Unilateral Pulmonary Edema: Clinical Scenarios and Differential Diagnosis

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After participating in this activity, the radiologist should be better able to describe the basic pathophysiology and characteristic imaging features of pulmonary edema, identify etiologies of unilateral pulmonary edema on the basis of an understanding of the underlying pathogenesis and clinical context, and identify entities that may mimic unilateral pulmonary edema.

Key Words: Unilateral Pulmonary Edema, Ipsilateral Pulmonary Edema, Contralateral Pulmonary Edema

Pulmonary edema is one of the most commonly encountered pathologic processes in chest radiology. Although pulmonary edema has classically a bilateral and symmetric distribution, unilateral pulmonary edema is less common and may be confused easily with pneumonia. Familiarity with the causes of unilateral pulmonary edema is important for correct diagnosis and patient management.

Pathophysiology and Classification of Pulmonary Edema

Pulmonary edema is defined as abnormal accumulation of liquid in the extravascular lung compartments. Distribution of liquid in the intravascular and extravascular compartments is determined by net liquid movement across the capillary membrane.

Pulmonary edema may be classified into four types on the basis of the mechanism: hydrostatic pressure edema, permeability edema with diffuse alveolar damage, permeability edema without diffuse alveolar damage, and mixed edema.

The mechanism of hydrostatic pressure edema is increased intravascular hydrostatic pressure relative to extravascular hydrostatic pressure, which will drive liquid into the extravascular space. Examples of hydrostatic pressure edema include left ventricular failure, volume overload, and renal failure. Clinically, intravascular hydrostatic pressure of the pulmonary capillaries is deduced from measurement of pulmonary capillary wedge pressure (PCWP). PCWP of 15 to 20 mm Hg leads to pulmonary vascular cephalization. When PCWP exceeds 20 mm Hg, interstitial pulmonary edema develops, which manifests as thickening of the interlobular septa such as Kerley lines and peribronchial cuffing, perivascular cuffing, and subtle ground-glass opacities on chest radiographs. If PCWP exceeds 25 mm Hg, alveolar pulmonary edema develops, with liquid-filling alveoli manifesting as perihilar ground-glass opacities progressing to consolidation, usually without air bronchograms.¹

Permeability edema results from increased porosity of the tight junctions in the alveolar-capillary membrane, which may occur with or without damage to the alveolar membrane. Permeability edema with diffuse alveolar damage leads clinically to acute respiratory distress syndrome (ARDS), which may be precipitated by severe pneumonia, sepsis, trauma, pancreatitis, or blood transfusion. Early alveolar...
Ipsilateral Unilateral Pulmonary Edema

Unilateral pulmonary edema may occur ipsilateral or contralateral to the side of pulmonary abnormality. Causes of ipsilateral pulmonary edema include rapid lung reexpansion, reimplantation response or acute rejection after lung transplantation, acute mitral regurgitation, pulmonary contusion, aspiration, bronchial obstruction, unilateral pulmonary venous occlusion, and prolonged lateral decubitus positioning.

Reexpansion pulmonary edema is the best described etiology of unilateral pulmonary edema (Figures 1 and 2). Chronic lung collapse results in decreased lung compliance secondary to decreased surfactant production and thickening of the pulmonary microvascular endothelium. When the lung is rapidly reexpanded in the setting of thoracentesis for hydrothorax or chest tube placement for pneumothorax, mechanical injury associated with stretching of the alveoli and capillary endothelium increases alveolar-capillary permeability. Reperfusion injury with release of cytokines and oxygen-free radicals further contributes to alveolar damage. A component of hydrostatic pressure edema results from decreased extravascular interstitial hydrostatic pressure because of applied negative suction pressure. Onset of pulmonary edema is acute, developing within hours of lung reexpansion. It may progress for 24 to 48 hours but should resolve gradually over 5 to 7 days. Reexpansion pulmonary edema typically involves the entire lung, but it may involve a single lobe or segment. Slow filling with liquid in a peripheral and dependent distribution with air bronchograms is a characteristic imaging feature of diffuse alveolar damage in ARDS. Examples of permeability edema without diffuse alveolar damage include heroin-induced and high-altitude pulmonary edema.

Mixed pulmonary edema is multifactorial, combining features of hydrostatic and permeability edema. Examples include neurogenic pulmonary edema, upper airway obstruction-induced pulmonary edema, and many of the entities associated with unilateral pulmonary edema as described below.

Figure 1. A: Spontaneous left-sided pneumothorax. B: Reexpansion pulmonary edema in the left lung after insertion of a thoracostomy tube and rapid evacuation of the pneumothorax.
Decreased surfactant production increases intra-alveolar surface tension with concurrent retention of alveolar liquid. Lymphatic disruption further contributes to pulmonary edema by preventing clearance of extravascular liquid.3 Acute rejection after lung transplantation results in permeability edema, with a cell-mediated immune response causing perivascular monocyte infiltration. Acute rejection can have an identical imaging appearance as reimplantation response, but acute rejection occurs later after surgery, within several days to weeks.3 Asymmetric pulmonary edema occurs in approximately 9% of patients admitted with acute mitral valve regurgitation (Figure 5).4 Acute mitral regurgitation most commonly

Figure 2. Right-sided reexpansion pulmonary edema after rapid drainage of 4 L of pleural effusion in a patient with liver cirrhosis and hepatic hydrothorax.

Two processes may occur after lung transplantation, either of which can cause pulmonary edema of the transplanted lung: reimplantation response (Figure 3) and acute rejection (Figure 4). Reimplantation response occurs in nearly all transplanted lungs, developing 24 hours postoperatively, peaking on postoperative day 4, and gradually clearing for up to several weeks. Both hypoxic injury of the transplanted lung before surgery, and reperfusion injury of the transplanted lung after surgery, damage the alveolar-capillary membrane. Redistribution of blood flow from the contralateral native lung to the transplanted lung also increases intravascular hydrostatic pressure. Decreased surfactant production increases intra-alveolar surface tension with concurrent retention of alveolar liquid. Lymphatic disruption further contributes to pulmonary edema by preventing clearance of extravascular liquid.3

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Figure 3. Twenty-four hours after right lung transplantation, reimplantation response developed in the transplanted right lung. This chest radiograph shows unilateral pulmonary edema with ground-glass opacification.

Figure 4. Acute rejection of the right lung 1 week after lung transplantation. This chest radiograph demonstrates right unilateral pulmonary edema.

Figure 5. Acute mitral valvular regurgitation secondary to rupture of a papillary muscle, resulting in right lung pulmonary edema with preferential involvement of the right upper lobe.
occurs in the setting of myocardial infarction, with dysfunction or rupture of the papillary muscles or chordae tendineae. The regurgitant jet is directed toward the right superior pulmonary vein during ventricular systole, resulting in preferential right upper lobe pulmonary edema. Acute exacerbation of chronic mitral regurgitation in a patient with rheumatic heart disease or cardiomyopathy also may cause pulmonary edema, but the cardiac silhouette is more likely to be enlarged with left atrial dilatation.

Pulmonary contusion results in hemorrhagic permeability edema secondary to shear mechanical injury of the alveolar-capillary membrane. Chest radiographic changes become evident within 4 to 6 hours after injury, peak at 24 to 48 hours after injury, and resolve within 3 to 10 days. Concurrent volume overload from IV resuscitation, transfusion, and aspiration can complicate interpretation of the chest radiograph and also must be considered in the differential diagnosis of pulmonary edema after chest trauma.

Aspiration-induced pulmonary edema results from chemical injury to the alveolar-capillary membrane (Figure 6). Pulmonary edema manifests during the acute phase, within 2 hours of aspiration. In the later phase, approximately 4 to 6 hours after aspiration, an inflammatory response ensues with neutrophilic infiltration and de-epithelialization of bronchial mucosa causing chemical pneumonia. It is important to note that gastric pH must be less than 2.5 to elicit chemical injury. Aspiration of higher-pH contents will not produce pulmonary edema but is more likely to cause bacterial pneumonia.

Bronchial obstruction may be caused by tumors, mucous plugging, foreign body aspiration, or ligation during surgery. Hypoxic injury and increased surface tension caused by lack of surfactant in the nonaerated lung result in alveolar-capillary membrane damage and permeability edema. Continued obstruction leads to retained proteinaceous secretions, resulting in the “drowned lung” appearance. Imaging appearance can be similar to postobstructive pneumonia, but if clinical features of infection are present, the differential diagnosis should favor pneumonia.

Unilateral pulmonary venous occlusion by tumors or thrombosis leads to stasis with subsequent increase in pulmonary vascular resistance, potentially resulting in hydrostatic pressure edema in the ipsilateral lung. Prolonged lateral decubitus positioning should be considered as a cause of unilateral pulmonary edema in patients who are unconsciousness and intubated for a long period. Gravity increases blood flow and capillary hydrostatic pressure in the dependent lung. Pulmonary edema is further exacerbated by decreased surfactant production with prolonged hypoxemia.

**Contralateral Pulmonary Edema**

Unilateral pulmonary edema occurring contralateral to the side of pulmonary abnormality is driven predominantly by hydrostatic pressure edema in the normal lung. In the setting of unilateral lung disease, hydrostatic pressure pulmonary edema will preferentially involve the contralateral normal lung. Entities that cause unilateral lung disease include asymmetric emphysema, lobectomy, and Swyer-James-MacLeod syndrome. In the patient with asymmetric emphysema, hypoxic vasoconstriction and vascular deficiency in the diseased lung lead to increased perfusion of the contralateral normal lung. When hydrostatic pressure increases, such as in left ventricular failure, pulmonary edema will occur in the nonemphysematous lung. Swyer-James-MacLeod syndrome is a type of postinfectious bronchiolitis obliterans that occurs early in childhood. Abnormal development of alveolar buds results in a reduced number of pulmonary capillaries and subsequent increased pulmonary vascular resistance. Therefore, should left ventricular failure occur, cardiogenic pulmonary edema will involve preferentially the hyperperfused, normal lung.

Unilateral congenital interruption of the pulmonary arteries and unilateral obstruction of the pulmonary arteries by tumors or thromboemboli also can result in pulmonary edema of the contralateral lung. Blood flow is shunted to patent pulmonary arteries in the normal lung, resulting in pulmonary arterial hyperperfusion and, potentially, pulmonary edema. Pulmonary edema is reported to occur in less than 10% of both acute (Figure 7) and chronic cases of pulmonary thromboembolism.

**Differential Diagnosis**

Various disease entities may cause unilateral lung opacification, thereby mimicking unilateral pulmonary edema.

In unilateral lung disease such as emphysema or thromboembolism, shunting of blood flow causes relative enlargement of hilar pulmonary vessels and increased opacification of the normal lung. When compared with the hyperperfused, abnormal lung, one may confuse these imaging findings with pulmonary edema (Figure 8). Absence of Kerley lines, which are only present with increased extravascular liquid, is an important distinguishing feature. For indeterminate cases, CT is a helpful examination to confirm or exclude the presence of pulmonary edema.

Amiodarone pulmonary toxicity in a patient who has undergone coronary artery bypass graft (CABG) is a unique
Additional causes of unilateral lung opacification include pneumonia and radiation injury. Both may present as asymmetric consolidation. Clinical signs of infection such as fever or leukocytosis clearly favor pneumonia. In the setting of radiation injury, comparison with remote images to assess prior presence of tumors, and a history of radiation therapy confined to one hemithorax, are helpful to determine the correct diagnosis.

Conclusion

Pulmonary edema is multifactorial, primarily involving increased intravascular hydrostatic pressure, increased alveolar-capillary membrane permeability, or both. Pulmonary edema can be asymmetric, involving the lung either ipsilateral or contralateral to the side of a pulmonary abnormality. This CME activity emphasizes that although unilateral pulmonary edema is a potentially confusing finding, clinical context and ancillary imaging findings can help narrow the differential diagnosis.

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References

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1. A patient with cirrhosis presents to the emergency department with shortness of breath. Chest radiography reveals complete right hemithorax opacification with contralateral mediastinal shift, suggesting a large right pleural effusion. The *most* appropriate therapy is chest tube placement with
   A. full lung reexpansion within 24 hours
   B. full lung reexpansion within 48 hours
   C. setting to low pressure negative suction
   D. 1 L of pleural effusion removed per day
   E. 2 L of pleural effusion removed per day

2. A patient presents to the emergency department with substernal chest pain and acute hypotension. Chest radiography demonstrates diffuse opacification of the right upper lobe without volume loss. The *most* likely diagnosis is
   A. pneumonia
   B. acute mitral valve regurgitation
   C. pulmonary embolism
   D. aspiration
   E. adenocarcinoma

3. Which one of the following unilateral conditions may cause contralateral pulmonary edema?
   A. Bronchial obstruction
   B. Pulmonary venous occlusion
   C. Pulmonary arterial occlusion
   D. Prolonged lateral decubitus positioning
   E. Pneumothorax treatment

4. The pathogenesis of reexpansion pulmonary edema following treatment of a pneumothorax or hydrothorax includes all of the following, except
   A. mechanical injury at the alveolar membrane
   B. increased extravascular interstitial hydrostatic pressure
   C. decreased surfactant production
   D. increased alveolar-capillary membrane permeability
   E. oxygen-free radical injury to the alveolar membrane

5. All of the following are causes of permeability pulmonary edema, except
   A. volume overload
   B. high-altitude sickness
   C. heroin overdose
   D. pancreatitis
   E. pulmonary contusion

6. Which one of the following pulmonary entities is associated with ipsilateral pulmonary edema?
   A. Unilateral pulmonary venous occlusion
   B. Pulmonary arterial occlusion
   C. Unilateral emphysema
   D. Single lobectomy
   E. Lymphangitic tumor spread to the lung

7. In a patient with Swyer-James-MacLeod syndrome who develops left ventricular failure, which one of the following will be affected by pulmonary edema?
   A. Ipsilateral lung
   B. Contralateral normal lung
   C. Bilateral lungs
   D. Ipsilateral lower lobe
   E. Contralateral lower lobe

8. One day after lung transplantation, chest radiography demonstrates diffuse increased opacification of the transplanted lung. The *most* likely diagnosis is
   A. acute transplant rejection
   B. aspiration
   C. pneumonia
   D. reimplantation response
   E. bronchial stenosis at anastomosis

9. Which one of the following is a key distinguishing radiographic feature of pulmonary interstitial edema?
   A. Redistribution of pulmonary vascular flow
   B. Indistinctness of perihilar vessels
   C. Kerley lines
   D. Pleural effusion
   E. Peripheral consolidation

10. Alveolar pulmonary edema occurs when PCWP is
    A. 5 mm Hg
    B. 10 mm Hg
    C. 15 mm Hg
    D. 20 mm Hg
    E. >25 mm Hg