Alveolar lung diseases (ALD) are a group of disorders characterized by pathological insult involving mainly the alveoli. The alveoli can be imagined as an empty cup, and alveolar diseases are classified according to the content of this cup. Alveolar diseases are characterized by filling of the alveoli with materials that impede its normal physiological function (ventilation). Alveolar diseases can be localized (focal) or diffuse. Names of the conditions depend upon the content of the material filling the alveoli.

### Types of Alveolar Lung Diseases

- **Alveoli filled with serous fluid**: cardiogenic and non-cardiogenic edema.
- **Alveoli filled with blood**: pulmonary hemorrhage, commonly due to vasculitis (e.g., Churge-Strauss syndrome).
- **Alveoli filled with pus**: pneumonia.
- **Alveoli filled with proteins**: alveolar proteinosis and amyloidosis.
- **Alveoli filled with malignant cells**: bronchoalveolar carcinoma.
- **Alveoli filled with calcium**: alveolar microlithiasis.

### Pulmonary Edema

Pulmonary edema can be either due to cardiac disease (cardiogenic), or other conditions (noncardiogenic). Most cases of noncardiogenic pulmonary edema are due to acute respiratory distress syndrome (ARDS).

Cardiogenic pulmonary edema is commonly seen with heart failure. It starts as an interstitial edema before it turns into alveolar edema, because the pulmonary veins lie in the interstitium. As the hydrostatic pressure within the veins rises, they leak into the interstitium first, and then progress to fill the alveoli. This process is rapid, and only very early edema can be seen as a pure interstitial linear pattern in chest radiographs.

Noncardiogenic Pulmonary edema has the same radiographic features as the cardiogenic pulmonary edema, but the causes are different: ARDS, chemical pneumonitis, drug-induced pulmonary edema, and transfusion-reaction are the most common causes for noncardiogenic pulmonary edema. ARDS is a situation where an alveolar capillary injury occurs as a result of variety of causes (e.g., sepsis). Chemical pneumonitis is a pulmonary edema that occurs due to inhalation of noxious chemical substance such as ammonia, smoking inhalation, near drowning situations, and gastric acid aspiration. The mechanism of pulmonary edema is the result of one of three mechanisms: irritation of the tracheo–bronchial tree that leads to inflammation and pulmonary edema formation; absorption of the noxious material from the respiratory tract, which can affect the lungs directly by its metabolites; and asphyxiation due to inhalation of high concentration of the noxious material that will displace oxygen from the blood and cause tissue hypoxia. Drug-induced and transfusion reactions pulmonary edema arise due to anaphylactic lupus-like reaction formation. The radiographic picture cannot be differentiated from ARDS unless you have history of drug ingestion or recent transfusion reaction. Classic examples of drugs causing pulmonary edema are heroin, aspirin, and penicillin. Negative pressure pulmonary edema is a term used to describe noncardiogenic edema that arises due to acute airway obstruction (type 1), or after the relief of chronic airway obstruction (type 2).
Signs on Radiograph

- There is a centrally-located, bilateral, symmetrical diffuse alveolar opacities emitting from the hilum and spares the periphery (butterfly or bat-wings sign) (Fig. 3.2.1). Usually, pulmonary edema causes homogenous opacities, but sometimes they can cause nodular or blotchy opacities.
- Cardiomegaly and signs of congestive heart failure (e.g., congested pulmonary vessels).
- Kerley lines: they represent thickening of the interlobar septae. Lung lymphatics and veins run in the interstitium, leakage of the veins (edema) or tumor infiltration of the lymphatics (lymphangitis carcinomatosis) can result in thickening of the interlobar septa, which are called Kerley lines. Kerley A lines are long lines located near the lung hilum and extend obliquely near the bronchoarterial bundle into the peripheries. Kerley B lines are short white lines seen perpendicular to the pleural surface at the lung bases, commonly near the costophrenic angles (Fig. 3.2.2). Kerley C lines are a mixture between the two lines resulting in a reticular pattern.
- Air-bronchogram sign: this is a sign seen when the alveoli are filled with fluid and the terminal bronchioles and bronchi are devoid of fluid (filled with air). The bronchioles appear as radiolucent lines within whitish radio-opaque opacities (Fig. 3.2.3). This sign is specific for alveolar disease, but nonspecific for the cause. Pulmonary edema, pulmonary hemorrhage, pneumonia, and alveolar carcinoma all look the same on radiographs. All appears as ALD with air-bronchogram. The medical history plays a very important role in differentiating these conditions because the radiographic signs can be nonspecific.
- Blood diversion: normally, the upper lobe vessels are not visualized on radiographs, and the lower lobes vessels are mildly dilated and visible due to the gravity effect in upright posteroanterior (PA) radiographs. In cases of cardiac diseases and pulmonary hypertension, the upper lobe vessels will be as wide as the lower lobe vessels in upright radiographs. Note that the upper lobe vessels can be seen dilated normally in supine (lying) chest radiographs (e.g., in intensive care unit radiographs).
- Silhouette sign: this sign refers to a patchy, ill-defined radio-opaque shadow that obscures part of the normal mediastinal configuration.

Fig. 3.2.1. Anteroposterior plain chest radiographs in two different patients show bilateral symmetrical pulmonary edema with bat wings appearance in (a), and bilateral, almost symmetrical pulmonary hemorrhage in (b). Notice that without history, you cannot differentiate pulmonary hemorrhage from pulmonary edema based on radiographic presentation alone.
How to differentiate between cardiogenic edema from ARDS on plain chest radiographs?

- ARDS usually has a normal heart size, while cardiogenic pulmonary edema shows signs of heart failure.
- ARDS usually affects peripheral lung field more than central, whereas cardiogenic edema typically starts from the center to the periphery.
- ARDS usually has no Kerley B lines.

Pneumonia

Pneumonia is a condition characterized by an infectious inflammation of the lung parenchyma and deposition of pus within the alveoli. Pneumonia can be caused by bacteria (e.g., Methicillin-resistant Staphylococcus aureus (MRSA)), fungi (e.g., pneumocystis cainii), and viruses (e.g., cytomegalovirus (CMV)).

Patients with pneumonia present with dyspnea, purulent sputum, fever, tachycardia, and maybe hemoptysis (e.g., tuberculosis). Complications of pneumonia include lung abscess formation, septicemia, and empyema. Rarely, arthritis and neurological symptoms may be encountered in atypical pneumonias (e.g., Mycoplasma pneumonia).

Pneumonias are divided into “typical pneumonia,” which is caused by Streptococcus pneumoniae (pneumococcus), and “atypical pneumonia,” which is caused by any pathogen that is not pneumococcus. Typical pneumonia is clinically dominated by respiratory symptoms, whereas atypical pneumonia clinically is dominated by symptoms of fever and malaise more than the respiratory symptoms.

Types of Pneumonias

- **Air-space pneumonia** (lobar pneumonia): in this type, the infection is confined to a single lobe. There is usually one patch filling the whole affected lobe. This type is seen with pneumococcus, Legionella, pseudomonas, and primary tuberculosis infection. Lobar pneumonia is characterized by an “air-bronchogram sign”.
- **Bronchopneumonia**: this type is characterized by an infection that starts in the bronchioles and small bronchi walls and then spread to the alveoli. This type is seen with Staphylococcus aureus, Hemophilus influenza, and Mycoplasma pneumonias.
- **Interstitial pneumonia**: this type is characterized by an infection that involves the interstitial septa and giving reticular interstitial pattern on chest radiograph. This type can be seen with viral infections like influenza virus and Varicella-zoster virus (VZV), and Mycoplasma infections (30% of cases).

MRSA is a serious infection with antibiotic-resistant staphylococci. MRSA is categorized as: community-acquired, nosocomial, and health care-associated infection. MRSA is the leading cause of nosocomial and health care-associated blood stream infection, globally. Also, it is responsible for 30–50% of ventilator-associated pneumonia. MRSA causes metastatic foci of infections in 30% of cases into the lungs, liver, kidneys, heart valves, and joints. Most community-associated MRSA strains carry the Panton-Valentine Leukocidin (PVL) gene, which is rarely found in the hospital-acquired MRSA or the normal strain of S. aureus. PVL toxin is a potent lethal factor to neutrophils, which causes tissue necrosis and severe necrotizing pneumonia. MRSA pneumonia is more frequently associated with sepsis, high-grade fever, hemoptysis, pleural...
effusion, and death compared to PVL-negative *S. aureus*. MRSA pneumonia can result in the formation of pulmonary cavitary infiltration due to the development of necrotizing pneumonia. The development of MRSA necrotizing pneumonia should be suspected in a young patient presenting with hypoxia, hemoptysis, and single or multiple cavitary lung lesions.

Viral pneumonias are characterized by several pathologies that include bronchiolitis, tracheobronchitis, and classical pneumonia. Viruses that attack immunocompetent patients include influenza viruses, Epstein–Barr virus, and adenoviruses. Viruses that attack immunocompromised patients include measles virus, VZV, and CMV. Measles virus attack usually children due to immunosuppression or vaccine failure. VZV pneumonia is a common complication of VZV septicaemia in children with a mortality rate of 9–50%. Up to 90% of VZV pneumonia cases are seen in patients with lymphoma or immunosuppression. CMV pneumonia is commonly seen in transplant patients and immunocompromised patients. Patients may develop severe necrotizing pneumonia in spite of antiviral therapy.

### Differential Diagnoses and Related Diseases

**Hyperimmunoglobulinemia E syndrome (Job’s syndrome):** is a rare condition characterized by marked elevation of serum IgE levels against *S. aureus* resulting in decreased production of anti-staphylococcus IgG. The patient with this syndrome presents with frequent attacks of *S. aureus* pneumonia, pustular dermatitis, eczema, and sinusitis. Formation of chronic lung abscesses is a common feature on radiographs.

---

**Signs on Radiograph**

- Radio-opaque patches with an air-bronchogram sign (Fig. 3.2.3).
- Bulging-fissure sign: some infections will increase the volume of the lobe involved causing the adjacent fissure to bulge (commonly the transverse fissure) (Fig. 3.2.4). This sign is classically seen in Klebsella pneumonia.
- Bronchopneumonia: there is multiple patchy infiltration of the lung with or without segmental lobe atelectasis (if the bronchus is totally obstructed). (Fig. 3.2.3)
- Interstitial Pneumonia: shows nonspecific linear or reticular interstitial lung pattern. Correlation with history and laboratory findings is essential to establish the diagnosis.
- Viral pneumonias can appear as poorly-defined nodules (4–10 mm in diameter), with lung hyperinflation due to bronchiolitis.
- Measles pneumonia show mix pattern of reticular interstitial pattern with patchy pneumonia (Fig. 3.2.5). Hilar lymphadenopathy may be associated.
- VZV pneumonia appears as multiple, ill-defined micronodules (5–10 mm) (Fig. 3.2.6). The lesions may calcify persisting as well-defined, randomly scattered, dense pulmonary calcification.
- CMV pneumonia is commonly seen as a mixed nodular interstitial pattern with ill-defined patchy lung infiltration. The patchy filling is caused pathologically by hemorrhage, neutrophilic and fibrinous exudates, and hyaline membrane formation (Fig. 3.2.7).
- Chronic pneumonia can lead to fibrosis, traction bronchiectasis, and paracicatricial emphysema (Fig. 3.2.8).
- In MRSA necrotizing pneumonia, a pneumonic patch or a pulmonary mass with central cavitary lesion can be found. The lesion can be single, or multi-focal. The same manifestations are observed in HRCT. Differential diagnoses of cavitary lung infiltrations include lung abscess, metastases, pulmonary lymphoma, and Wegner’s granulomatosis.

---

**Fig. 3.2.3.** Posteroanterior plain chest radiographs in two different patients with pneumonia show pneumonic lung patch with air columns within the patchy due to unaffected bronchi in (a) (arrowhead), and pneumonic lung patch with no air-bronchogram sign in (b). Patient (a) presents with air-space pneumonia, whereas patient (b) presents with bronchopneumonia.
3.2 Alveolar Lung Diseases

Fig. 3.2.4. Anteroposterior plain chest radiograph of a bedridden patient shows right upper lobe pneumonia with bulging of the transverse fissure (arrowhead)

Fig. 3.2.5. Posteroanterior plain chest radiograph of a 5-year-old child with measles presenting with dyspnea shows ill-defined patchy pneumonia in the upper zone of the left lung (arrowhead)

Fig. 3.2.6. Posteroanterior plain chest radiograph of a patient with Varicella-zoster virus (VZV) pneumonia shows diffuse micronodular interstitial lung pattern bilaterally

Fig. 3.2.7. Posteroanterior plain chest radiograph of a patient with cytomegalovirus (CMV) pneumonia after heart transplant shows mixed patchy lung infiltration with micronodular interstitial lung pattern
For Further Reading

1. Gattinoni L et al. The role of CT-scan studies for the diagnosis and therapy of acute respiratory distress syndrome. Clin Chest Med. 2006;27:559–70
2. Fujinaga S et al. Pulmonary edema in a boy with biopsy-proven poststreptococcal glomerulonephritis without urinary abnormalities. Pediatr Nephrol. 2007;22:154–55
3. Kawamata M et al. Acute pulmonary edema associated with transfusion of packed red blood cells. Intensive Care Med. 1995;21:443–46
4. Chuang YC et al. Negative pressure pulmonary edema: report of three cases and review of the literature. Eur Arch Otorhinolaryngol. 2007;264:1113–16
5. Kim EA et al. Viral pneumonias in adults: radiologic and pathologic findings. RadioGraphics. 2002;22:S137–S149
6. Anuradha G. Methicillin-resistant *Staphylococcus aureus* bacteremia and pneumonia. Dis Mon. 2008;54:787–92
7. Corriere MD et al. MRSA: an evolving pathogen. Dis Mon. 2008;54:751–55
8. Decker CF. Pathogenesis of MRSA infection. Dis Mon. 2008;54:774–79
9. Ebert MD et al. Necrotizing pneumonia caused by community-acquired methicillin-resistant *Staphylococcus aureus*: an increasing cause of “mayhem in the lung”. Emerg Radiol. 2009;16:159–62
10. Connolly B et al. Bronchial artery aneurysm in hyperimmunoglobulinemia E syndrome. Pediatr Radiol. 1994;24:592–93

**Fig. 3.2.8.** Posteroanterior plain chest radiograph of a patient with mycoplasma pneumonia shows right upper lobe fibrosis with honeycombing due to traction bronchiectasis (*arrow*) and paracicatricial emphysema (*arrowheads*)