and conditions. Antibiotics and adjunctive steroids are given to PCP patients for better recovery and maintaining their immune system. Patients must be observed carefully for clinical outcomes and it must also be assured that no drug interactions and toxicity occurs during treatment. If the treatment is carried out by a general family physician, then the patient should be aware of this PCP fungal infection transmission and treatment protocols.

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