Imaging spectrum of pulmonary infections in renal transplant patients

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Abstract

In the post renal transplant setting, pulmonary infections comprise an important set of complications. Microbiological diagnosis although specific is often delayed and insensitive. Radiography is the most common and first imaging test for which patient is referred, however it is relatively insensitive. HRCT is a very useful imaging tool in the scenario where radiography is negative or inconclusive and high clinical suspicion for infection is present. HRCT features vary among the various pathogens and also depend on the level of immunocompromise. Certain HRCT findings are characteristic for specific pathogens and may help narrow diagnosis. In this review article, we will summarize the imaging findings of various pulmonary infections encountered in post renal transplant patients.

Key words: High resolution computed tomography, immunocompromised, peritransplant, pneumonia, renal transplant

Introduction

In the immunocompromised transplant recipient, several pulmonary complications are prevalent of which three-fourth are infections.[1] Early diagnosis and treatment for pulmonary infections is of paramount importance due to its associated high morbidity and mortality. One of the important factors affecting the spectrum of infections is timing since renal transplant. Early diagnosis of infection and narrowing down the possible differential diagnosis helps significantly in deciding appropriate treatment. Plain radiograph of chest, though is the first investigation for clinical work up, is neither sensitive nor specific for specific etiology of pulmonary infections. In majority of patients, additional imaging modalities like CT chest and additional investigations like BAL and percutaneous lung biopsy are often required for reaching to a specific diagnosis. In this respect, HRCT is an important tool with a high negative predictive value.

Imaging modalities

- Radiography is a useful modality for initial screening and follow up, where a definite abnormality is detected. In a neutropenic patient, due to decreased inflammatory response, often radiographic findings are minimal, and this modality alone may not suffice. Obvious advantages include low radiation, frequent repeatability, and bedside/ICU availability. Radiography is useful in detecting pleural effusion, large consolidation, widespread lung abnormality and large sized nodules. Flip side of this modality is low sensitivity and the inability to detect focal ground glass
abnormality, small localized nodules, and abnormality in hidden areas. One of the major advantages of radiography is to give the initial impression of etiology of infection by pattern of lung involvement so that initial empirical antibacterial can be started pending definitive diagnosis.

- High-resolution computed tomography in immunosuppressed patients is mostly required to assess more details of the extent of pulmonary involvement and pattern of involvement. Further, it becomes mandatory in a patient with pulmonary symptoms with normal chest radiograph. It may be advisable to consider thin section CT in all patients with neutropenia and normal chest radiographs. In a study of 20 patients, Gulati et al. found that HRCT revealed additional findings as compared to radiography in 11 patients. Seventeen of the 20 patients had a final diagnosis of infection of which 11 were diagnosed by HRCT and the final diagnosis coincided with HRCT diagnosis in all except one patient. In some cases, the imaging patterns are specific or highly suggestive of a particular infection like nodule with halo in invasive aspergillosis, bilateral ground glass, or reticular opacity in cytomegalovirus (CMV)/Pneumocystis jiroveci pneumonia (PCP) and bulging fissure sign in *Klebsiella* infection. This helps us in narrowing the differential diagnosis and guiding the specific treatment.

- Ultrasound Its use is limited to detecting pleural effusion on bedside and guiding interventions like pleural fluid aspiration or guided pulmonary biopsy.

### Timeline of infections

Pulmonary infections after renal transplantation are most common in the first 6 months with a peak at about 3 months. During the first month, infections are similar to patients undergoing other thoracic and abdominal surgeries. During this period, the common infections are pneumonia due to gram negative bacterial infections and septic emboli due to intravenous lines. Between months 1 and 6, common infections are viral (CMV, EBV, and HSV), fungal (aspergillus, PCP), and tubercular infections. Viral infections may also predispose to fungal infections (Table 1).

### Common infections in peri-transplant period

In recent studies by Gandhi *et al.* (2018) and Japerumal *et al.* (2016), bacterial infection followed by tuberculosis and fungal infections were found to be the most common infections.

### Table 1: Timeline of infections in renal transplant patients

<table>
<thead>
<tr>
<th>Timeline of infections</th>
<th>First month</th>
<th>One to six months</th>
<th>After 6 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infections similar to other surgery patients</td>
<td>Viral (CMV, EBV, HSV)</td>
<td>Chronic viral infection 5-10%</td>
<td></td>
</tr>
<tr>
<td>Aspiration pneumonia due to oral bacteria</td>
<td>Fungal (aspergillus, PJP)</td>
<td>Predisposed to organ failure and malignancy including PTLD</td>
<td></td>
</tr>
<tr>
<td>Gram negative bacterial infections</td>
<td>Normal graft function 75-85%</td>
<td>Suboptimal graft function requiring immunosuppression 5-10%</td>
<td></td>
</tr>
<tr>
<td>Septic emboli</td>
<td>Infections similar to general population</td>
<td>Opportunistic infection</td>
<td></td>
</tr>
</tbody>
</table>
infections in renal transplant recipients. Another study by Affara et al. (2015), bacterial followed by mixed bacterial, tuberculosis, and CMV infections were found to be most common in the first year after renal transplant. Wang et al., found mixed infections, followed by virus and bacterial as the most common etiology. Another study from India found tuberculosis to be most common infection in the group of patients they studied.

**Bacterial**

Imaging findings in bacterial infections in these patients are not much different from the general population. However, there is a propensity to rapid progression and complications like abscess and bacteremia, if patients are not treated promptly in time.

**Mycobacterial infections**

Mycobacterium tuberculosis comprises 10–15% of pulmonary involvement in kidney transplant patients in endemic areas like India, though it is much less in Western countries. A majority of tuberculosis patients will present in the first year post transplant, though it is still common in the later part of the posttransplant period Tuberculosis has been traditionally classified into primary and secondary. Primary tuberculosis presents as consolidations, necrotic lymph nodes, miliary nodules, and pleural effusions. Secondary tuberculosis which is due to reactivation presents as patchy consolidations with cavities more often in upper lobes in the background of fibrosis [Figure 1A].

Renal transplant patients are immunocompromised and may present with the findings of the primary disease irrespective of prior exposure [Table 2]. Imaging findings in immunocompromised patients may include lower lung disease, necrotic adenopathy [Figure 1B], pleural effusion among other findings as compared to upper lobe cavitatory disease in immunocompetent patients. Cavitation is relatively uncommon in post renal transplant setting as compared to the general population. Tree in bud appearance which is due to airway dissemination is more common in tuberculosis as compared to other bacterial infections. Miliary nodules are an indication of severe immunocompromised state and hence may have a poor prognosis associated with higher mortality [Figure 1C]. Signs of activity in TB are consolidation, tree in bud appearance, miliary nodules and cavities, while calcified nodules, linear opacities, and bronchiectasis indicate inactivity.

**Gram positive bacteria**

Streptococcus, which is the most common cause of community-acquired pneumonia typically causes lobar pneumonia. It may be associated with small pleural effusions; however, abscess and empyema are uncommon. Staphylococcus causes bronchopneumonia, which may

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**Table 2: Tuberculosis in renal transplant patients**

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>May show primary disease irrespective of prior exposure</td>
<td>Imaging findings</td>
</tr>
<tr>
<td>Necrotic nodes, lower lung disease, pleural effusion rather than upper lobe cavitatory disease</td>
<td>in immunocompromised patients</td>
</tr>
<tr>
<td>Tree in bud due to airway dissemination</td>
<td>as compared to upper lobe cavitatory disease</td>
</tr>
<tr>
<td>Miliary: poor prognosis</td>
<td>in immunocompetent patients</td>
</tr>
</tbody>
</table>

**Table 3: Gram positive bacteria in renal transplant patients**

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Streptococcus</td>
<td>Lobar pneumonia</td>
</tr>
<tr>
<td></td>
<td>Small effusion</td>
</tr>
<tr>
<td></td>
<td>Bronchopneumonia</td>
</tr>
<tr>
<td></td>
<td>Pleural effusion, empyema</td>
</tr>
<tr>
<td></td>
<td>Cavitation and pneumatoceles</td>
</tr>
</tbody>
</table>

**Table 4: Gram negative bacteria in renal transplant patients**

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pseudomonas</td>
<td>Bronchopneumonia</td>
</tr>
<tr>
<td></td>
<td>Bilateral complex lower lobe nodules</td>
</tr>
<tr>
<td></td>
<td>Pleural effusion, abscess</td>
</tr>
<tr>
<td></td>
<td>Klebsiella</td>
</tr>
<tr>
<td></td>
<td>Lobar pneumonia</td>
</tr>
<tr>
<td></td>
<td>Pleural effusion, cavitation, and abscess</td>
</tr>
<tr>
<td></td>
<td>Nocardia</td>
</tr>
<tr>
<td></td>
<td>Nodules, consolidation, cavitation, and lymphadenopathy</td>
</tr>
<tr>
<td></td>
<td>Effusion, abscess</td>
</tr>
<tr>
<td></td>
<td>Extension to mediastinum, pericardium, and chest wall</td>
</tr>
<tr>
<td>Anaerobic bacteria</td>
<td>Aspiration</td>
</tr>
<tr>
<td></td>
<td>Pneumonia affecting posterior segment of upper lobes, superior and posterior basal segments of lower lobes</td>
</tr>
<tr>
<td></td>
<td>Abscess and empyema</td>
</tr>
</tbody>
</table>
later become confluent leading to lobar pneumonia. It may be associated with pleural effusion, empyema, cavitatin, and pneumatoceles. Staphylococcus is a common cause of secondary bacterial infection in post influenza patients [Table 3].

**Table 5: Fungal infections in renal transplant patients**

<table>
<thead>
<tr>
<th>Fungal Infection</th>
<th>Clinical Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aspergillus</strong></td>
<td></td>
</tr>
<tr>
<td>ABPA: Bronchiectasis with mucus plugging, tree in bud opacities</td>
<td></td>
</tr>
<tr>
<td>Semi-invasive: Nodules &gt;1 cm, consolidation +/- cavitation</td>
<td></td>
</tr>
<tr>
<td>D/D TB</td>
<td></td>
</tr>
<tr>
<td>Angioinvasive: Nodule with halo, mass, wedge-shaped consolidation, cavitatin</td>
<td></td>
</tr>
<tr>
<td>Airway invasive: Bronchiolitis or bronchopneumonia</td>
<td></td>
</tr>
<tr>
<td>Candida</td>
<td></td>
</tr>
<tr>
<td>Multiple nodules/consolidation in lower lobes</td>
<td></td>
</tr>
<tr>
<td>Cryptococcus</td>
<td></td>
</tr>
<tr>
<td>Multiple nodules or masses, segmental or lobar consolidation in lower lobes</td>
<td></td>
</tr>
<tr>
<td>Mucormycosis</td>
<td></td>
</tr>
<tr>
<td>Large nodules, consolidations with reverse halo sign, and large areas of peripheral GGO</td>
<td></td>
</tr>
<tr>
<td>Fissural and chest wall invasion</td>
<td></td>
</tr>
<tr>
<td><strong>Pneumocystis jiroveci</strong></td>
<td>Bilateral upper lobe and perihilar GGO and septal thickening with subpleural sparing</td>
</tr>
<tr>
<td><strong>Crazy-paving, pneumatoceles and cysts</strong></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 2 (A-D):** (A-D) Fungal infections (A) Angioinvasive aspergillosis. Patient presented with fever and blood tinged sputum. Axial CT shows multiple nodules with surrounding ground glass opacity and consolidation. (Nodule with halo sign)(arrow). Some of the nodules revealed central cavitation (not shown). (B). Mucormycosis. Axial HRCT and sagittal reformat show a single large mass-like area of consolidation with surrounding ground glass opacity (arrow) in posterior segment of right upper lobe extending across the major fissure (thin arrow) into the superior segment of the lower lobe. Fissural invasion and perilesional GGO suggest an aggressive fungal infection. On biopsy this was proven to be mucormycosis. (C) Pneumocystis jiroveci pneumonia. Radiograph shows ill-defined air space opacity in bilateral upper and mid-zones in perihilar region. (D) Pneumocystis jiroveci pneumonia. Axial HRCT shows diffuse bilateral asymmetrical ground glass opacity with areas of interlobular septal thickening. Few scattered intrapulmonary cysts were also seen (not shown). Bronchoalveolar lavage with gomori methanamine silver staining confirmed the diagnosis.

**Aspergillus**

The spectrum of aspergillus infection varies depending upon the severity of immunocompromised status. Aspergilloma and allergic bronchopulmonary aspergillosis (ABPA) affect patients with normal immune status. Aspergilloma is seen as a ball of fungal hyphae in a preexisting cavity. The fungal ball/mycetoma may be seen to move between prone and supine scans. It may also present as a irregular sponge-like opacity with air spaces filling a preexisting cavity. Allergic bronchopulmonary aspergillosis (ABPA) is seen as bilateral central bronchiectasis with mucus plugging and peripheral tree in bud opacities. Semi-invasive aspergillosis is seen in patients with mild immunocompromised status usually with underlying chronic lung disease like prior tuberculosis, fibrosis, or COPD. Imaging findings include nodules larger than 1 cm, consolidation with or without cavitation in the upper lobes. **Semi-invasive aspergillosis may be difficult to differentiate from active tuberculosis. Invasive aspergillosis affects patients who are immunosuppressed, and may be angioinvasive or airwayinvasive. Invasive aspergillosis has a high fatality rate approaching 75 percent.** In angioinvasive aspergillosis, the typical finding of nodules with surrounding ground glass opacity representing hemorrhage is specific; however, it is uncommon [Figure 2A). Nodule with halo sign is also described in other conditions like Wegener’s granulomatosis, Kaposi sarcoma, and other infections; however, in the setting of infections not responding to...
standard antibiotics particularly in transplant setting, it is highly suggestive of angioinvasive aspergillosis. Other imaging findings can include masses and wedge-shaped consolidation. Cavitation, when present, generally occurs two weeks after the appearance of nodules. Airway invasive aspergillosis presents as bronchiolitis or bronchopneumonia. HRCT findings are peribronchial consolidation, centrilobular nodules, and tree-in-bud appearance.

**Candida albicans**

Candida infection in a transplant setting is more commonly seen in oropharynx and esophagus. Pulmonary infection is relatively uncommon. Imaging findings include multiple nodules and focal consolidation more commonly seen in lower lobes.

**Cryptococcal pneumonia**

Cryptococcal infection is quite rare in a renal transplant setting. Imaging findings of cryptococcal pneumonia include nodules or masses of segmental or lobar consolidation which are often bilateral and asymmetrical. Peripheral and lower lobe distribution is more common.

**Mucormycosis**

The most common site of mucor infection is rhinocerebral followed by pulmonary and disseminated infections. Common imaging findings include large nodules, consolidations with reverse halo sign (Bird nest sign) and large areas of perilesional ground glass opacity. Fissural and chest wall invasion is highly suggestive of mucormycosis. Lesions often show a peripheral predominance. Patients with severe infections may show a multifocal pneumonia pattern which is associated with poor prognosis.

**Pneumocystis jiroveci**

Prior to the era of universal cotrimoxazole prophylaxis, *P. jiroveci* pneumonia (PCP) incidence was 5–10%, among renal transplant patients. PCP patients show severe hypoxemia, dyspnea, and cough with paucity of physical findings. Radiographs are commonly abnormal and show diffuse bilateral interstitial opacities in a perihilar distribution. Reticular and ground-glass opacities may progress to frank consolidation over 3–4 days. Hallmark appearance on CT is bilateral upper lobe and perihilar ground-glass opacities and septal thickening with subpleural sparing. HRCT has a high sensitivity and specificity for diagnosis of PCP; so, a normal study may help in the exclusion of the diagnosis. Imaging appearance may worsen initially during therapy due to inflammatory reaction; however, ultimately ground-glass opacities get resolved completely once therapy is continued.

**CMV**

CMV is the most common virus encountered in renal transplant recipients. CMV infection ranges from subclinical viremia, a mononucleosis like CMV syndrome with fever, malaise, and neutropenia, and organ specific infection among which lung is one of the common involvement. Given that shedding virus in respiratory tract may occur without tissue invasion, the detection of CMV DNA in bronchoalveolar lavage can only suggest a presumptive diagnosis. For the above reason, it is important to correlate with clinical and radiological findings. CMV pneumonia incidence among kidney transplant patients is 2%. Moreover, CMV infection may predispose to other infections. Most common imaging findings are diffuse bilateral ground glass, interstitial opacities, consolidation, and centrilobular nodules. CMV pneumonia incidence among kidney transplant patients is 2%. Moreover, CMV infection may predispose to other infections. Most common imaging findings are diffuse bilateral ground glass, interstitial opacities, consolidation, and centrilobular nodules. [Figure 3A and B]. Centrilobular nodules less than 10 mm favor viral infection over other etiologies. The close differential is PCP infection; however, pleural effusion is more common in CMV than PCP.

**Table 6: Viral infections in renal transplant patients**

<table>
<thead>
<tr>
<th>CMV</th>
</tr>
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<tbody>
<tr>
<td>Diffuse bilateral GGO, interstitial opacities, consolidation</td>
</tr>
<tr>
<td>Centrilobular nodules &lt; 10 mm</td>
</tr>
<tr>
<td>Community respiratory viruses</td>
</tr>
<tr>
<td>Bronchiolitis and pneumonia</td>
</tr>
<tr>
<td>Ground glass opacity, centrilobular nodules, and tree-in-bud appearance</td>
</tr>
<tr>
<td>Varicella zoster virus</td>
</tr>
<tr>
<td>Small nodules, nodule with surrounding GGO, diffuse miliary pattern, patchy GGO, and coalescent nodules</td>
</tr>
<tr>
<td>Coronavirus disease 2019 (COVID-19)</td>
</tr>
<tr>
<td>Multifocal patchy, predominantly peripheral ground glass opacities</td>
</tr>
<tr>
<td>Confluent ground glass and consolidation in later stages</td>
</tr>
</tbody>
</table>
Ahmad, et al.: Postrenal transplant pulmonary infection imaging

Review Article

Figure 3D: Nasopharyngeal swab real-time reverse transcription polymerase chain reaction (rRT-PCR) for SARS-CoV-2 is essential to make the diagnosis when there is high chance of COVID-19 infection in appropriate clinical setting [Table 6].


Imaging patterns can be broadly divided into 1. Consolidation 2. Nodules 3. Diffuse/interstitial pattern. When the predominant imaging finding is consolidation, the causative organism is commonly tuberculosis or bacteria. The causes of lobar pneumonia include streptococcus and Klebsiella while the causes of bronchopneumonia include staphylococcus and pseudomonas. If nodules are the predominant findings, common etiologies may be fungi, nocardia, tuberculosis, fungi, and viruses. If the size of nodules is less than 10 mm, viral infection is more likely.

If the size of nodules is more than 1 cm, then fungal or tubercular infection is more likely. Tree in bud nodules are more common in the setting of tuberculosis as compared to other infections. If cavitation is present in the nodules, then the differentials may include septic emboli or invasive aspergillosis; the latter may show peripheral ground glass halo. Diffuse/interstitial pattern is shown by viruses like CMV and VZV in addition to PCP and miliary tuberculosis. Diffuse pattern may also be caused by bacteria and fungi less frequently.

Coronavirus disease 2019 (COVID-19) pneumonia

The ongoing Coronavirus disease 2019 (COVID-19) pandemic also involves renal transplant patient giving rise to pneumonia. Patient can present with fever, followed by cough, myalgia, chills, and fatigue. The most common chest X-ray and computed tomography abnormality was multifocal patchy opacities. On HRCT, common findings in early disease and mild to moderate cases may be multifocal, bilateral, patchy ground glass opacities [Figure 4]. In later stages and in severe disease, more confluent ground glass opacities, consolidation and an ARDS like picture may be seen. Nasopharyngeal swab real-time reverse transcription polymerase chain reaction (rRT-PCR) for SARS-CoV-2 is essential to make the diagnosis when there is high chance of COVID-19 infection in appropriate clinical setting [Table 6].

Approach to radiological imaging

The presentation of pulmonary infections in the setting of renal transplant may be either acute or subacute/chronic. An acute process which evolves over hours may be due to bacterial pneumonia. A subacute/chronic process which presents over days to weeks may be due to PCP, viruses, mycobacteria, or fungi.

Image patterns can be broadly divided into 1. Consolidation 2. Nodules 3. Diffuse/interstitial pattern. When the predominant imaging finding is consolidation, the causative organism is commonly tuberculosis or bacteria. The causes of lobar pneumonia include streptococcus and Klebsiella while the causes of bronchopneumonia include staphylococcus and pseudomonas. If nodules are the predominant findings, common etiologies may be fungi, nocardia, tuberculosis, fungi, and viruses. If the size of nodules is less than 10 mm, viral infection is more likely. If the size of nodules is more than 1 cm, then fungal or tubercular infection is more likely. Tree in bud nodules are more common in the setting of tuberculosis as compared to other infections. If cavitation is present in the nodules, then the differentials may include septic emboli or invasive aspergillosis; the latter may show peripheral ground glass halo. Diffuse/interstitial pattern is shown by viruses like CMV and VZV in addition to PCP and miliary tuberculosis. Diffuse pattern may also be caused by bacteria and fungi less frequently.

Conclusion

To conclude, pulmonary infections are most important infections in renal transplant recipients and the important cause of morbidity and mortality. There is a large spectrum of opportunistic organisms which may cause such infections owing to immunocompromised status. Early diagnosis is essential for specific treatment which is key to recovery. As microbiological diagnosis is often delayed, an empirical therapy is started on the likely diagnosis of infection based on the clinical and radiological patterns. Hence,

Community respiratory viruses

Community respiratory viruses including influenza, parainfluenza, adenovirus, HSV, VZV, and RSV cause mild upper respiratory tract infection in patients with normal immunity. They may cause more severe illness along with broncholitis and pneumonia in transplant recipients. Respiratory viral infections increase the risk of superimposed fungal or bacterial pneumonia. HRCT findings of pneumonia due to influenza and respiratory syncytial viruses include ground glass opacity, centrilobular nodules, and tree in bud appearance [Figure 3C].

Varicella zoster virus (VZV)

A majority (upto 90%) of varicella zoster pneumonias occur in immunocompromised patients including renal transplant recipients. Histological features of diffuse alveolar damage are observed in varicella zoster pneumonia. HRCT findings include small less than 10 mm nodules, nodule with surrounding GGO, diffuse miliary pattern, patchy ground glass opacities, and coalescent nodules [Figure 3D]. These findings usually resolve simultaneously with skin nodules after antiviral treatment; however, they may leave widespread 2-3 mm residual calcifications.
an appropriate approach to these infections becomes
mandatory for the favorable outcome of infection.

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Conflicts of interest
There are no conflicts of interest.

References

1. Rosenow EC, Wilson WR, Cockerill FR. Pulmonary disease in the
in the renal transplant recipients: Analysis of the radiologic
High-resolution CT in renal transplant patients with suspected
4. John GT, Shankar V, Abraham AM, Mukundan U, Thomas PP,
Jacob CK. Risk factors for post-transplant tuberculosis. Kidney Int
2001;60:1148‑53.
5. Singh N, Paterson DL. Mycobacterium tuberculosis infection in
solid-organ transplant recipients: Impact and implications for
6. Unger JD, Rose HD, Unger GF. Gram-negative pneumonia.
7. Rozenstein A, Hao F, Starc MT, Pearson GDN. Radiographic
appearance of pulmonary tuberculosis: Dogma disproved. AJR
8. Sundaram M, Adhikary SD, John GT, Kekre NS. Tuberculosis in
9. Pereira M, Gazzoni FF, Marchiori E, Irion K, Moreira J,
Giacomelli IL, et al. High-resolution CT findings of pulmonary
Mycobacterium tuberculosis infection in renal transplant
10. Leung AN. Pulmonary tuberculosis: The essentials. Radiology
features of pulmonary infection in post renal transplant recipients:
et al. The diagnosis of pneumonia in renal transplant recipients using
13. Minero MV, Martín M, Cercenado E, Rabadán PM, Bouza E,
Muñoz P. Nocardiosis at the turn of the century. Medicine (Baltimore)
2009;88:250‑61.
14. Franquet T, Müller NL, Giménez A, Domingo P, Plaza V, Bordes R.
Semiinvasive pulmonary aspergillosis in chronic obstructive
Invasive aspergillosis in solid organ transplant recipients. Am J
17. Logan PM, Primack SL, Miller RR, Müller NL. Invasive aspergillosis
of the airways: Radiographic, CT, and pathologic findings.
patients. Medical Mycology: Current trends & future prospects
2015: Taylor & Francis group, LLC 0.2015. p. 110‑146.
in renal transplant recipients: Review of 174 reported cases. BMC
Infect Dis 2017;17:283.
20. Franquet T, Müller NL, Giménez A, Martinez S, Madrid M,
Domíngo P. Infectious pulmonary nodules in immunocompromised
patients: Usefulness of computed tomography in predicting their
21. Boiselle PM, Tocino I, Hooley RJ, Pumerantz AS, Selwyn PA,
Neklesa VP, et al. Chest radiograph interpretation of Pneumocystis
carini pneumonia, bacterial pneumonia, and pulmonary
tuberculosis in HIV-positive patients: Accuracy, distinguishing
Update on pulmonary Pneumocystis jirovecii infection in non-HIV
23. Vogel MN, Brodoffel H, Hierl T, Beck R, Bethge WA, Claussen CD,
et al. Differences and similarities of cytomegalovirus and
pneumocystis pneumonia in HIV-negative immunocompromised
patients thin section CT morphology in the early phase of the
Radiol 2015;56:NP53‑NP53.
25. Vogel MN, Vatlach M, Weissgerber P, Goepert B, Claussen CD,
Hetzel J, et al. HRCT-features of Pneumocystis jiroveci pneumonia and
their evolution before and after treatment in non-HIV
26. Kotloff RM, Ahya VN, Crawford SW. Pulmonary complications of
solid organ and hematopoietic stem cell transplantation. Am J
Respir Crit Care Med 2004;170:22‑48.
27. Franquet T, Lee KS, Müller NL. Thin-section CT findings in 32
immunocompromised patients with cytomegalovirus pneumonia
who do not have AIDS. Am J Roentgenol 2003;181:1059‑63.
28. Horger MS, Pfannenberg C, Einsele H, Beck R, Hebart H,
Lengerke C, et al. Cytomegalovirus pneumonia after stem cell
transplantation: Correlation of CT findings with clinical outcome
29. Wendt CH. Community respiratory viruses: Organ transplant
30. Ison MG. Respiratory viral infections in transplant recipients.
31. Gandhi S, Kute V, Patel K, Sutariya H, Pandya V. Role of high
resolution computed tomography of chest in posttransplant
pulmonary infection. Indian J Transplant 2017;11:49‑54.
32. Ariza-Heredia EJ, Fishman JE, Cleary T, Smith L, Razonable RR,
Abbo L. Clinical and radiological features of respiratory syncytial
virus in solid organ transplant recipients: A single-center
experience. Transpl Infect Dis 2012;14:64‑71.
Viral pneumonias in adults: Radiologic and pathologic findings.
Radiographics 2002;22(suppl_1):S137‑49.
35. Nair V, Jandovitz N, Hirsch JS, Nair G, Abate M, Bhaskaran M,
36. Oh YW, Effeemann EL, Godwin JD. Pulmonary infections in
immunocompromised hosts: The importance of correlating the
conventional radiologic appearance with the clinical setting.
Radiology 2000;217:647‑56.