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REVIEW ARTICLE

# Pneumonia in the immunocompetent patient

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**ABSTRACT.** Pneumonia is an acute inflammation of the lower respiratory tract. Lower respiratory tract infection is a major cause of mortality worldwide. Pneumonia is most common at the extremes of life. Predisposing factors in children include an underdeveloped immune system together with other factors, such as malnutrition and overcrowding. In adults, tobacco smoking is the single most important preventable risk factor. The commonest infecting organisms in children are respiratory viruses and *Streptoccocus pneumoniae*. In adults, pneumonia can be broadly classified, on the basis of chest radiographic appearance, into lobar pneumonia, bronchopneumonia and pneumonia producing an interstitial pattern. Lobar pneumonia is most commonly associated with community acquired pneumonia, bronchopneumonia with hospital acquired infection and an interstitial pattern with the so called atypical pneumonias, which can be caused by viruses or organisms such as *Mycoplasma pneumoniae*. Most cases of pneumonia can be managed with chest radiographs as the only form of imaging, but CT can detect pneumonia not visible on the chest radiograph and may be of value, particularly in the hospital setting. Complications of pneumonia include pleural effusion, empyema and lung abscess. The chest radiograph may initially indicate an effusion but ultrasound is more sensitive, allows characterisation in some cases and can guide catheter placement for drainage. CT can also be used to characterise and estimate the extent of pleural disease. Most lung abscesses respond to medical therapy, with surgery and image guided catheter drainage serving as options for those cases who do not respond.

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## Epidemiology

Pneumonia is the acute inflammation of the lower respiratory tract and lung parenchyma resulting in a clinical syndrome of fever, cough, shortness of breath and malaise. Radiological change on a plain chest radiograph is used as a diagnostic criterion in many clinical studies.

Lower respiratory tract infection causes 3.9 million deaths per year worldwide, of which 1.8 million are in children under the age of five years [1]. Pneumonia is most common at the extremes of age and among human immunodeficiency virus (HIV)-infected adults. In children, pneumonia is closely associated with specific risk factors including aged less than 2 years, malnutrition, crowding and exposure to smoke, which includes both tobacco smoke and smoke from other causes such as cooking in confined spaces. Tobacco smoking in adults is the single most important preventable risk factor for pneumonia and invasive pneumococcal disease. HIV results in increased rates of disease even when immunocompetence is assumed because of a normal $CD4^+$ T-cell count; thus, lobar pneumonia in otherwise well adults should prompt physicians to consider an HIV test [2]. Pregnancy also results in a marked increase in susceptibility to pneumococcal pneumonia and should be considered in young healthy women presenting with pneumonia [3].

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## Pathogenesis

The most common cause of bacterial pneumonia is *Streptococcus pneumoniae*, which is an extracellular pathogen characterised by a thick polysaccharide capsule [4].

Children under 2 years of age lack specific splenic functions required for immunoglobulin responses to polysaccharide antigens [5]. As a result, these young children share an immunodeficiency similar to that seen in sickle cell disease and other conditions in that they cannot effectively combat capsulate bacteria and struggle to control pneumococcal colonisation of the nasopharynx, mucosal infections (such as otitis media, sinusitis and pneumonia) and invasive infections (bacteraemia and meningitis).

Cigarette smoking is a global scourge associated with acute and chronic respiratory and non-respiratory disease. Clear epidemiological data have been published to show that tobacco smoking is the most important preventable cause of invasive pneumococcal disease in immunocompetent adults in the USA, but the mechanisms to explain this association remain elusive [6]. Possibilities include altered ciliary motility, increased nasopharyngeal carriage of organisms, altered alveolar macrophage function and increased epithelial permeability [7].

Globally, however, the association of pneumonia with smoke inhalation affects 2 billion people daily — most of whom are women and children exposed to indoor air pollution. This includes both tobacco smoke and smoke related to cooking, heating and so on. Studies of upper and lower respiratory tract infection rates have shown clear correlation with measured domestic smoke levels both in children and among adults who have never smoked tobacco [8, 9]. The mechanism behind this association is likely to involve disruption of the systems that protect the lung against oxidative damage — the lung redox balance. The subject of pulmonary redox balance is still in its infancy, but early data suggest that smoke increases the oxidative stress on pulmonary cells by a pro-inflammatory mechanism [10, 11], while vitamin levels are crucial in maintaining appropriate anti-oxidant defences. This mechanism provides a possible link with the compelling evidence that zinc supplementation can reduce rates of childhood pneumonia [12], as zinc is linked to anti-oxidant defence.

## Clinicoradiological patterns of pneumonia

Pulmonary infections can be thought of as occurring in three main clinical subsets: community-acquired pneumonia (CAP); nosocomial (or hospital-acquired) pneumonia; and the immunocompromised patient populations [13]. Taking the clinical features into account with the radiographic pattern might help limit the differential diagnosis of causative pathogens.

Three basic patterns of radiographic abnormality are recognised: lobar (non-segmental) pneumonia; bronchopneumonia (lobular pneumonia); and interstitial pneumonia. These patterns are sufficiently well recognised and are associated with specific causative organisms in sufficient numbers of cases that their recognition is diagnostically useful [13]. The radiographic pattern, however, should be regarded only as a guide. There is great variation in the way that specific organisms can present, and patient factors such as underlying lung disease or immunocompromise might modify the radiological appearances [13].

### *Lobar pneumonia*

The commonest CAP in adults is pneumococcal pneumonia due to *Streptococcus pneumoniae*, accounting for around 40% of cases. This infection is associated with a lobar pattern of opacity on the chest radiograph.

The infection develops in the distal air spaces and spreads via collateral drift to adjacent lung producing a homogeneous pattern involving partial or complete segments of lung and occasionally an entire lobe. Airways are not primarily involved and remain patent, therefore lobar volumes tend to be preserved and air bronchograms might be seen. This process is seen radiographically as a peripheral homogeneous opacity with or without air bronchograms (Figure 1). The lobar volume generally remains unchanged, but can increase [13].

The consolidation is typically basal and solitary, but can affect any lobe. Round pneumonias, although less common than in children, do occur in adults and can mimic lung masses. Parapneumonic effusions are fairly common, empyema less so.

*Legionella pneumophila* is found in 2–25% of adults hospitalised for pneumonia. Imaging at initial presentation can be normal. Commonly there are focal infiltrates that are poorly demarcated [14]. Some studies have demonstrated an alveolar pattern of shadowing in the initial stages in up to 81% of patients, not the classically taught interstitial shadowing [15]. There is initially a unilateral and unifocal infiltrate, although this can be multifocal at presentation. There is then rapid progression of the radiographic appearances with bilateral infiltrates and patchy consolidative changes that progress and become confluent [16]. There is a middle and lower zone predominance [15, 17]. Pleural effusions have been seen in over 50% of patients in some studies. Ground-glass opacification is commonly seen on CT, although the commonest CT appearance is of sharply demarcated peribronchovascular foci of consolidation [18].

Radiographic appearances lag behind the clinical picture in *Legionella* infection and imaging deterioration occurs despite clinical improvement. Long-term follow-up has shown persisting abnormalities several months later: a variety of slowly resolving or permanent abnormalities are seen [19]. Owing to this lack of correlation, imaging severity cannot be used to predict or monitor the clinical severity [14, 20, 21].

*Haemophilus influenzae* is responsible for about 5–20% of CAPs in which an organism can be identified. It is also

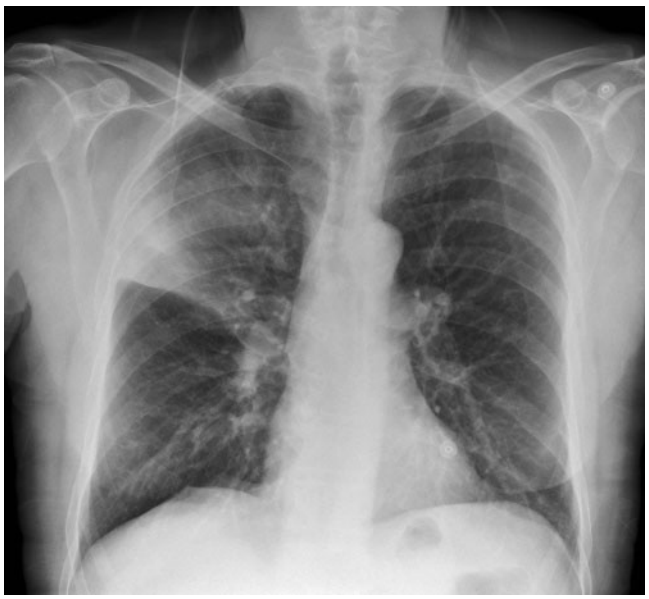


**Figure 1.** Peripheral right upper lobe consolidation in an adult with community-acquired streptococcal pneumonia.

an important cause of nosocomial infection. Radiographically, this type of infection most commonly presents a bronchopneumonia pattern, but less frequently can exhibit non-segmental consolidation similar to streptococcal pneumonia or can display a combination pattern. A reticulonodular interstitial pattern in combination with air-space consolidation occurs in 15–30% of cases.

*Klebsiella pneumoniae* pneumonia is an acute air-space pneumonia that is an uncommon CAP. Typically, *K pneumoniae* causes acute pneumonia in men in their 50s who are chronic alcoholics. Factors that predispose to increased susceptibility in alcoholics include depressed ciliary function, reduced surfactant production, reduced neutrophil migration and impaired macrophage function. Other factors such as malnutrition, aspiration and excessive smoking can also contribute to the increased incidence of pneumonia [22]. The radiographic features of klebsiella pneumonia are essentially the same as for streptococcal pneumonia —– a homogeneous lobar parenchymal consolidation containing air bronchograms. Compared with pneumococcal pneumonia, klebsiella pneumonia has a greater tendency to develop voluminous inflammatory exudates, which leads to lobar expansion with bulging of interlobar fissures, and a greater tendency towards abscess formation [13].

*Chlamydia pneumoniae* pneumonia can produce consolidation. In a comparative series of thin-section CT findings, it was found that chlamydia pneumonia features were similar to those of streptococcal and mycoplasma pneumonia, although airway dilatation and bronchovascular thickening were more common in patients with chlamydia pneumonia [23].

There are many organisms that cause pneumonia in children, but the commonest are the respiratory viruses and *S pneumoniae*. The clinical presentation can suggest the cause: a pyrexia above 38.5°C with tachypnoea and recession is suggestive of a bacterial cause, whereas wheezing, particularly in pre-school children, is suggestive of a viral cause. In the older child, mycoplasma pneumonia is associated with fever, headaches and myalgia, whereas in neonates sticky eyes are associated with chlamydia pneumonia. The majority of children with pneumonia are managed in the community, but those with underlying respiratory or cardiac abnormalities, particularly those less than 2 years old, are more likely to require hospital admission [24].

Recurrent chest infections in children can be associated with conditions such as cystic fibrosis, recurrent aspiration, immunodeficiencies, primary ciliary dyskinesia or underlying lung lesions such as a sequestration, congenital cystic adenomatoid malformation or bronchogenic cyst. Inhaled foreign bodies can also present as recurrent chest infections so it is important in young children to elicit any history of choking, as this might have been related to foreign body inhalation (Figure 2).

Most children never come to hospital with a chest infection, but for those who do present to hospital and require imaging the chest radiograph is the main modality for assessment. Follow-up chest radiographs are not usually required if there is clinical resolution unless there is a specific reason (*e.g.* to check the resolution of a round pneumonia; discussed below). Ultrasound can be useful for assessing parapneumonic effusions and will show septations well. CT with its high radiation dose is reserved for those cases with persistent high pyrexia in whom the pneumonia fails to resolve despite adequate medical treatment, in order to assess complications (Figure 3). Moreover, CT can detect underlying causes such as congenital lung cysts, lymphadenopathy and tumours.

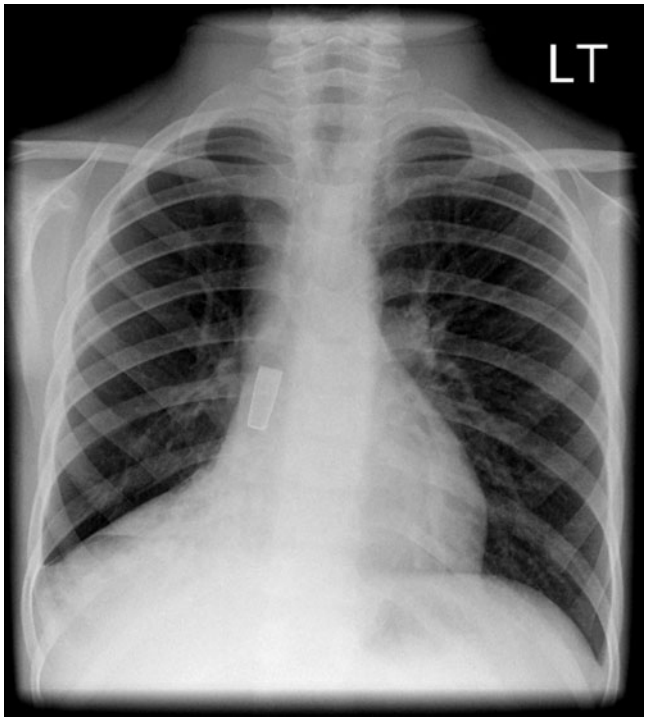


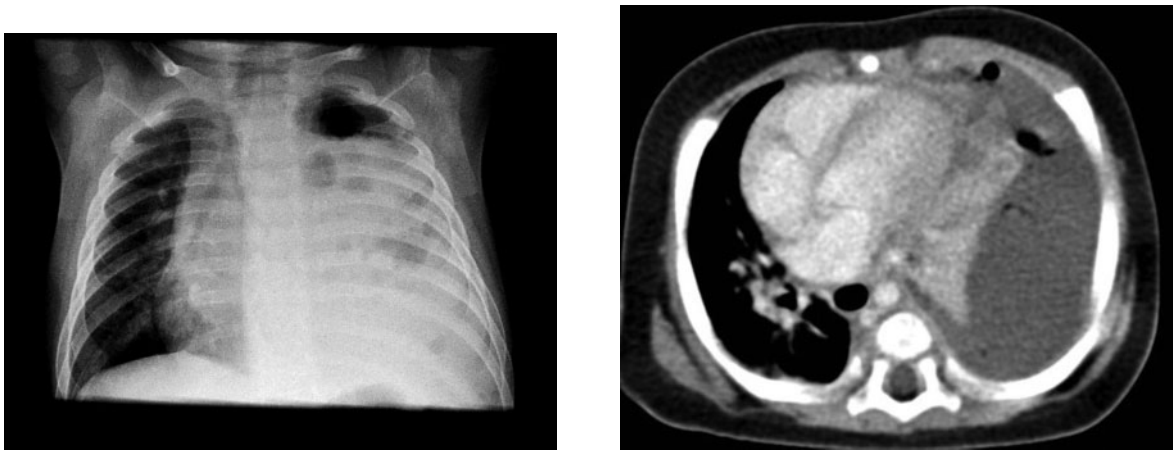

**Figure 2.** Chest radiograph demonstrating a foreign body in the right intermediate bronchus.

Round pneumonia occurs predominantly in younger children and appears as a circular opacity on the chest radiograph, which might mimic a metastasis. For this reason a follow-up radiograph after completion of a course of antibiotics is usually performed to avoid unnecessary investigations in search of a primary tumour. It is usually a solitary lesion and has a predilection for the posterior segments of the lower lobes and the right upper lobe (Figure 4) [25].

Childhood pneumonia owing to *Staphylococcus aureus* is often severe and associated with complications such as empyema, pneumatocoeles and pneumothorax. Since 2002 an even more virulent form of staphylococcal pneumonia has been recognised, associated with the Panton–Valentine leukocidin (PVL) toxin. This toxin causes alveolar haemorrhage and necrosis of the interlobular septa. This form of pneumonia rapidly progresses within a few days from a flu-like illness to a severe pneumonia, with high fever, hypotension, tachycardia, cyanosis, haemoptysis and leucopenia, and carries a high mortality rate. Radiologically there is rapid progression of a complicated pneumonia that might progress to acute respiratory distress syndrome (Figures 5 and 6) [26].

### *Bronchopneumonia*

Bronchopneumoina is commonly caused by aspiration of secretions from a colonised trachea. This pneumonia is typically multifocal and centred in distal airways.



(a) (b)

**Figure 3.** (a) Chest radiograph and (b) CT scan performed on the same day showing a large left effusion with extensive collapse/consolidation in the left lung on the chest radiograph. The CT scan shows the large left empyema with underlying collapse of the left lung. The lingula shows patchy enhancement with contrast suggestive of infarction.

Radiographic opacities are normally heterogeneous and distributed along the course of the airways. The shadowing can become more homogeneous as infection progresses. Air bronchograms are usually absent (Figure 7). Bronchopneumonia is associated with nosocomial or hospital-acquired pneumonia with organisms such as *S aureus* and Gram-negative bacteria [13].

*S aureus* is an uncommon cause of CAP in adults, accounting for around 3% of all cases; however, it is an important cause of nosocomial pneumonia, especially in the intensive care unit. The parenchymal consolidation in acute staphylococcal bronchopneumonia is typically segmental in distribution. Depending on the severity, the process may be patchy or homogeneous, representing confluent bronchopneumonia. Inflammatory exudates fill the airways and segmental atelectasis occurs; air bronchograms are usually absent. Abscesses occur in 15–30% of patients. Pleural effusions occur in 30–50% with around a half representing empyema.

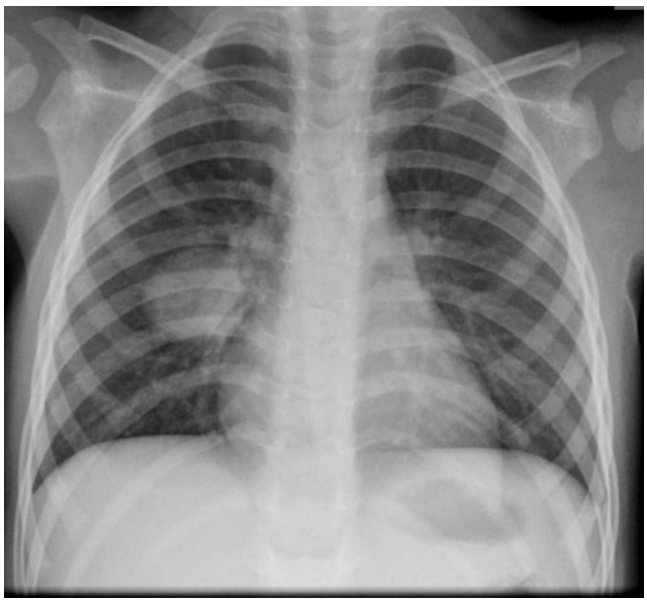


**Figure 4.** Chest radiograph illustrating ''round pneumonia'', which is seen as a circular opacity adjacent to the right hilum.

*Pseudomonas aeruginosa* is the most common and lethal form of nosocomial pulmonary infection. The organism is the cause of approximately 20% of nosocomial pneumonia in adult patients in the intensive care unit. The radiographic manifestations are usually those of bronchopneumonia consisting of multifocal bilateral areas of consolidation (Figure 8) [13].

### *Pneumonia with an interstitial pattern on imaging*

Interstitial pneumonia is most commonly caused by mycoplasma, viruses and (in immunocompromised patients) pneumocystis. The pattern is characterised by oedema and an inflammatory cellular infiltrate situated

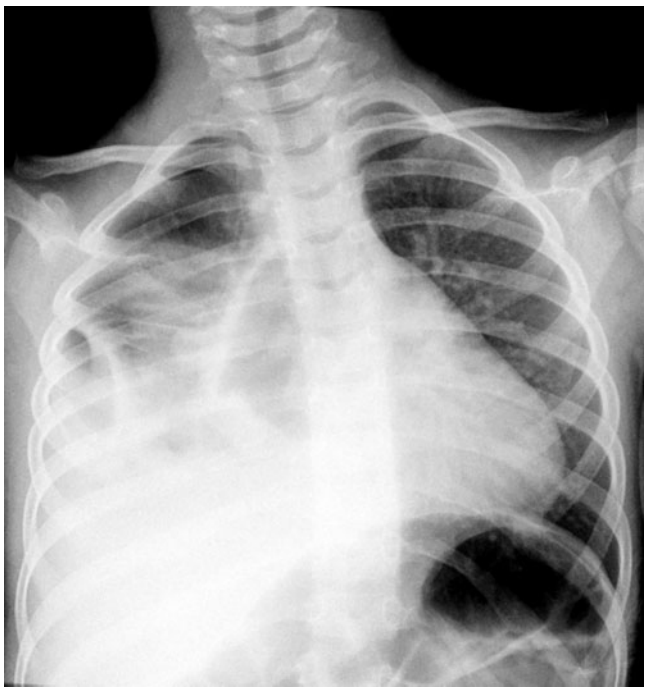


**Figure 5.** Chest radiograph with extensive collapse/consolidation with a loculated pneumothorax in a child with staphylococcal-Panton–Valentine leukocidin pneumonia.

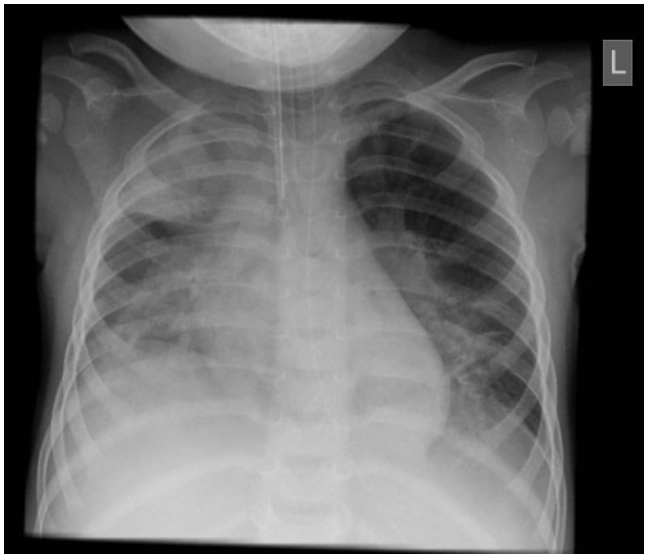



**Figure 6.** Chest radiograph with extensive bilateral consolidation in a child with staphylococcal-Panton–Valentine leukocidin pneumonia.

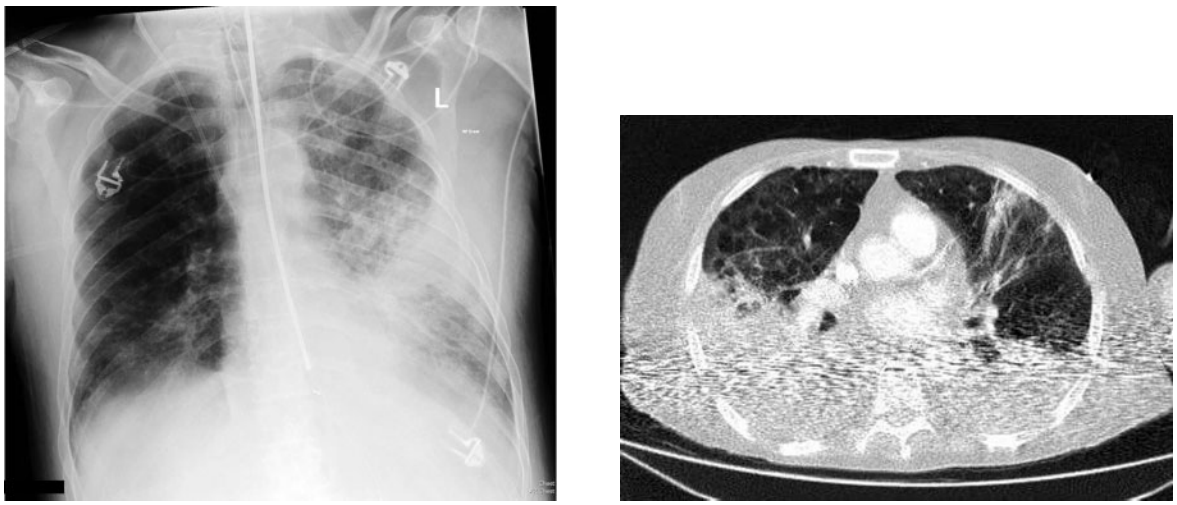
predominantly in the interstitial tissues within the alveolar septa and the peribronchovascular interstitium. The radiographic manifestations of mycoplasma or viral infections consist of a reticular or a reticulonodular pattern [13]. The term atypical pneumonia (which is commonly applied to pulmonary infections such as mycoplasma or viruses) was used to describe infections that did not have the classical clinical and radiographic manifestations of streptococcal pneumonia.

*Mycoplasma pneumoniae* is a common cause of bronchitis and CAP in Western countries [27]. On imaging, appearances are very variable and the most commonly found radiographic abnormality is a bronchopneumonia-type pattern with patchy consolidation [28]. However, several studies state that bronchial wall thickening is the commonest finding, found in over 80% of patients [29, 30]. Other common imaging findings seen on CT are centrilobular nodules [29–31] and ground-glass opacification in a multifocal, centrilobular or peribronchovascular distribution [32] (Figure 9). There is a lower lobe predominance with the lower lobe being affected in 52% of cases [33].

The respiratory viruses account for most chest infections in children and the respiratory syncytial virus causing bronchiolitis is the most important, particularly in children under the age of two. The chest radiograph shows hyperinflation and patchy areas of atelectasis (Figure 10). Superadded bacterial infection can occur. Human metapneumovirus is another important virus causing chest infections in children, again manifesting itself in the winter with a seasonal peak in December in the UK (Figure 11) [34]. This virus also typically presents as bronchiolitis in children less than 1 year of age.

Although more commonly associated with children, viral respiratory tract infections still occur in large numbers of adults with numerous causative viruses. Viral lower respiratory tract infections can manifest in several ways including tracheobronchitis, bronchiolitis and pneumonia. There are no radiological manifestations of note in tracheobronchitis [35]. Bronchiolitis leads to partial airway obstruction with hyperinflation and nodular opacities. Nodules predominate in all forms of viral pneumonia with nodular infiltrates of between 1 and 20 mm [36]. Other common findings are diffuse ground-glass attenuation, which is commonly seen on CT, focal areas of consolidation as the pneumonia progresses and small pleural effusions.

More than half the viral pneumonias in adults are found to be caused by influenza virus types A and B [37]. Primary viral pneumonia typically occurs after the onset of classical influenza symptoms with rapid deterioration [38]. The chest radiograph can show ground-glass opacity or linear shadowing [39]. As the disease progresses, patchy consolidation can appear on the radiograph which becomes confluent over time with nodular opacities also seen. On CT, consolidation and ground-glass attenuation with centrilobular nodules characteristically occur [40] (Figure 12). Avian flu (H5N1 strain)




(a) (b)

**Figure 7.** (a) Chest radiograph showing left lower zone bronchopneumonia in a hospitalised patient. (b) The corresponding CT image demonstrates bilateral basal consolidation. Note the lack of air bronchograms on both the CT and chest radiograph images.

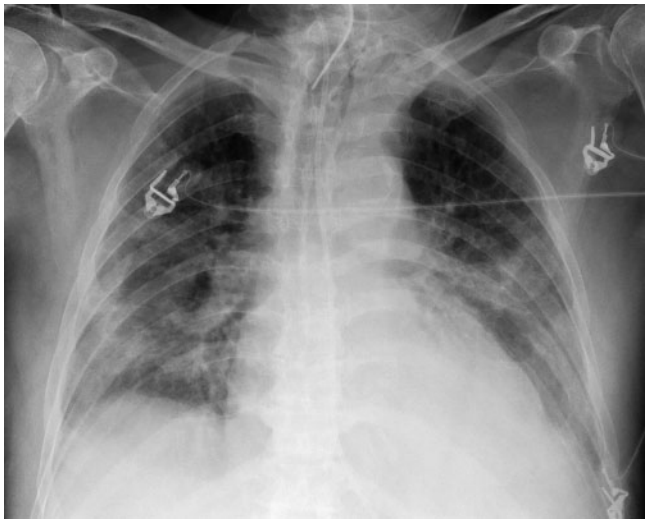


**Figure 8.** Chest radiograph of an intensive care patient showing bilateral patchy consolidation owing to a hospital-acquired infection. The presence of pseudomonas was confirmed on sputum culture.

causes extensive infiltration which is multifocal with a lower zone predominance [41].

In 2003 an outbreak of viral pneumonia defined by the World Health Organization as severe acute respiratory syndrome (SARS) originated in Hong Kong. This was associated with mainly peripheral air-space opacity with progression from unifocal to multifocal and bilateral shadowing on chest radiography [42]. Initial fears that the 2009 swine variant H1N1 influenza A pandemic would have similar clinical features to SARS have proved unfounded, although severe illness in children is more common with swine flu than with previous seasonal influenza A [43]. Bacterial superinfection is a common occurrence in influenza cases and this has also been observed in H1N1 swine flu [44]. One report on findings in children with H1N1 influenza A has found that chest radiographs in children with a mild and self-limited course of swine-origin influenza A (H1N1) are often normal, but they can demonstrate prominent peribronchial markings with hyperinflation. Bilateral, symmetrical and multifocal areas of consolidation, often associated with ground-glass opacities, are the predominant radiographic findings in children with a more severe clinical course of H1N1 infection [45].

Adult infection with varicella is more severe than childhood infection and more likely to have serious sequelae, with pneumonia being one such outcome [46]. On the chest radiograph, multiple nodular shadows ranging from 1 to 20 mm in diameter have been reported [36, 47] with a surrounding halo of ground-glass opacification. A predominantly basal nodular infiltrate can be seen and pleural effusions have been reported [46, 48].

### *Tuberculosis*

A detailed account of the manifestation of tuberculosis (TB) is beyond the scope of this article, but briefly TB occurs in two broad categories: primary and post-primary. Primary pulmonary TB occurs in previously uninfected individuals and, although the focus on lung involvement or ''Ghon focus'' might have no radiographic manifestations, this phase can be associated with parenchymal consolidation, lymphadenopathy or pleural effusion. Post-primary or reactivation TB has a wide range of imaging manifestations including air-space consolidation, cavitation, focal nodular opacities, endobronchial spread and military disease with multiple small pulmonary nodules [13].

## Complications of pneumonia

### *Empyema and parapneumonic effusion*

A parapneumonic effusion is an effusion arising secondary to a pneumonia. Empyema occurs when the parenchymal infection spreads to the pleural cavity.

As there is a significant morbidity associated with empyema and a necessity for external drainage, the role

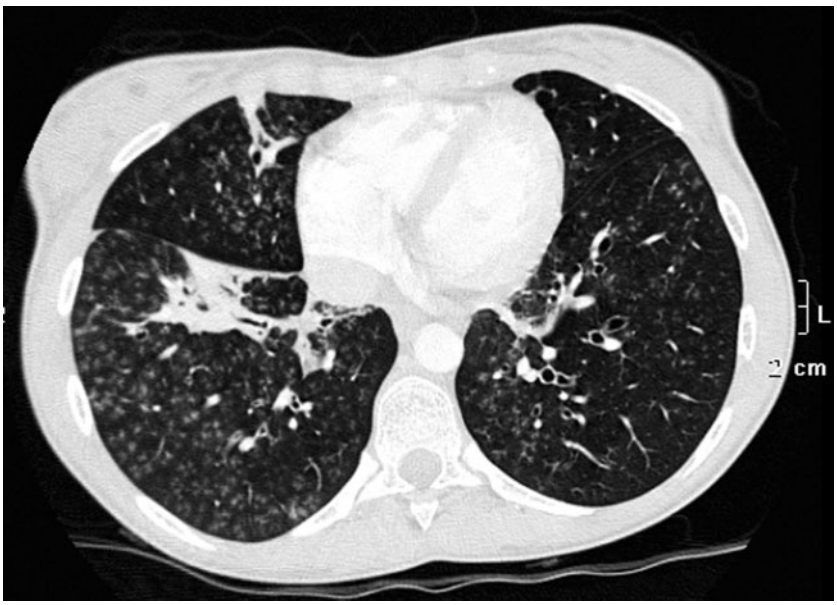



**Figure 9.** CT image with a centrilobular nodular pattern from a patient with *Mycoplasma pneumoniae* infection in the right lower lobe.

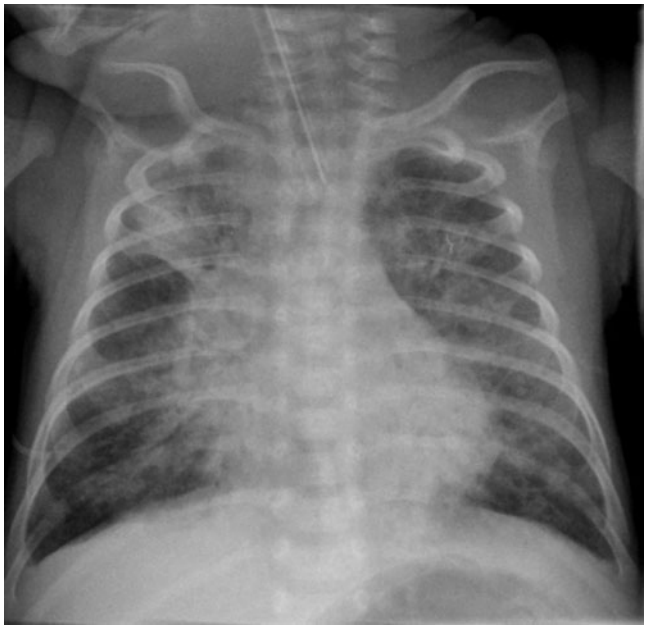


**Figure 10.** Chest radiograph showing hyperinflation with bilateral infiltrates in a child with bronchiolitis.

of radiology is increasing in both its diagnosis and treatment [49].

Pleural effusions can be classified into uncomplicated and complicated [50, 51]. Effusions such as simple parapneumonic effusions that will resolve with treatment of the pneumonia are uncomplicated. Complicated effusions are those that will not resolve without drainage. These include large, uniloculated or multiloculated parapneumonic effusions, empyema as well as non-infectious effusions such as those owing to malignant disease and traumatic haemorrhage. Drainage of

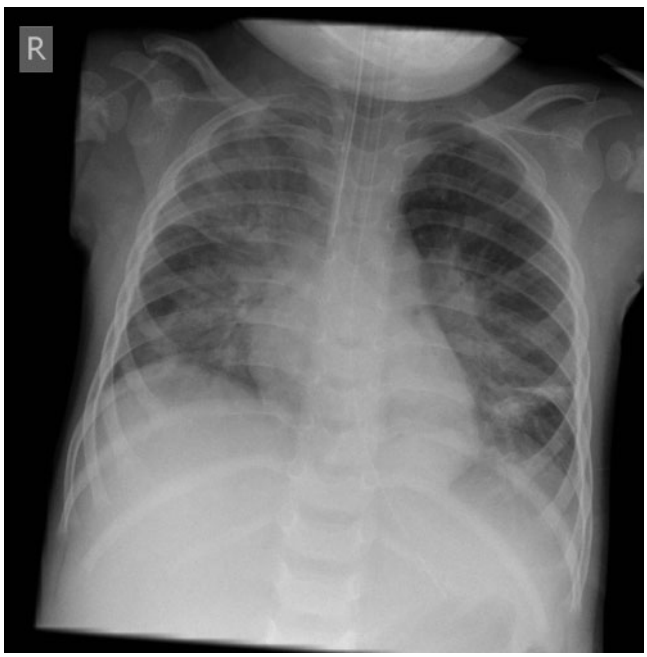



**Figure 11.** Bilateral infiltrates and ground-glass opacity on the chest radiograph of a child with human metapneumovirus infection.

complicated pleural effusions is necessary to limit pleural sepsis, allow re-expansion of the underlying lung and to prevent long-term sequelae such as pleural fibrosis and lung entrapment [50].

The evolution of a parapneumonic effusion can be divided into three stages that represent a continuous spectrum. The first is the exudative phase where there is a parapneumonic effusion with rapid outpouring of fluid into the pleural space. If the pneumonia is not successfully treated then the effusion may evolve into the second stage, the fibropurulent stage. In this stage the pleural fluid becomes infected and progressively loculated. If a second stage effusion is not drained, the effusion can progress to the third stage in which fibroblasts grow into the pleural fluid from both the visceral and parietal pleura producing a thick pleural peel. Because the pleural space must be eradicated if a pleural infection is to be eliminated, this peel must be removed if the infection is to be cured [51].

A wide range of interventional procedures is available for drainage of complicated effusions. These include single or repeated thoracocentesis, closed-tube thoracostomy drainage, thoracoscopy and formal thoracotomy with either decortication or open drainage. The most common method of treatment is a trial of closed-tube thoracostomy drainage followed by surgical drainage if unsuccessful. Many surgeons advocate either a short trial of tube drainage or even surgery as a first option, as ineffective tube drainage can make subsequent surgery technically more difficult [50].

Image-guided placement of thoracostomy tubes avoids the complications of misplacement of a tube. Radiologists tend to use narrower gauge tubes (8–16 French) than those used for non-guided thoracostomy (22–34 French). These narrower bore catheters are better tolerated by patients but are more prone to occlusion from fibrinous debris. Stage 3 effusions are not normally treated successfully by tube drainage and usually require a surgical approach.

Ultrasound can confirm the presence of the effusion and can be used to assess its character and guide drain placement. Pleural effusions with complex septated, complex non-septated or homogeneously echogenic patterns on ultrasound are always exudates, whereas hypoechoic effusions can be either transudates or exudates even when purulent. Most parapneumonic effusions and empyemas are septated on ultrasound [52].

CT is not required in the majority of patients with a parapneumonic effusion or empyema. Septations within the effusion are less readily seen on CT than ultrasound, although gas within separate pockets within an effusion suggests that they are present. Contrast enhancement should be used with imaging performed at 60 s to allow maximum tissue enhancement [52].

CT appearances are dependent on the pathophysiological stage of the empyema. In the initial, exudative stage, there is increased capillary permeability resulting in pleural fluid without significant pleural thickening [53]. The second, or fibropurulent, stage, results in fibrin deposition on the pleural surface. On CT at this stage, the visceral and parietal pleura usually appear thickened and are separated by fluid, the so-called ''split pleura sign'' [54], which has been shown to be present in up to 68% of empyema patients [55] (Figure 13). At this stage

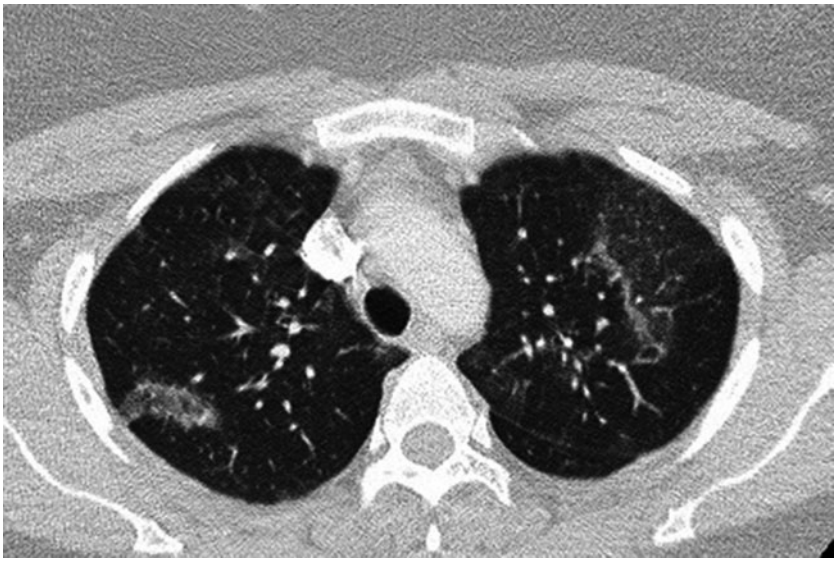


**Figure 12.** CT image demonstrating patchy ground-glass opacity in a patient with influenza viral infection with pulmonary involvement.

pleural enhancement is usually evident on contrast-enhanced CT.

In the third stage, pleural fibrosis occurs. Lung trapping can occur at this stage owing to the exuberant fibrotic reaction, and extensive pleural thickening might be apparent on imaging. In addition to the above findings, prominence of the extrapleural fat has been noted in up to 76% of patients with proven empyema [56]. Other features possibly present on CT are air-fluid levels and pleural microbubbles [57].

As yet, no imaging findings of empyema have been shown to accurately correlate with the development stage or clinical severity of the empyema [57, 58].

Another possible associated finding is thoracic lymphadenopathy. This condition is commonly associated with parapneumonic effusions and empyema, being seen in up to 36% of patients [58]. Other pathologies should also be considered if significant thoracic lymphadenopathy is apparent.

Intrapleural fibrinolysis using streptokinase has been used in an attempt to improve clinical outcomes in cases of parapneumonic effusion and empyema. However, a large randomised controlled trial found that there was no evidence of a reduced need for surgical drainage, mortality or length of hospital stay after the administration of streptokinase [59]. Work is ongoing to see if selected clinical subgroups will benefit from intrapleural streptokinase or if combining streptokinase with other agents such as deoxyribonuclease will be of any benefit [60].

### *Lung abscess*

Lung abscesses can occur secondary to pneumonia or to a retained foreign body, the latter being more common in children.

It can be difficult to differentiate between an empyema and a lung abscess on imaging. A lung abscess is characteristically seen on CT as a thick-walled, spherical cavity with adjacent lung destruction (Figure 14). Surrounding consolidation might be seen with air bronchograms tracking into the area, as opposed to being displaced [53].

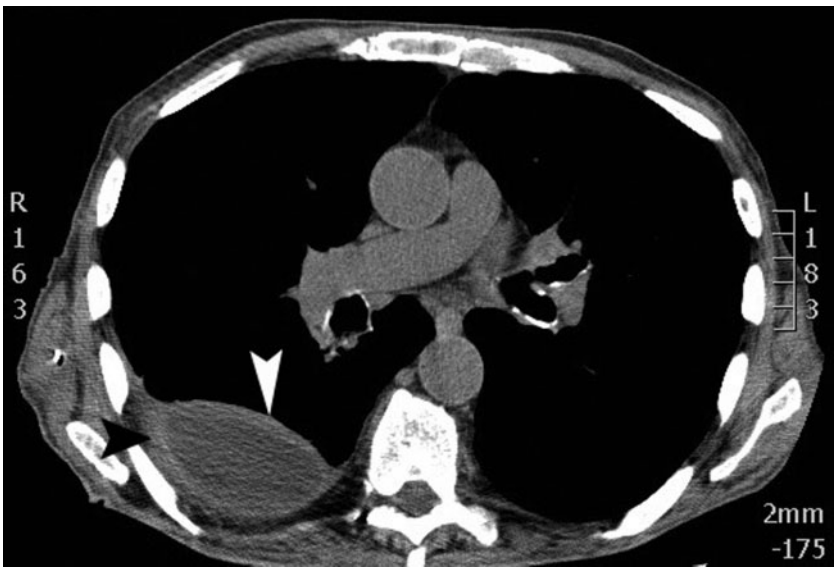



**Figure 13.** CT image demonstrating thickening and enhancement of the parietal pleura (black arrowhead) and visceral pleura (white arrowhead) with fluid in between — the so-called ''split pleura sign''.

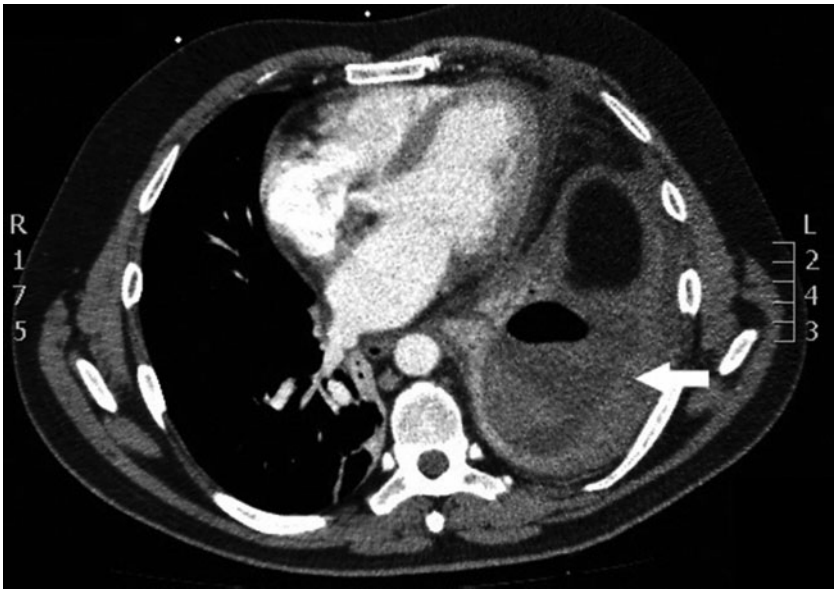



**Figure 14.** CT image of a lung abscess with a thick, enhancing wall and an air fluid level within (arrow).

Lung abscesses also tend to make an acute angle with the pleura compared with the obtuse angle that is characteristic of an empyema [55]. As with empyema, an air–fluid level might be apparent.

Medical therapy (systemic antibiotics and physiotherapy with postural drainage) is the initial treatment of choice for lung abscess and is curative in most patients. Lung abscesses in children under 7 years often do not drain spontaneously and are less likely to respond to medical treatment. Surgical or percutaneous drainage is likely to be required in the 11–21% of patients with a lung abscess who do not respond to medical treatment [61].

Percutaneous drainage can successfully treat lung abscesses. In one series, all 19 patients treated with lung abscess drainage under CT guidance were cured [62]. Complications included tube blockage and haemothorax. The haemothorax occurred in one of two patients in whom the catheter traversed normal lung, and the authors concluded that a catheter drainage route through an abscess–pleural syndesis is preferable. A systematic review of percutaneous lung abscess drainage concluded that the procedure was safe; complications overall occurred in 9.7% of cases and these included catheter occlusion, chest pain, pneumothorax and haemothorax [62].

Ultrasound has been shown to be of value in both aspirating fluid for microbiological assessment and guiding catheter drainage in cases of lung abscess; the authors concluded that both aspiration and drainage were safe procedures [63]. In this series 71% of the abscesses abutted the parietal pleura. Another series found a good diagnostic yield in terms of allowing a microbiological diagnosis using fluoroscopic guidance and aspiration with a spinal needle — cultures were positive in 40 of 49 (82%) cases [64]. The complication rate was low with 7 cases (14%) developing a pneumothorax.

In summary, most patients with a lung abscess will respond to medical therapy. For those patients who do not respond, the options will rest between surgical management of the abscess and percutaneous catheter drainage. Catheter drainage should be considered particularly in those patients who are unfit for a thoracic surgical procedure, in whom the abscess abuts the pleural surface and the possible complications from traversing normal lung parenchyma with a catheter can be avoided. The approach should be multidisciplinary with early involvement of the thoracic surgical service if the development of a lung abscess is suspected.

## The role of imaging in diagnosis and follow-up

The majority of cases of CAP are managed by general practitioners in a pragmatic fashion. Various prediction rules have been published for the diagnosis of CAP, but most have shown the need for confirmatory radiographic evidence. In one large study, the presence of fever, raised respiratory rate, sputum production throughout the day, myalgia and night sweats, and the absence of sore throat and rhinorrhoea were the only clinical features that predicted CAP when used in a diagnostic algorithm [65]. British Thoracic Society (BTS) 2009 Pneumonia guidelines indicate that it is only necessary to perform a chest radiograph in patients with suspected CAP if one of three criteria apply: the diagnosis is in doubt and a chest radiograph will assist in the differential diagnosis; progress for treatment of CAP is not satisfactory; or the patient is considered at risk of underlying pathology such as lung cancer [66]. All patients admitted to hospital with suspected CAP should have a chest radiograph performed as soon as possible to confirm or refute the diagnosis [66].

Mimics of pneumonia on the chest radiograph include conditions such as cryptogenic organising pneumonia, eosinophilic pneumonia and pulmonary vasculitis [67]. Aspiration pneumonia can give rise to multifocal consolidation affecting primarily the dependent portions of the lungs and, in particular, the posterior segments of the upper lobes and apical segments of the lower lobes.

Chest radiographs have been shown to be of little value in predicting the causative pathogen, but are of use

in determining the extent of pneumonia and in detecting complications such as parapneumonic effusions [68].

Radiographic changes resolve slowly after pneumonia and lag behind clinical recovery. This is particularly so in the case of *Legionella* and bacteraemic pneumococcal infection. Pneumonia caused by atypical pathogens clears more quickly than pneumonia caused by the bacterial pathogens associated with classical lobar pneumonia. Radiological resolution is slower in elderly patients and when there is multilobar involvement. It has been suggested that in elderly patients a waiting period of 12–14 weeks is appropriate for a slowly resolving pneumonia to be considered non-resolving [69].

It is common practice to repeat the chest radiograph 6 weeks after the initial presentation; however, there is no evidence to support this practice in patients who are otherwise recovering satisfactorily. A major concern is whether the CAP is a complication of an underlying condition such as lung cancer. Latest guidelines therefore recommend a repeat chest radiograph after 6 weeks for all those patients who have persistence of symptoms, physical signs or who are at higher risk of underlying malignancy (especially smokers and those aged over 50 years, whether or not they have been admitted to hospital) [66].

CT scanning currently has no routine role in the investigation of CAP; however, it is a useful adjunct to the plain radiograph in selected cases. CT is more sensitive in the detection of pneumonia. Hayden and Wrenn [70] found that in 27% of patients who had a chest radiograph and CT scan, pneumonia was demonstrated on the CT scan in the face of a negative or non-diagnostic chest radiograph. In the intensive care setting, the interpretational difficulty with plain films frequently limits their accuracy as a diagnostic tool. CT, with its excellent contrast resolution, is the most sensitive modality for evaluating lung parenchymal infections [71]. In the emergency department setting, a large series of patients with chest radiographic findings of pneumonia also underwent CT examination and CT was found to be useful in guiding therapy or providing an alternative diagnosis [72]. CT, however, is little better than the chest radiograph in helping to determine the aetiology of the infection. Reittner et al [73] found that, with the exceptions of *Pneumocystis carinii* pneumonia and *M pneumoniae* pneumonia, CT was of little value in the differential diagnosis of the various types of infective pneumonia.

The only definitive way to reach a specific diagnosis is through demonstration of the infecting organism by microscopic or molecular examination of stained smears of sputum, pleural fluid or other biological material, or by culture of respiratory secretions or blood [74]. Bronchoscopy with bronchoalveolar lavage is the most commonly utilised procedure for obtaining fluid for culture. CT can guide to the segments most likely to yield diagnostic washings. Although not commonly practiced in the UK, image-guided percutaneous aspiration or biopsy provides another means of obtaining material for microbiological examination. One study found that core-needle biopsy gave a higher diagnostic yield than fine-needle aspiration; the former gave the diagnosis in 42 out of 48 patients [75].

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