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Imaging of Pneumonia: An Overview

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Abstract
Purpose of review Pneumonia is one of the common causes of morbidity and mortality in general population. Imaging plays an important role in the management of pneumonia.
Recent findings In the current era, there has been an increase in the patients with extremes of age, immunocompromised status, underlying lung pathology, post-transplant status, and atypical infections. It is necessary to use cross-sectional imaging modalities like computed tomography (CT) due to atypical or non-specific chest radiograph findings in such cases. CT narrows down the differential diagnosis, for etiological agent. It helps in the evaluation of the causes of non-resolving pneumonia, pulmonary, and non-pulmonary complications of pneumonia. Pneumonia is classified into three main types as community-acquired pneumonia, hospital-acquired pneumonia, and aspiration pneumonia. It is important to differentiate these three types, since host factors and etiological organisms differ, thus changing the course and management in these patients.
Summary Knowing the clinical background and correlation with imaging findings may help in the early detection of pathogen and direct the physician toward appropriate management. Imaging also helps in follow-up of patients to look for response to therapy. Cross-sectional imaging can help in ruling out diseases mimicking pneumonia.

Keywords Pneumonia · Lung · Infection · Tuberculosis · Radiograph · Chest

Introduction

Pneumonia is one of the common causes of morbidity and mortality in general population. Imaging plays an important role in the management of pneumonia. In a patient suffering from fever, cough or sputum production, imaging helps in confirming the diagnosis of pneumonia. However, identification of specific etiological agent is not always possible, since the imaging findings may be non-specific. Response of lungs to any kind of inflammation or infection is limited, most of them presenting as alveolar opacities, and hence non-infectious pathologies may also have an appearance of pneumonias and are most often termed as pneumonia mimics. Chest radiography is the most widely used radiological investigation and in most cases may be the only investigation necessary in treating a patient with pneumonia. However, in the current era with an increase in the people with extremes of age, immunocompromised status, underlying lung pathology, post-transplant patients, and also infections due to atypical organisms, it is necessary to use cross-sectional imaging modalities like computed tomography (CT) due to atypical or non-specific chest radiograph findings [1]. CT also helps in determining the causes of non-resolving pneumonias, pulmonary and non-pulmonary complications

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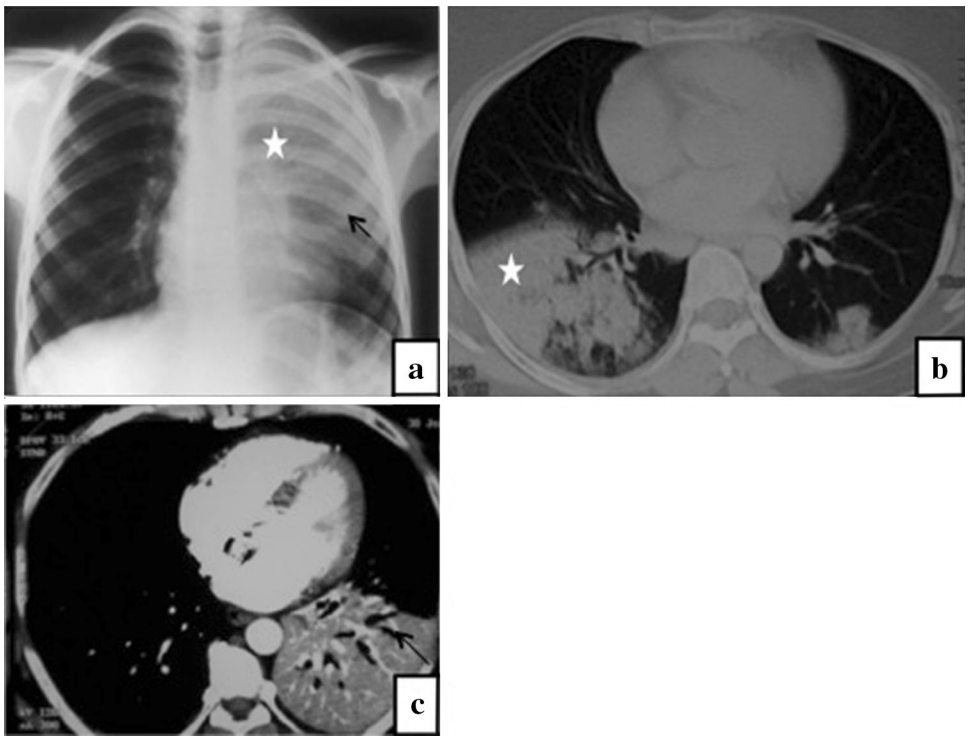

Fig. 1 Lobar Pneumonia due to Streptococcus in different patients. **a** Chest radiograph shows the presence of consolidation (*asterisk*) in the left upper lobe with the presence of air bronchogram (*black arrow*). **b** Chest CT in another patient showing consolidation involving the right lower lobe (*asterisk*). **c** CT in a patient with lobar consolidation showing air bronchogram sign (*black arrow*)

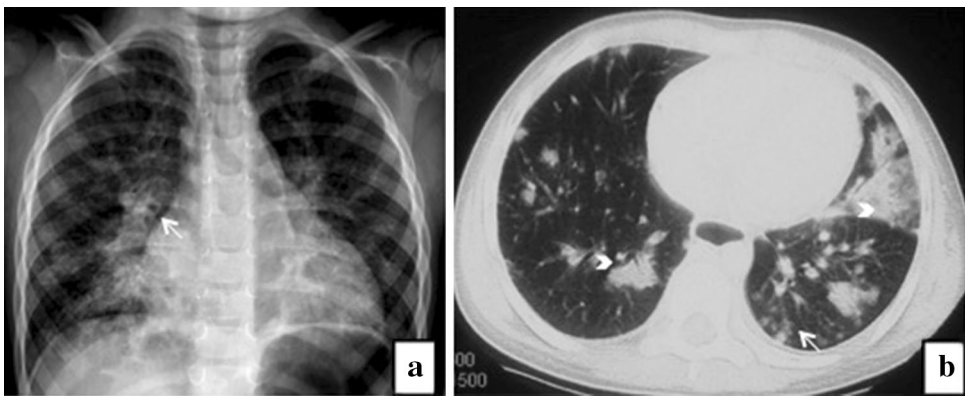

Fig. 2 Lobular pneumonia due to *P. aeruginosa*. **a** Chest radiograph shows the presence of patchy opacities with ill-defined centrilobular nodules and peribronchial thickening (*white arrow*). **b** Chest CT shows patchy peribronchial areas of consolidation (*white arrow head*) and peribronchial nodules in both lungs (*white arrow*)

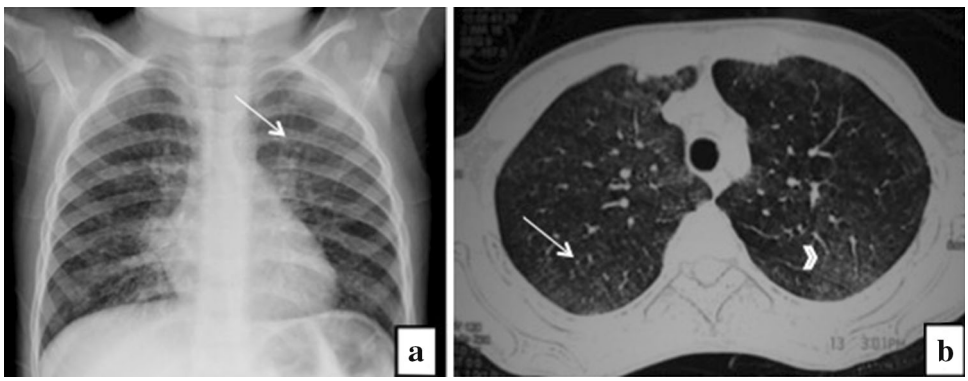

Fig. 3 Interstitial pneumonia, in a patient with atypical pneumonia due to Mycoplasma. **a** Chest radiograph shows the presence of bilateral reticulonodular opacities (*white arrow*). **b** Chest CT shows ground glass opacities (*arrow head*) and ill-defined nodules in bilateral lungs (*white arrow*)

of pneumonia and serves as a guide to intervention in choosing the site for transbronchial lung biopsy or percutaneous biopsy and drainage of abscesses or pleural collections [2]. This review article gives an overall view about different types of pneumonias with special emphasis on pneumonias in immunocompromised patients.

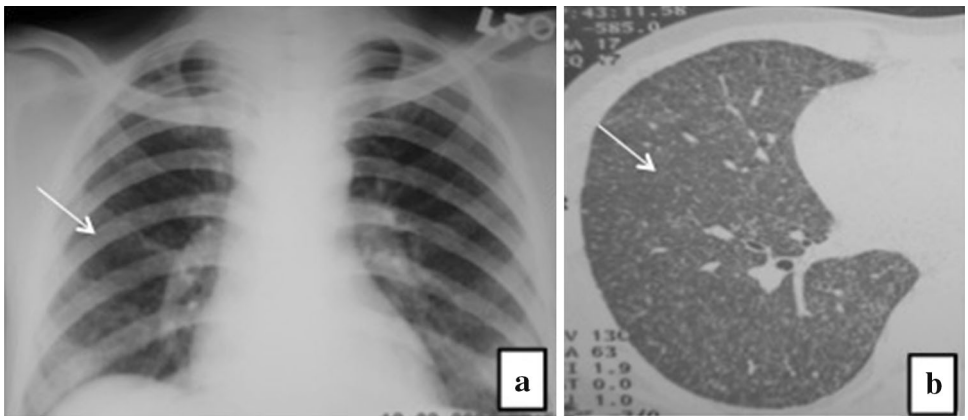

Fig. 4 Nodular pattern of pneumonia in a case of miliary TB. **a** Chest radiograph shows the presence of bilateral nodular opacities. **b** Tiny random nodules(<5 mm) are seen in right lung on chest CT

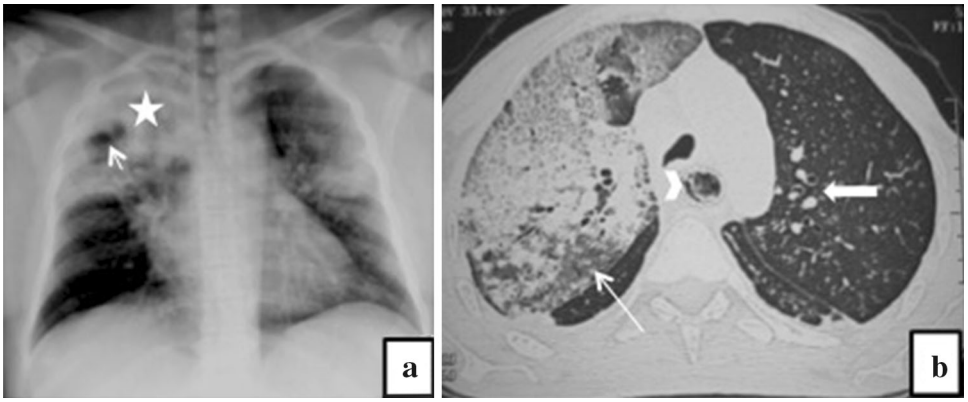

Fig. 5 *Klebsiella Pneumonia* in two different patients. **a** Chest radiograph shows the presence of lobar consolidation (*asterisk*) with break down and cavitation (*small white arrow*) in right upper lobe. **b** Chest CT shows the presence of lobar consolidation with bulging fissures (*long white arrow*). Note the stent in esophagus (*white arrow head*) and centrilobular nodules in left upper lobe (*white block arrow*)

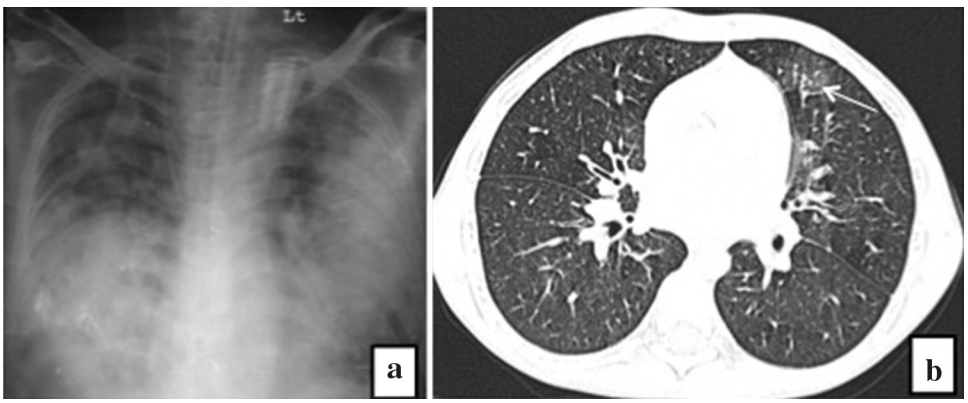

Fig. 6 **a** Chest radiograph shows the presence of lobar and patchy consolidation in both lungs in a patient with Legionella pneumonia. **b** Chest CT in a patient with *Mycoplasma pneumonia* shows the presence of patchy areas of GGOs in lingula (*white arrow*)

Classification of Pneumonia

Pneumonia is classified into three main types as community-acquired pneumonia (CAP), hospital-acquired pneumonia (HAP), and aspiration pneumonia [3]. It is important to differentiate these three types since host factors and etiological organisms differ, thus changing the course and management in these patients [4, 5]. Based on the radiological pattern, pneumonias can be lobar, lobular and interstitial pneumonia [6]. This pattern approach is

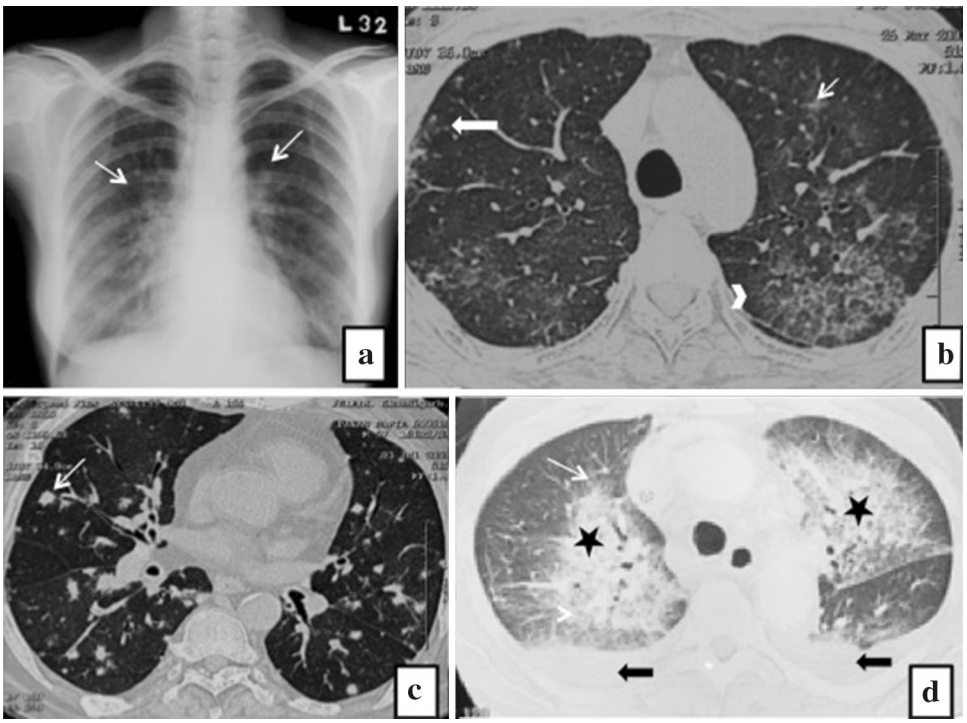

Fig. 7 Spectrum of viral pneumonias. **a** Chest radiograph shows reticular opacities in bilateral lungs predominantly in the perihilar region (*arrow*) with hyperinflated lung fields in a patient with viral pneumonia. **b** Chest CT shows the presence of ill-defined nodules (*block white arrow*) and GGOs (*short white arrow*) in both lungs with subtle interstitial thickening (*arrow head*) in a patient with viral pneumonia. **c** Chest CT showing multiple random nodules of varying sizes (*white arrow*) in a patient with Varicella pneumonia. **d** Chest CT in a patient with H1N1 influenza, bilateral perihilar consolidation (*black asterisk*) with adjacent GGOs (*white arrow*) and bilateral pleural effusion (*black block arrow*). This patient presented with fever, altered sensorium, and dyspnea with a possibility of pulmonary edema

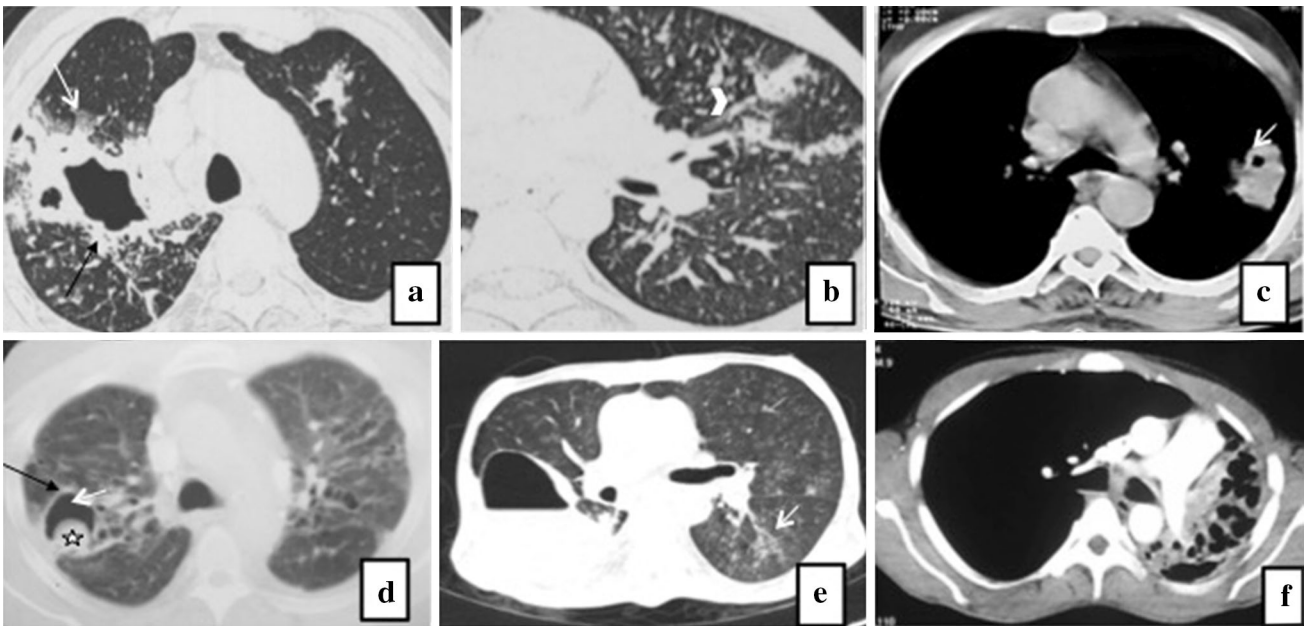

Fig. 8 Spectrum of post-primary TB. **a**, **b** Chest CT shows the presence of thick-walled cavity (*black arrow*) in right upper lobe with centrilobular nodules in both upper lobes, with few areas of GGOs (*white arrow*). Note associated peribronchial thickening with coalescing nodules in left upper lobe (*white arrow head*). **c** Chest CT in a case of Tuberculoma, showing well-defined nodule with eccentric cavitation (*white arrow*) in left upper lobe. **d** Chest CT showing cavity (*black arrow*) with fungal ball (*asterisk*) producing air crescent sign (*white arrow*). **e** Chest CT showing loculated right hydropneumothorax with the presence of diffuse centrilobular nodules in both lungs (*white arrow*). **f** Chest CT shows volume loss with bronchiectatic cavities in left lung secondary to TB

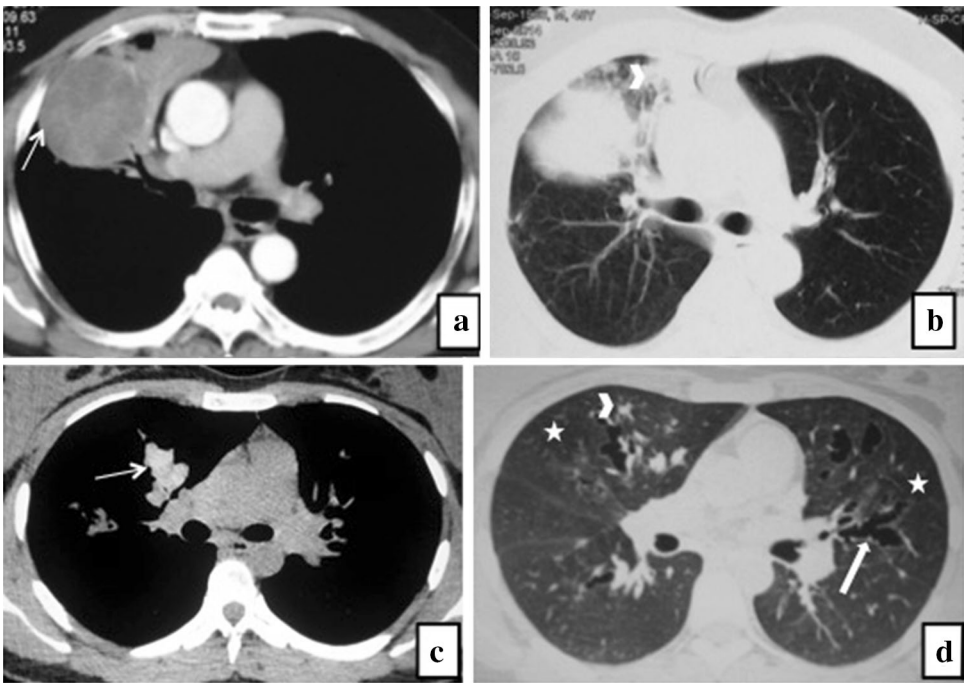

Fig. 9 **a**, **b** Chest CT shows the presence of well-defined mass in right upper lobe with adjacent lung atelectasis (*white arrow* in **a** and *arrow head* in **b**) in a patient with cryptococcoma. **c**, **d** Case of ABPA, chest CT shows high-attenuation mucous plugging in dilated bronchus in right lung (*white arrow* in **c**), central bronchiectatic changes in both lungs (*white block arrow*) and centrilobular nodules (*arrow head*). Note mosaic attenuation in both lungs (*asterisk*)

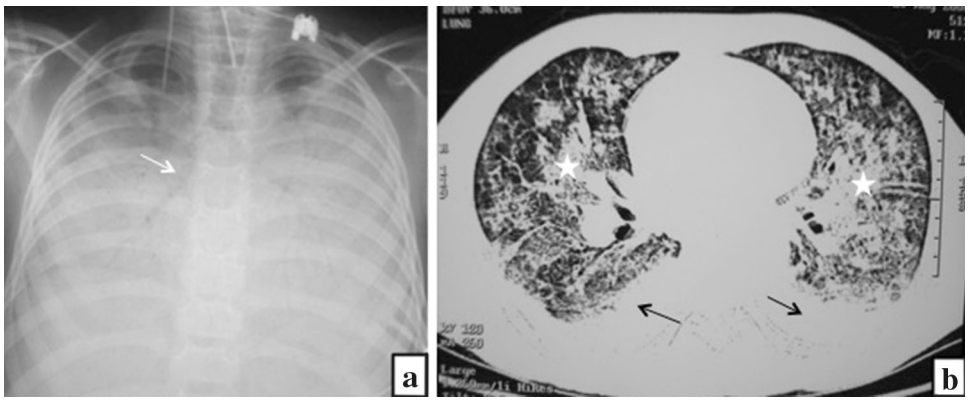

Fig. 10 **a** Chest radiograph in a patient with VAP shows the presence of bilateral homogeneous opacities with sparing of bilateral lung apices with the presence of air bronchogram (*white arrow*). **b** Chest CT shows the presence of patchy consolidation in both lungs (*asterisk*) with bilateral pleural effusion (*black arrow*)

sometimes useful in identifying the etiological agent. However, the radiological pattern should be correlated with clinical findings and should only be used as a guide to diagnosis, as variation in imaging findings are common. For example, single organism can manifest in wide variety of ways like mycobacterium tuberculosis presenting as consolidation, nodules, miliary pattern, etc. In addition, patients with pre-existing lung pathologies and immunocompromised status may not have classical imaging findings. Clinical suspicion and cross-sectional imaging can help in identifying the type of organism in these patients, even if chest radiograph is non-contributory.

Morphological Patterns of Pneumonia

Airspace Consolidation/Lobar Pneumonia

In air space consolidation, the microorganisms damage the alveoli leading on to increase in secretion of fluid into the alveoli that further spreads through collateral drift (terminal airways and pores of Kohn) to involve a entire segment or lobe. Consolidation of lung is caused by fluid, cellular infiltration, and fibrinous exudates. Lobar pneumonia is characterized by relatively sharply marginated homogeneous consolidation of lung parenchyma with patent air

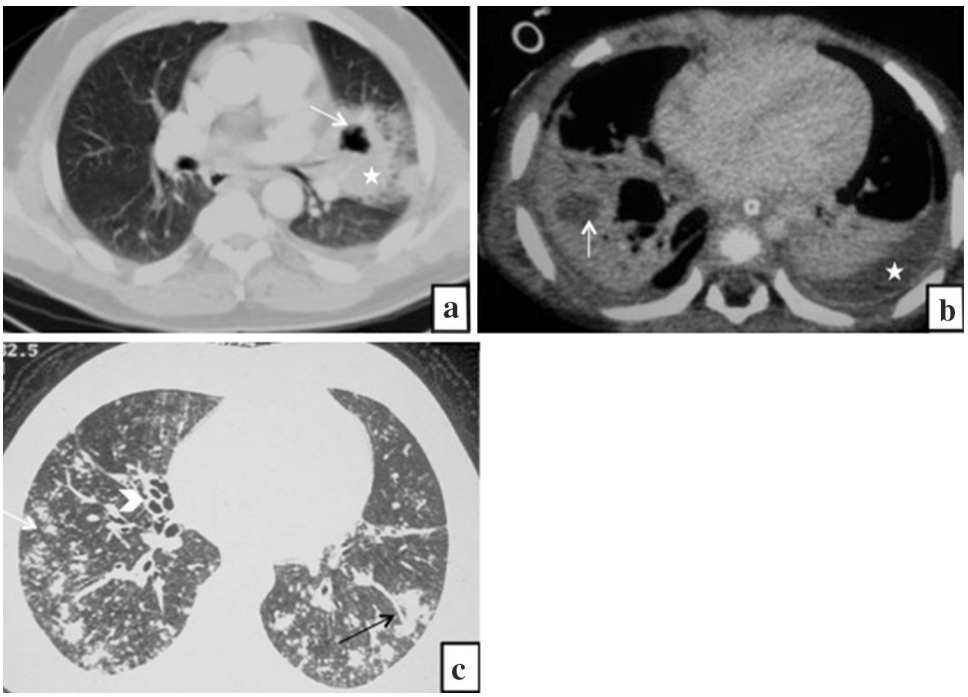

Fig. 11 **a** Chest CT in a patient with *E. coli* pneumonia. Patchy area of consolidation (*asterisk*) is seen in left upper lobe with cavitation (*white arrow*) and adjacent GGOs. **b** Chest CT in another patient with *E. coli* pneumonia. Bilateral lower lobe consolidation with abscess formation in right lower lobe (*white arrow*). Note pleural enhancement and thickening on both sides with left empyema (*asterisk*). **c** Chest CT shows the presence of nodules in both lungs (*white arrow*) with patchy areas of consolidation (*black arrow*) in a patient with hemophilus pneumonia. Note made of bronchiectasis involving right middle lobe (*arrow head*)

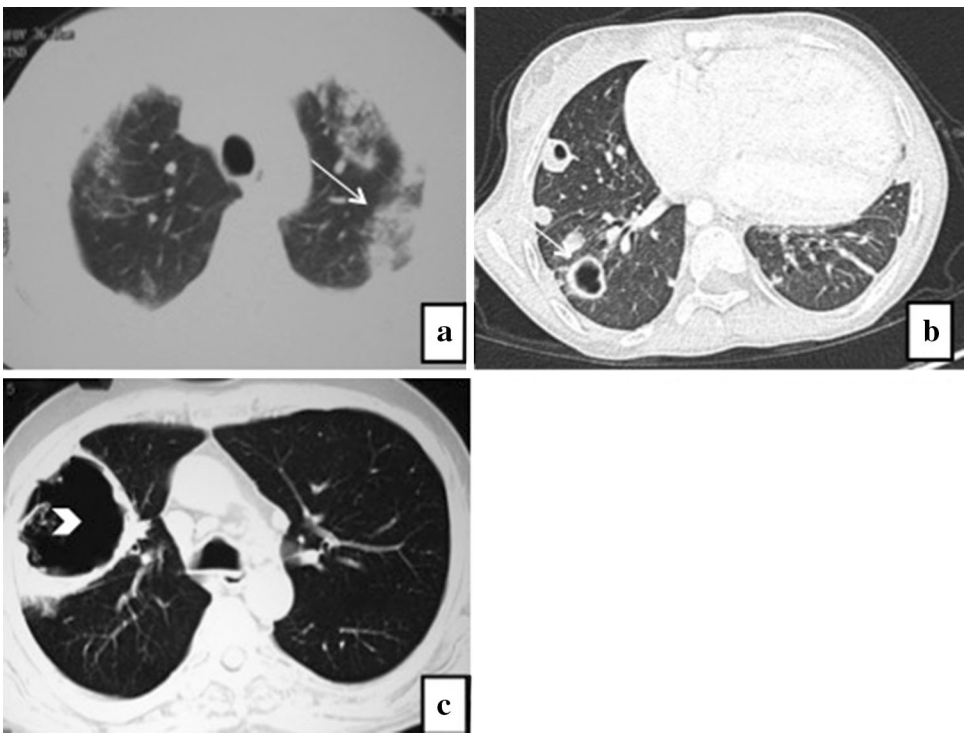

Fig. 12 Staphylococcal pneumonia. **a** Chest CT shows coalescing peribronchial nodules with patchy consolidation in bilateral upper lobes c/w bronchopneumonia. **b** Multiple nodules with few of them show cavitation (*white arrow*) in right lung in a patient with septic embolism. **c** Chest CT shows well-defined large thin-walled air containing cyst likely pneumatocele (*arrowhead*)

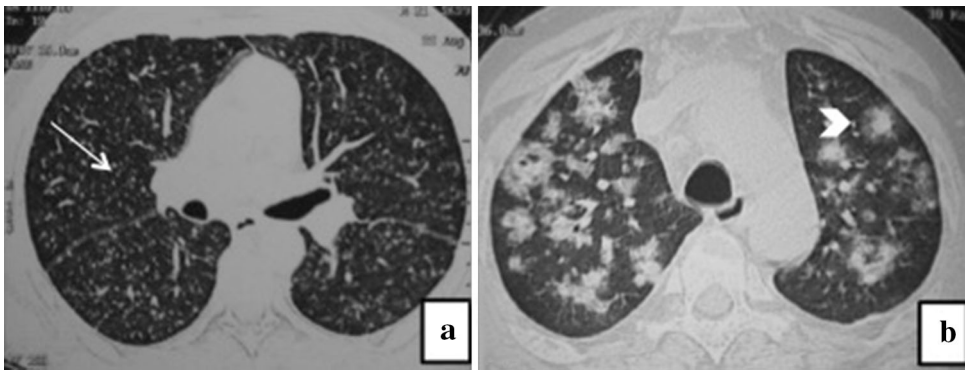

Fig. 13 Fungal pneumonia. **a** Chest CT shows the presence of tiny random nodules in both lungs in a patient with disseminated candida infection. **b** Chest CT shows multiple nodules of varying sizes with few of them showing surrounding GGOs (Halo sign, *arrow head*) and central cavitation in a patient with *Aspergillus pneumonia*

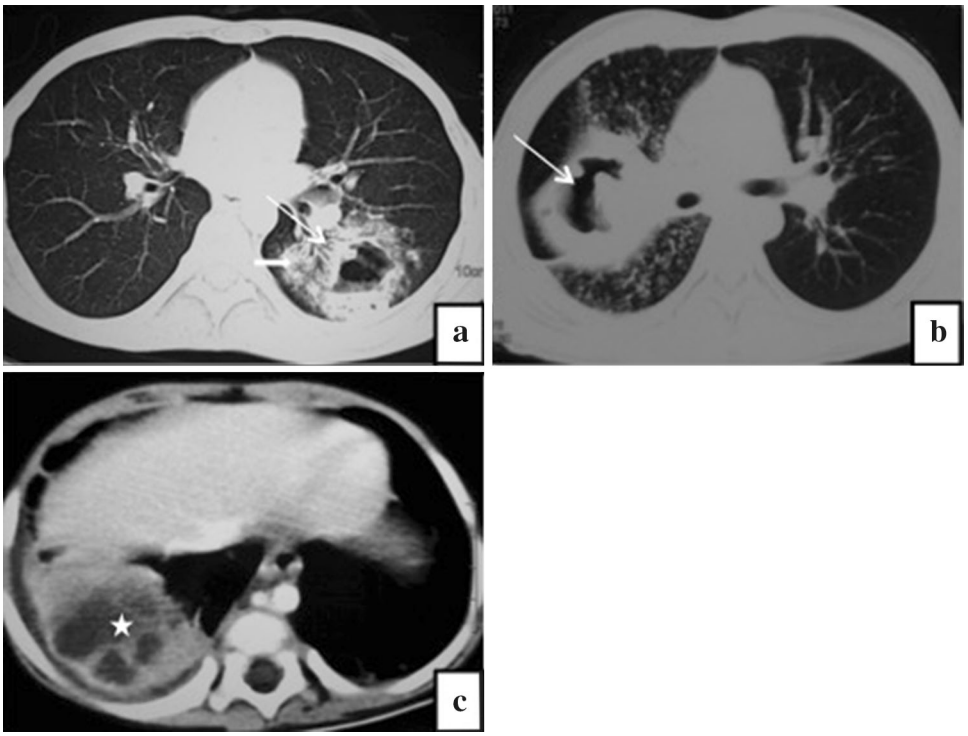

Fig. 14 Aspiration Pneumonia. **a** Chest CT shows the presence of cavity (*white arrow*) with irregular walls and air fluid level in left lower lobe. Note the presence of adjacent centrilobular nodules (*white block arrow*) in patient with aspiration pneumonia. **b** Chest CT shows thick-walled cavity (*arrow*) with multiple centrilobular nodules in right lung. **c** Consolidation involving right lower lobe with hypodense areas (*asterisk*) within s/o evolving abscess secondary to aspiration

ways thus producing air bronchogram sign (Fig. 1). Most common causes of lobar pneumonia include *Streptococcus pneumonia*, *Chlamydia pneumophila*, *Mycoplasma pneumonia* and *Klebsiella pneumonia* [6].

Bronchopneumonia/Lobular Pneumonia

In lobular pneumonia, the causative organism directly attacks the peripheral airways damaging the walls of terminal and respiratory bronchioles causing necrosis of walls leading on to bronchiolitis and bronchitis which further cause secretion of fluid and inflammatory cells and later on involvement of parenchyma [6]. Radiologically, it is seen as patchy centrilobular or peribronchial nodules which later on cause dense consolidation (Fig. 2). Most common causes of bronchopneumonia are *Staphylococcus aureus* and *Pseudomonas aeruginosa*. Sometimes this pattern of involvement can be seen with *Hemophilus influenzae*, *Mycoplasma pneumonia*, and *Mycobacterium tuberculosis*.

Interstitial Pneumonia

Interstitial pneumonia is secondary to an infectious agent that damages the ciliated epithelial cells and bronchial

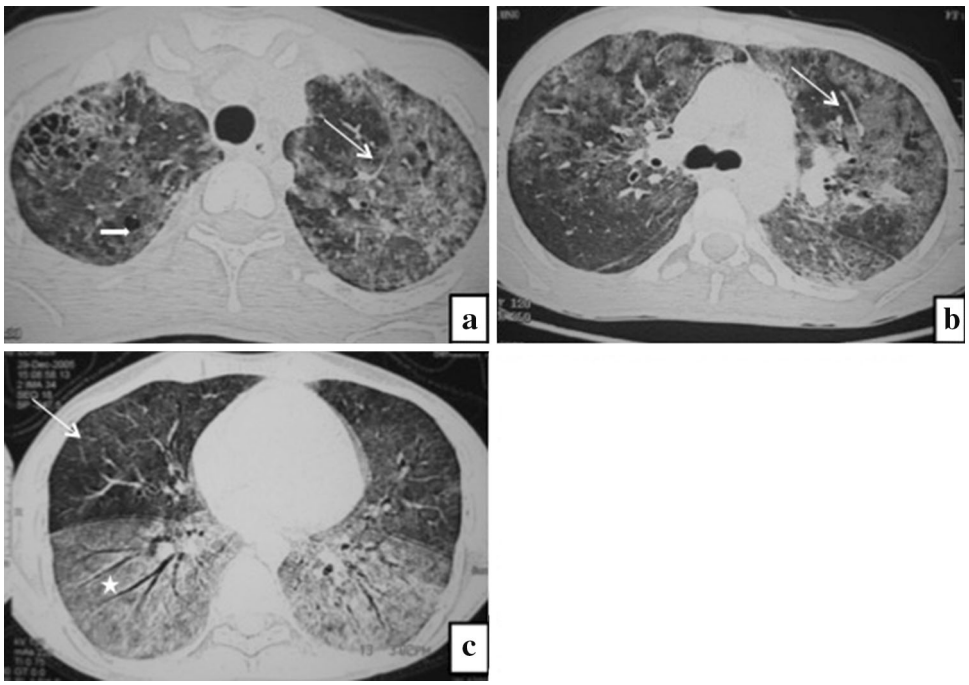

Fig. 15 *Pneumocystis jiroveci* Pneumonia. **a**, **b** Chest CT shows bilateral interstitial pattern of pneumonia with GGOs (*arrow* in **a** and **b**) and few cysts (*block white arrow* in **a**). **c** Chest CT in a different patient shows diffuse GGO's (*asterisk*) in both lower lobes with few ill-defined centrilobular nodules (*arrow*) in a post-renal transplant patient (combined cytomegalovirus and *P. jiroveci* infection)

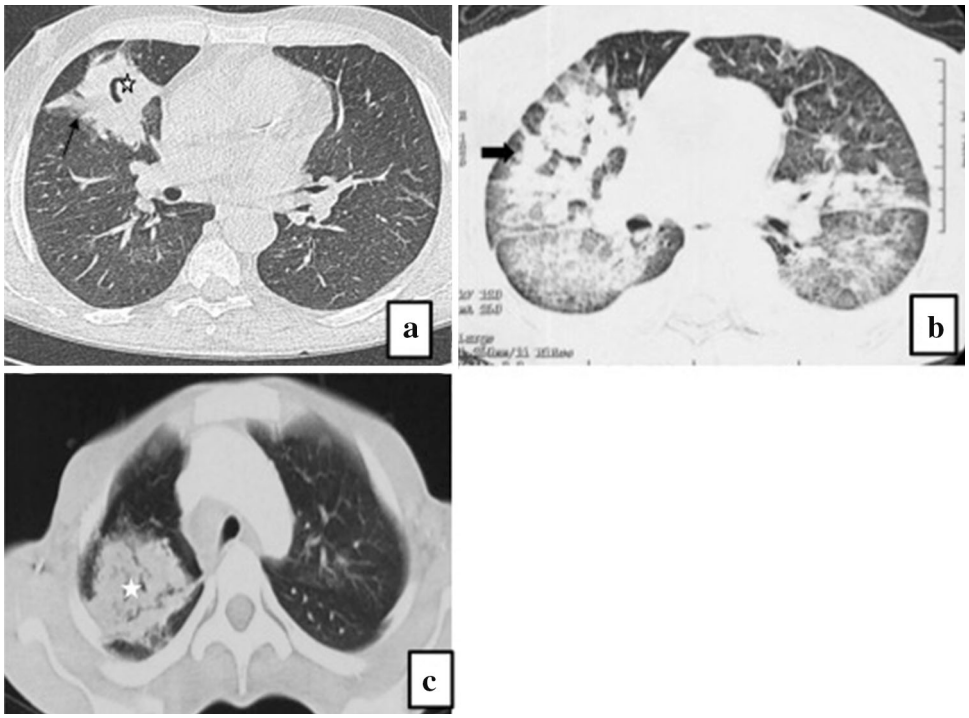

Fig. 16 **a** Semi-invasive aspergillosis in an immumocompromised patient, chest CT shows cavity with eccentric soft tissue (*asterisk*) and surrounding GGOs (*black arrow*). GGOs represent hemorrhage secondary to vascular invasion. **b** Airway Invasive Aspergillosis, chest CT shows coalescing areas of consolidation with GGOs in right lung (*black block arrow* in **b**). **c** Disseminated *Histoplasmosis* in a post-renal transplant patient. Chest CT shows areas of consolidation in right upper lobe (*asterisk*)

mucous gland cells due to which edema and lymphocytic cellular infiltration occurs. This results in alveolar infiltrates and interstitial septal thickening. Imaging findings include ground glass opacities (GGOs), linear reticular or reticulonodular, and random nodules or patchy consolidations (Fig. 3). In addition to viral pneumonias, Mycoplasma pneumonia and Chlamydia are the most common pathogens causing interstitial pneumonia, together they are called as atypical pneumonias [6].

Nodular Predominant Pattern

This unique pattern is secondary to hematogenous spread of pathogens or granulomata formation. Most

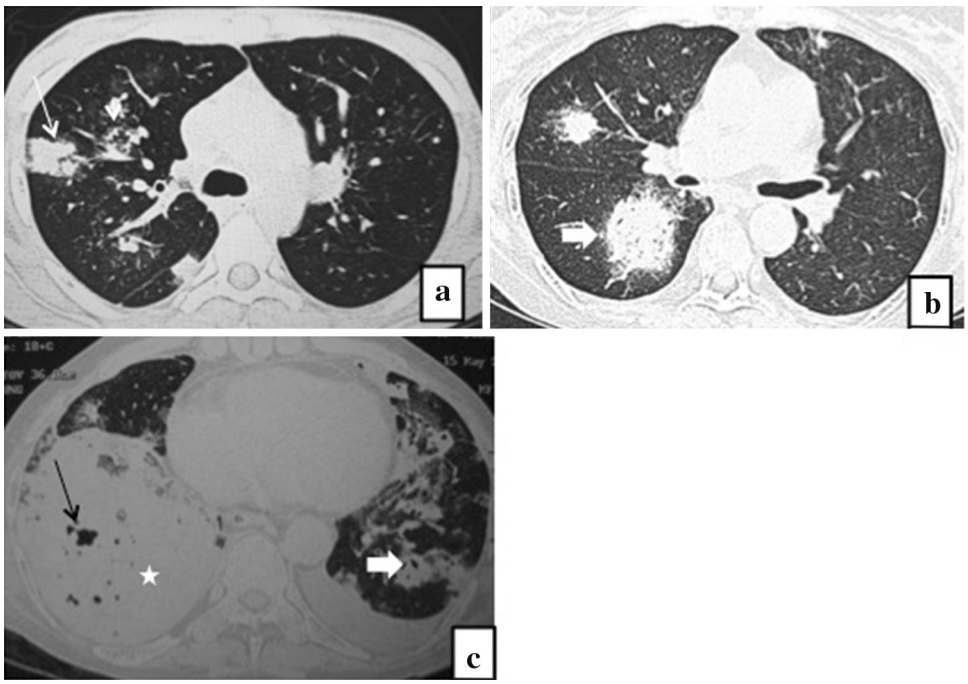

Fig. 17 **a**, **b** Mucormycosis in two different patients. **a** Chest CT shows patchy consolidation (*long white arrow*) in right upper lobe with centrilobular nodules (*short white arrow*). **b** Chest CT shows nodular mass like consolidation in right lung with adjacent GGOs (*white block arrow*). **c** In a post-renal transplant patient with Nocardiosis, chest CT shows the presence of consolidation (*asterisk*) with cavitation (*black arrow*) in right lower lobe and peribronchial thickening (*block white arrow*) in left lung

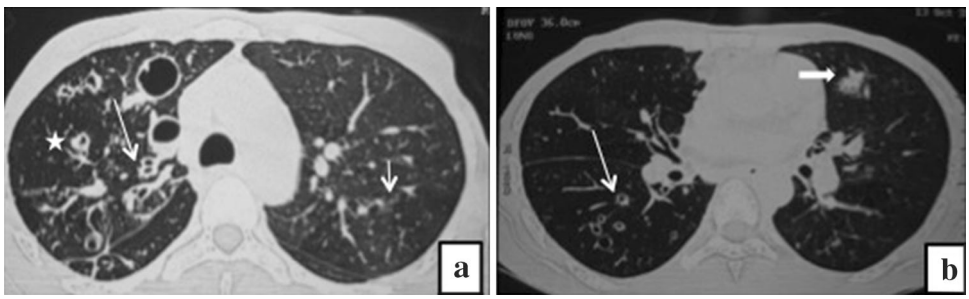

Fig. 18 Non-tubercular mycobacterium infection. **a** Chest CT shows the presence of bronchiectasis with peribronchial thickening (*long white arrow*) in right lung with mosaic attenuation (*asterisk*) and ill-defined centrilobular nodules in left lung (*short white arrow*). **b** Chest CT shows bronchiectasis with peribronchial thickening (*long white arrow*) and patchy consolidation in left lung (*block white arrow*)

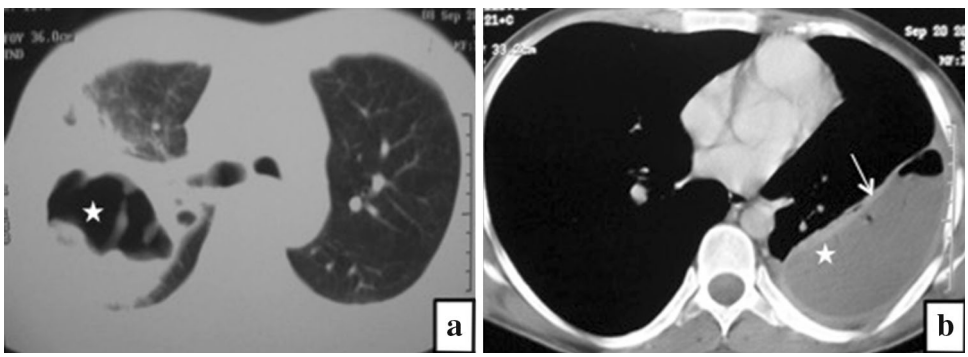

Fig. 19 **a** Chest CT shows pneumonia with cavitation in right lung (*asterisk*). **b** Chest CT shows the presence of loculated pleural effusion with air fluid level (*asterisk*) and enhancing pleura producing split pleura sign (*white arrow*)

commonly encountered nodules are secondary to septic embolism, tuberculosis, or fungal infections and rarely viral infection (for example, Varicella zoster pneumonia). Random nodules are seen which do not respect any segmental boundaries or bronchovascular pattern [6, 7] (Fig. 4).

Clinicoradiological Classification of Pneumonia

Community-Acquired Pneumonia

Organisms most commonly causing CAP pneumonia in previously healthy patients include Gram-positive bacteria

Table 1 Imaging findings in various organisms causing CAP

Organisms	Clinical features	Imaging findings
Streptococcal pneumonia	Accounts for 40–48% cases of CAP	Peripheral homogenous consolidation and basal predominance (Fig. 1)
	Usually seen in young adults and previously healthy patients [8]	Preserved lung volumes
		Small parapneumonic effusion (50%)
		Rarely cavitates
		Manifests as round Pneumonias in children [9]
Klebsiella pneumonia	Incidence: 3–10%	Unilateral or bilateral
	Commonly seen in diabetics, alcoholics, and immunocompromised patients	Consolidation with increased lung volumes causing bulging fissures [10•] (Fig. 5)
	Associated with characteristic red currant jelly sputum in majority of cases [8]	Cavitation seen commonly (40% cases)
		Rarely, pulmonary gangrene can be seen
Legionella pneumonia	Accounts for 3% of cases of CAP	Multifocal consolidation usually involving middle and lower lobes (Fig. 6a)
	Usually acquired by breathing contaminated droplets example from humidifiers and air conditioners colonized by these germs	Pleural effusion is commonly seen
	Mostly associated with fever and severe myalgia [8]	Slow resolution of radiological findings even after treatment
		Persistent abnormalities in imaging in long-term follow-up [8]
Mycoplasma pneumonia	Accounts for 3–13% of CAP	Diffuse or patchy bilateral reticulonodular pattern of involvement
	Usually affects children and adults less than forty years of age	Patchy air space consolidation and GGOs can also be seen (Fig. 6b)
	Associated with fever and dry cough [11, 12••]	Minimal pleural effusion [11]
Chlamydia pneumonia	Accounts for 13% of CAP and is usually seen as co infection	Patchy areas of consolidation or reticulonodular predominant pattern is seen
	Serological tests are used to confirm the diagnosis of Chlamydia pneumonia [11]	Also lobar pneumonia, peribronchial nodules, GGOs, or sometimes infectious bronchiolitis pattern are seen [12••]
Viral pneumonias	Caused by variety of organisms, most commonly influenza, adeno, RSV, varicella, etc.	In patients with milder form of disease, chest radiograph is usually normal or shows bilateral hyperinflated lungs with increased peribronchovascular markings [13] (Fig. 7a)
	Mostly seen in children and patients in extremes of age associated with upper respiratory tract infections	Adeno virus and Influenza viruses produce patchy or lobar areas of consolidation with associated GGOs and peribronchial nodules (Fig. 7b, d)
	Most of the viral infections are complicated by secondary bacterial infections [13, 14]	Varicella pneumonia is usually associated with random nodules in both lungs [13] (Fig. 7c)
Tuberculosis (TB)	Predominantly seen in developing countries and in patients with immunocompromised status	Primary TB is associated with consolidation usually subpleural with ipsilateral hilar lymphadenopathy
	Two forms are seen. Primary and post-primary tuberculosis [15]	Pleural effusion is common
		Post-primary TB usually occurs secondary to reactivation of underlying focus of infection (Fig. 8a–f)
		Centrilobular nodules, cavitation, consolidation, and miliary pattern can be seen [15]
Fungal	Cryptococcus affects immunocompetent patients [16]	Radiologically seen as lobar pneumonia and may show cavity formation or Nodules of varying sizes and GGOs (Fig. 9a, b)
		Allergic bronchopulmonary aspergillosis (ABPA) shows hyperinflated lungs with centrilobular nodules; mucous plugging can be seen giving finger in glove appearance in chest radiograph; high-attenuation mucous; and mosaic attenuation secondary to air trapping are also seen [16] (Fig. 9c, d)

Table 2 Imaging findings in organisms causing NP

Organisms	Clinical characteristics	Imaging findings
Escherichia coli	Mostly seen in ventilated and immunocompromised patients [21]	Bilateral and lower lobe involvement is commonly seen
		Peribronchial nodules or patchy areas of consolidation
		Cavitation is common (Fig. 11a, b)
		Pleural effusion seen in 30% cases [22]
Pseudomonas aeruginosa	Immunocompromised patients predominantly with acquired immunodeficiency syndrome and intravenous drug abusers	Most commonly presents as bronchopneumonia pattern (Fig. 2)
	Associated with greenish colored sputum	Lower lobe involvement is more common
		Necrosis and cavitation is more frequent [23]
Staphylococcus aureus	Mostly seen as secondary infection in patients with viral illness	Bilateral patchy consolidation or peribronchial nodules are seen (Fig. 12a)
	Hematogenous spread of infection can occur [24]	Hematogenous spread of disease causes septic emboli in the form of multiple random nodules with or without cavitation (Fig. 12b)
		During the resolution phase, there is a tendency to form thin-walled cavities called pneumatoceles which increases the risk of pneumothorax [22] (Fig. 12c)
Hemophilus influenza	Patients with immunoglobulin defects are at risk of acquiring infection	Bronchopneumonia pattern is seen in 50% of cases (Fig. 11c)
	Two types of bacteria seen: encapsulated and unencapsulated variants, where unencapsulated variants are associated with severe forms of disease	In severe cases, lobar pneumonia can be seen
		Cavitation is seen in 15% cases
		Pleural effusion is seen in 50% cases [25]
Acinetobacter species, *Stenotrophomonas maltophilia*, and *Burkholderia cepacia*	Rare cause of nosocomial pneumonia [26]	Non-specific bilateral patchy consolidation can be seen
Viral pathogens (influenza, parainfluenza and RSV)	Rare in the setting of nosocomial pneumonia	Bilateral consolidations and GGOs are commonly seen [13]
Fungal pathogens (*Candida* species and *Aspergillus* species)	In patients with compromised immune status and other comorbidities	Nodules, patchy consolidation, sometimes GGOs seen surrounding the nodules producing 'halo sign' (Fig. 13)
		Rarely central clearing in a nodule called 'reverse halo' sign can be seen [27, 28]

such as *Streptococcus pneumonia* and atypical bacteria such as *Mycoplasma pneumoniae* and *Legionella pneumophila*. In elderly patients with compromised immune status, *Staphylococcus*, Gram-negative bacilli and *Streptococcus* are responsible for majority of cases [4, 8]. *Streptococcus pneumonia* is the most common cause of CAP accounting for ~40% of cases [9]. CAP is mostly associated with mild parapneumonic effusion. Most commonly encountered imaging findings in various organisms causing community-acquired pneumonia are given in Table 1.

Nosocomial Pneumonia/Hospital-Acquired Pneumonia

Nosocomial pneumonia (NP) or hospital-acquired pneumonia is defined as pneumonia occurring 48 h after hospital admission, excluding any infection that is incubating at the time of hospital admission. NP also includes pneumonia which occurs within 48 h after discharge from the hospital [17]. It is divided into two types as ventilator-associated pneumonia (VAP) and pneumonia in non-ventilated patients. Patients on ventilator have increased risk of acquiring pneumonia due to favorable condition and also have higher mortality rates [18]. Immune status of the patient, extremes of age, severity of comorbid conditions, and longer hospital stay are risk factors for NP. Aerobic Gram-negative bacilli like *Escherichia coli* and *P. aeruginosa*, *Staphylococcus aureus*, and *Streptococcus pneumonia* are common etiological organisms. Polymicrobial infections are common. In VAP, if the initial period is within 5 days of ventilation,

Table 3 Imaging findings in organisms causing pneumonia in immunocompromised patients

Organism	Clinical characteristics	Imaging findings
Pneumocystis jiroveci	Mostly seen in patients with acquired immunodeficiency	Bilateral symmetrical perihilar nodules, GGOs and cysts (Fig. 15)
	Patients presents with fever and dry cough [33]	Consolidation and pleural effusion are rare [34]
Aspergillus species	Aplastic anemia and patients with febrile neutropenia [35]	Semi-invasive, airway invasive, and angioinvasive pattern
		Consolidation or nodules with adjacent GGOs (halo sign) seen in angioinvasive forms. GGOs representing areas of hemorrhage secondary to vascular invasion (Fig. 16a)
		Cavitation seen commonly
		Peribronchial thickening/consolidation and nodules are seen in airway invasive forms [36] (Fig. 16b)
Candida	Pulmonary candidiasis is seen in patients with deficient cell-mediated immunity	Predominantly presents as random nodules < 1 cm in size [35] (Fig. 13a)
Cryptococcus neoformans, *Histoplasmosis*	Immunocompromised patients with reduced cell-mediated immunity [37]	Reticular and reticulonodular opacities in chest radiograph
		Focal consolidation, random as well as centrilobular nodules [37] (Fig. 16c)
Mucormycosis	Patients with febrile neutropenia and diabetes mellitus [35]	Focal consolidation, nodules with adjacent GGOs
		Cavitation is commonly seen [35] (Fig. 17a, b)
Nocardiosis	Patients with defects in cell-mediated immunity and patients on steroids	Bilateral cavitating nodules, patchy consolidation
		Chest wall involvement seen in 15% cases [38] (Fig. 17c)
Pulmonary TB and Atypical non-Tubercular mycobacteria	Infection from Pulmonary TB and non-TB mycobacteria are difficult to differentiate clinically	Common cause of chronic infection. Associated with bronchiectasis, cavitation, centrilobular nodules, and lymphadenopathy [39] (Fig. 18)
Viral (Cytomegalovirus)	Usually affects infants or adult patients with impaired immunity	Centrilobular nodules, GGOs, and rarely patchy consolidation [40] (Fig. 15c)
	Viral DNA is isolated from bronchoalveolar fluid lavage	
	Coinfection with pneumocystis pneumonia is seen	

etiological agents are *Streptococcus pneumonia*, *Hemophilus influenza*, and *Moraxella catarrhalis*. Late onset VAP (after 5 days) is usually due to aerobic Gram-negative rods and methicillin-resistant *Staphylococcus aureus* [18]. Role of radiology in NP is to diagnose and in follow-up. It is difficult to radiologically identify the etiological agent as most causative organisms show multilobar consolidation as predominant finding. Imaging findings may also mimic acute respiratory distress syndrome [19, 20] (Fig. 10). Imaging findings are given in Table 2.

Aspiration Pneumonia

Aspiration is defined as intake of solid or liquid materials into airways and lungs. Aspiration pneumonia can either be due to microorganisms or due to chemicals for example gastric acidic contents [29]. Common pathogens causing aspiration are organisms colonizing the oropharynx and stomach. Gram-negative anaerobic organisms are most common pathogens. Aspiration pneumonia can be either acute or chronic. In acute aspiration, lobar or segmental pneumonia, bronchopneumonia, lung abscess, and empyema are seen (Fig. 14). Chronic aspiration pneumonia is usually due to repeated aspiration and is seen as focal centrilobular nodules or peribronchial thickening [30]. The posterior segment of the upper lobes and the superior segment of the lower lobes are commonly affected.

Infections in Immunocompromised Patients

In the current era, with the increase in prevalence of patients with diabetes mellitus, post-transplant immunosuppression and patients with acquired and congenital immune deficiency disorders, there is increase in the infections with atypical organisms [31–33]. Most common

pathogens causing infection includes fungal (*Pneumocystis jiroveci*, *Aspergillus*, *Mucormycosis*, *Histoplasmosis*, *Candida*, and *Cryptococcus*), bacterial (*Pseudomonas*, *Streptococcal pneumonia*, *Staphylococcal*, *Nocardiosis*, *Legionella*, *Rhodococcus* etc.), and viral (Cytomegalovirus, Herpes simplex, and influenza). Imaging findings in different types of infection is given in Table 3.

Complications of Pneumonia

Complications after pulmonary infections are common in immunosuppresed patients. The most commonly encountered complications are pleural effusion, empyema, cavitation, bronchopleural fistula, hydropneumothorax, and chest wall involvement. Reactive pleural effusion is commonly associated with streptococcal and Gram-negative pneumonias. Empyema is usually seen in pneumonia secondary to Gram-negative organisms and aspiration pneumonia (Fig. 19). Cavitation is commonly seen in anaerobic infection, TB, and in fungal infections. Chest wall involvement in the form of rib erosions and abscess formation is seen in TB, Nocardiosis, and in actinomycosis [38]. Pneumatoceles leading on to pneumothorax is commonly seen in staphylococcal pneumonia. Rarely pulmonary gangrene can occur in severe cases of Staphylococcal and *Klebsiella pneumonia* [41].

Conclusion

Imaging plays an important role in the management of pneumonia. Knowing the clinical background and correlation with imaging findings may help in early detection of pathogen and direct the physician towards appropriate management. Imaging also helps in follow-up of patients to look for response to therapy. Imaging can identify the complications of pneumonia. In addition, imaging particularly cross-sectional, helps in ruling out other lung diseases which may mimic pneumonia.

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Compliance with Ethical Standards

Conflict of Interest Mandeep Garg, Nidhi Prabhakar, P. Kiruthika, Ritesh Agarwal, Ashutosh Aggarwal, Ajay Gulati, and Niranjan Khandelwal each declare no potential conflicts of interest.

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