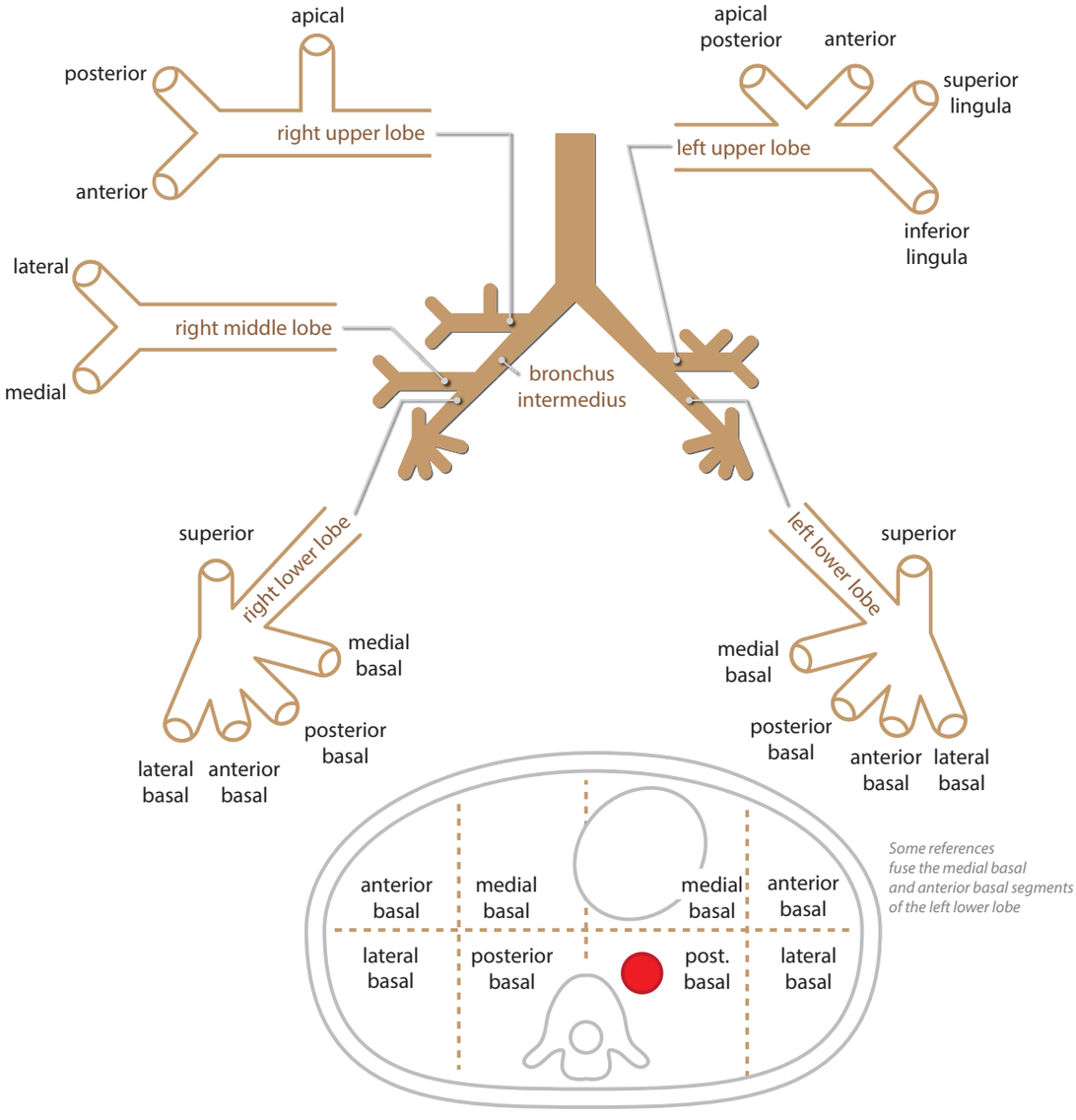
1 Thoracic Imaging

Contents

Lobar and segmental anatomy



Overview of atelectasis

- Atelectasis is loss of lung volume due to decreased aeration. Atelectasis is synonymous with collapse.
- Direct signs of atelectasis are from lobar volume loss and include:

Displacement of the fissures.	Vascular crowding.

- Indirect signs of atelectasis are due to the effect of volume loss on adjacent structures and include:

Elevation of the diaphragm. Rib crowding on the side with volume loss. Mediastinal shift to the side with volume loss.	Overinflation of adjacent or contralateral lobes. Hilar displacement.

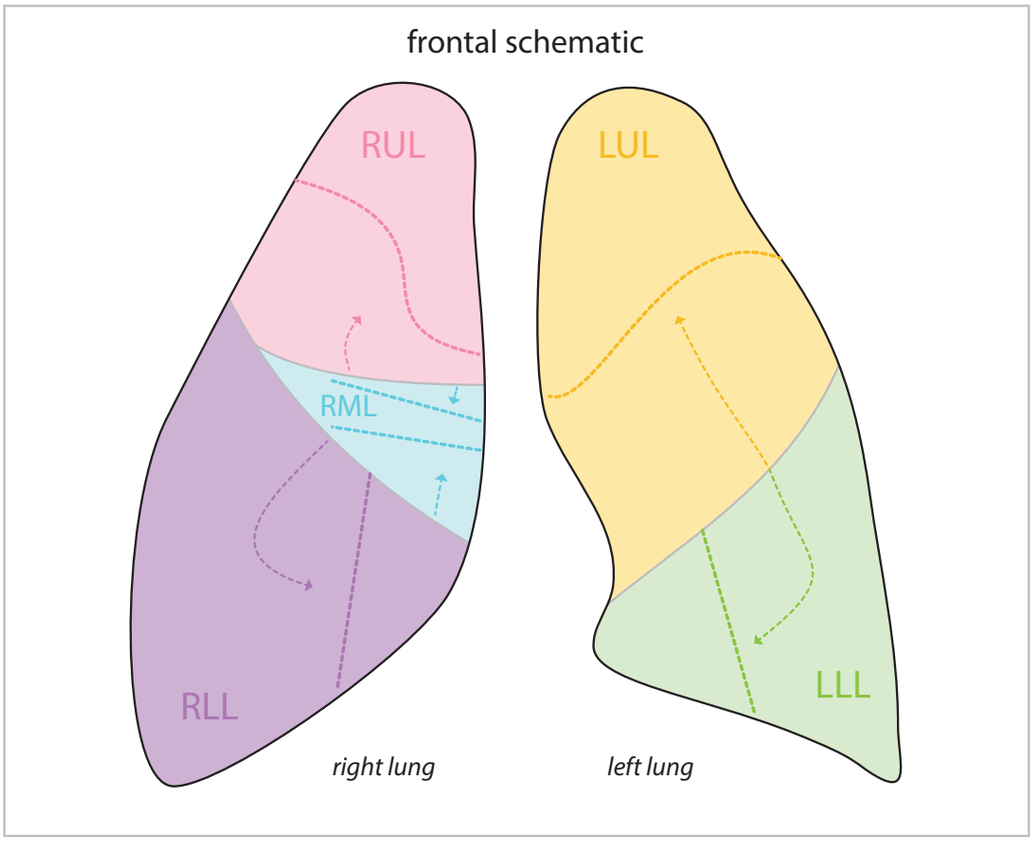
- Air bronchograms are *not* seen in atelectasis when the cause of the atelectasis is central bronchial obstruction, but air bronchograms can be seen in subsegmental atelectasis. Subsegmental atelectasis is caused by obstruction of small peripheral bronchi, usually by secretions.
- Subsegmental atelectasis and mild fever are both commonly encountered in postsurgical patients, although it has been proposed that there is no causative relationship between atelectasis and postoperative fever.

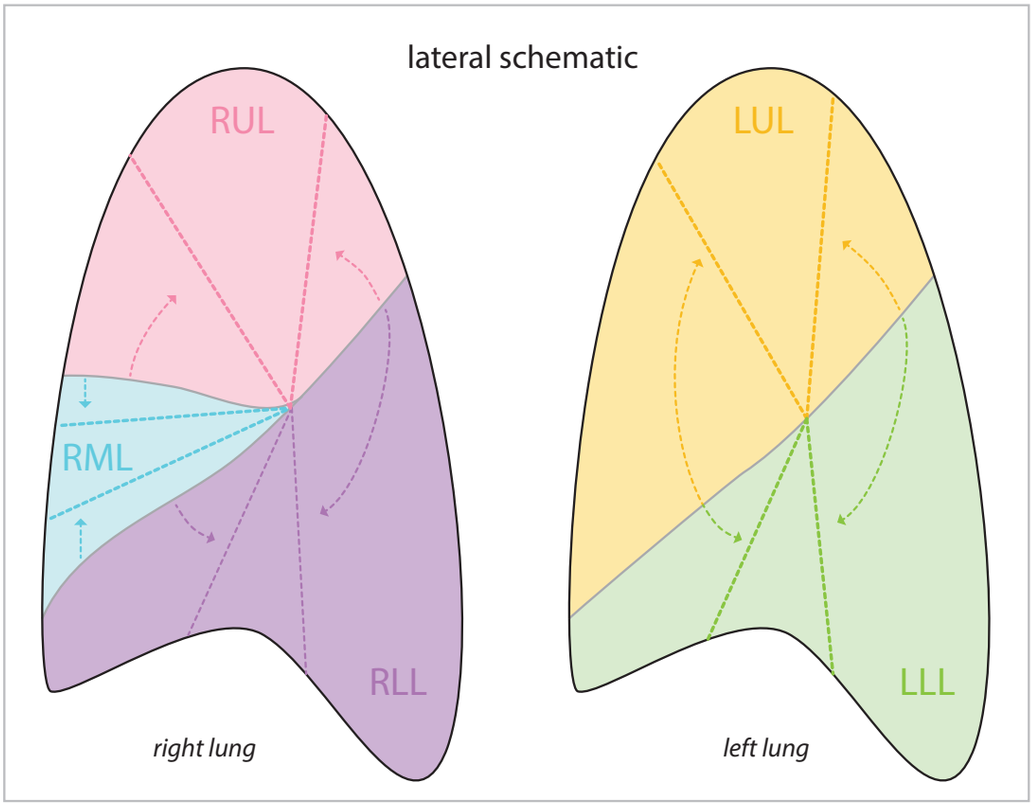
Mechanisms of atelectasis

- **Obstructive** atelectasis occurs when alveolar gas is absorbed by blood circulating through alveolar capillaries but is not replaced by inspired air due to bronchial obstruction.
  - Obstructive atelectasis can cause lobar atelectasis, which is complete collapse of a lobe, discussed on the following page.
  - Obstructive atelectasis occurs more quickly when the patient is breathing supplemental oxygen since oxygen is absorbed from the alveoli more rapidly than nitrogen.
  - In general, obstructive atelectasis is associated with volume loss. In critically ill ICU patients, however, there may be rapid transudation of fluid into the obstructed alveoli, causing superimposed consolidation.
  - In children, airway obstruction is most often due to an aspirated foreign object. In contrast to adults, the affected side becomes hyperexpanded in children due to a ball-valve effect.
  - Subsegmental atelectasis is a subtype of obstructive atelectasis commonly seen after surgery or general illness, due to mucus obstruction of the small airways.
- **Relaxation** (passive) atelectasis is caused by relaxation of lung adjacent to an intrathoracic lesion causing mass effect, such as a pleural effusion, pneumothorax, or pulmonary mass.
- **Adhesive** atelectasis is due to surfactant deficiency.
  - Adhesive atelectasis is seen most commonly in neonatal respiratory distress syndrome, but can also be seen in acute respiratory distress syndrome (ARDS).
- **Cicatricial** atelectasis is volume loss from architectural distortion of lung parenchyma by fibrosis.

Lobar atelectasis

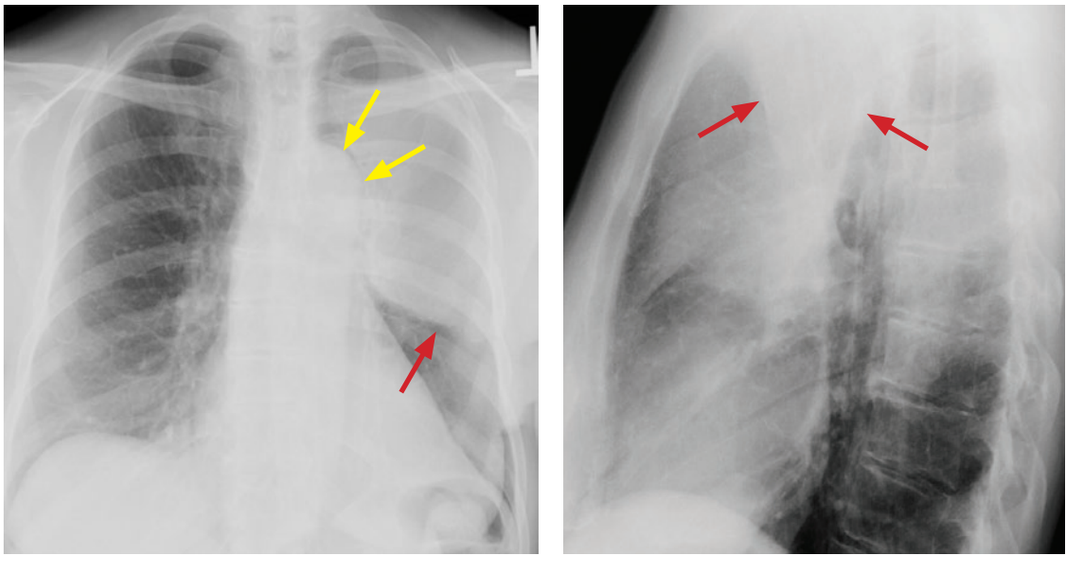
- Lobar atelectasis is usually caused by central bronchial obstruction (obstructive atelectasis), which may be secondary to mucus plugging or an obstructing neoplasm.
  - If the lobar atelectasis occurs acutely, mucus plugging is the most likely cause.
  - If lobar atelectasis is seen in an outpatient, an obstructing central tumor must be ruled out.
- Lobar atelectasis, or collapse of an entire lobe, has characteristic appearances depending on which of the five lobes is collapsed.





- Each of the five lobes tends to collapse in a predictable direction, as shown above.

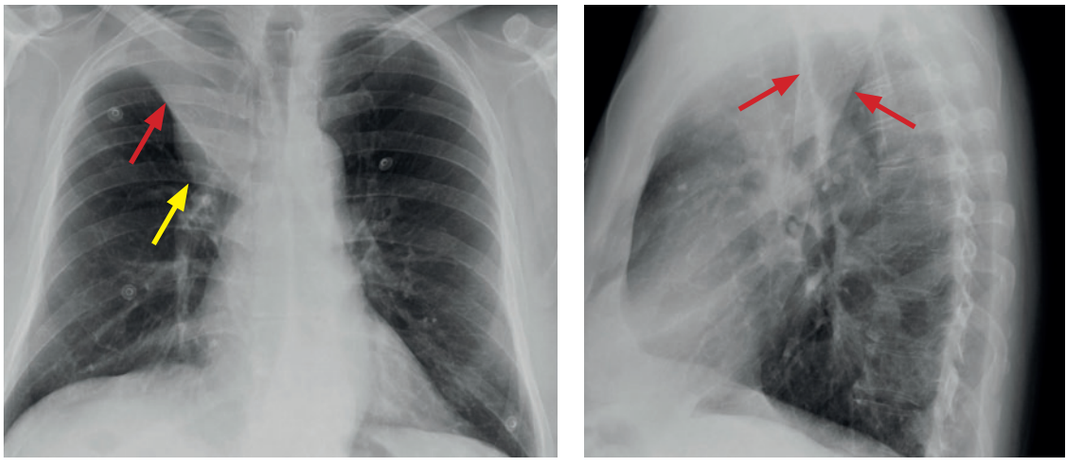
Left upper lobe atelectasis



Left upper lobe collapse and *luftsichel* sign: Frontal radiograph (left image) shows a veil-like left upper lung opacity representing the collapsed left upper lobe (red arrow). A crescent of air lateral to the aortic arch is the *luftsichel* (yellow arrows). The lateral view (right image) shows the anterior wedge-shaped collapsed left upper lobe (red arrows). *Case courtesy Ritu R. Gill, MD, MPH, Brigham and Women's Hospital.*

- The *luftsichel* (*air-sickle* in German) sign of left upper lobe collapse is a crescent of air seen on the frontal radiograph, which represents the interface between the aorta and the hyperexpanded superior segment of the left lower lobe.
- It is important to recognize left upper lobe collapse and not mistake the left lung opacity for pneumonia, since a mass obstructing the airway may be the cause of the lobar atelectasis.

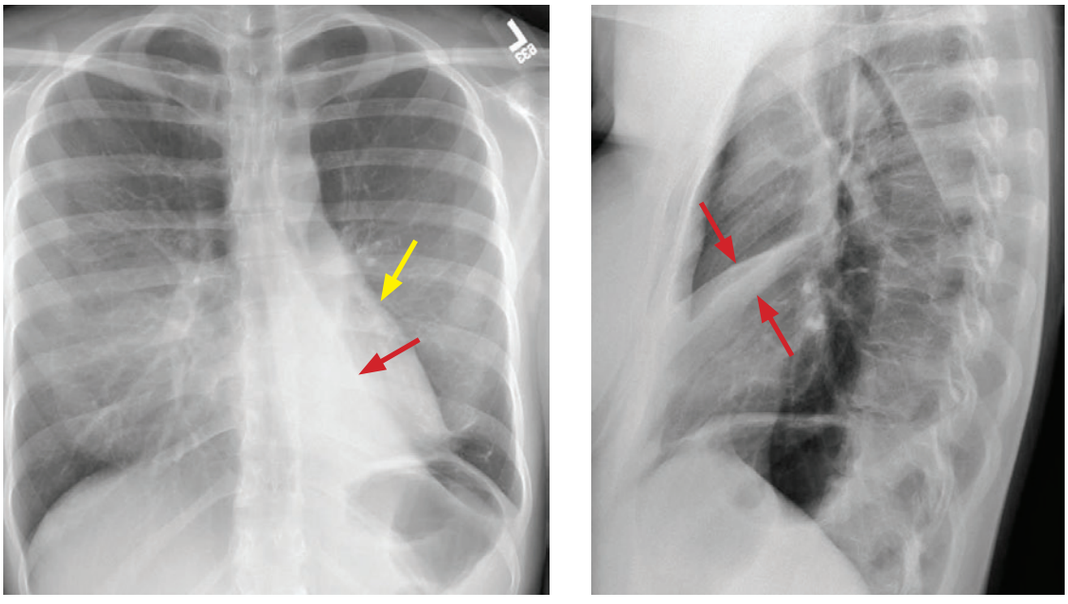
Right upper lobe atelectasis



Right upper lobe collapse and *Golden's S* sign: Frontal radiograph (left image) shows a right upper lobe opacity with superior displacement of the minor fissure (red arrow) and a convex mass (yellow arrow). Lateral radiograph (right image) shows the wedge-shaped collapsed RUL projecting superiorly (red arrows).

- *The reverse S sign of Golden* is seen in right upper lobe collapse caused by an obstructing mass. The central convex margins of the mass form a reverse S. Although the sign describes a *reverse* S, it is also commonly known as *Golden's S* sign. Similar to left upper lobe collapse, a right upper lobe collapse should raise concern for an underlying malignancy, especially with a Golden's S sign present.
- The juxtaphrenic peak sign is a peridiaphragmatic triangular opacity caused by diaphragmatic traction from an inferior accessory fissure or an inferior pulmonary ligament.

Left lower lobe atelectasis

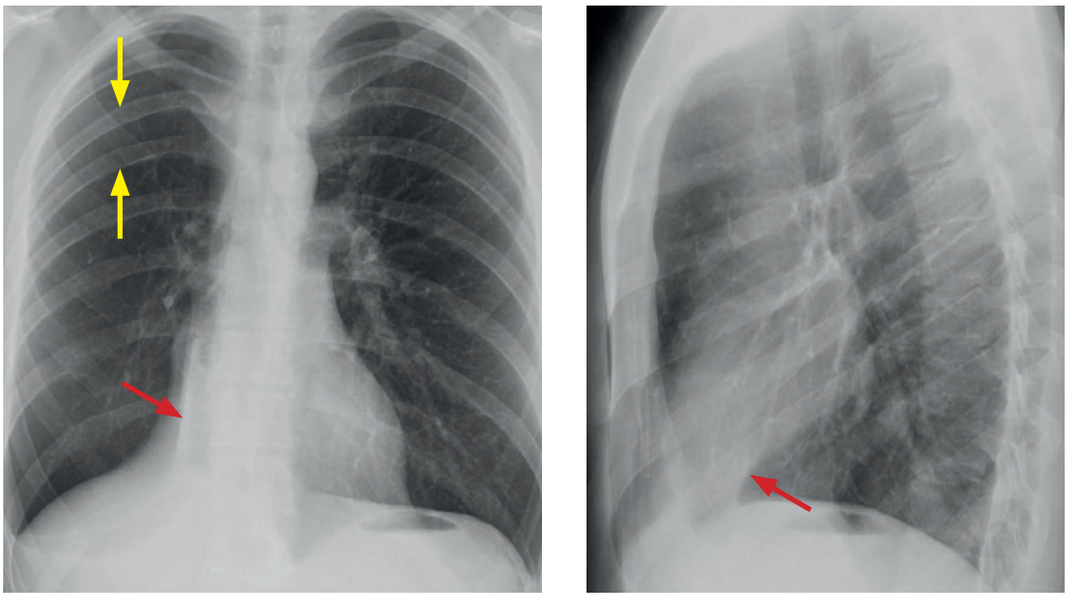


Left lower lobe collapse: Frontal and lateral radiographs demonstrate a triangular retrocardiac opacity representing the collapsed left lower lobe (red arrows). There is loss of concavity of the left heart border (the *flat waist* sign; yellow arrow).

Case courtesy Ritu R. Gill, MD, MPH, Brigham and Women's Hospital.

- In left lower lobe collapse, the heart slightly rotates and the left hilum is pulled down.
- The *flat waist* sign describes the flattening of the left heart border as a result of downward shift of hilar structures and resultant cardiac rotation.

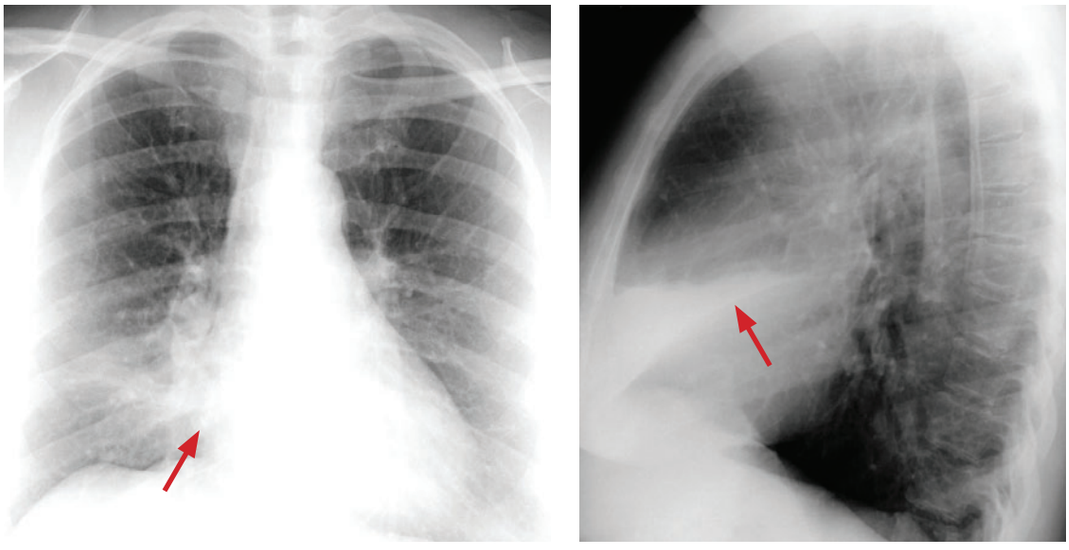
Right lower lobe atelectasis



Right lower lobe collapse: Frontal radiograph shows an abnormal vertically oriented interface medial to the right heart border (red arrow), which corresponds to a wedge-shaped opacity projecting over the heart on the lateral view (red arrow) and represents the collapsed right lower lobe. On the frontal radiograph, there is subtle crowding of the ribs (yellow arrows) in the right hemithorax due to volume loss.

- Right lower lobe atelectasis is the mirror-image of left lower lobe atelectasis.
- The collapsed lower lobe appears as a wedge-shaped retrocardiac opacity.

Right middle lobe atelectasis



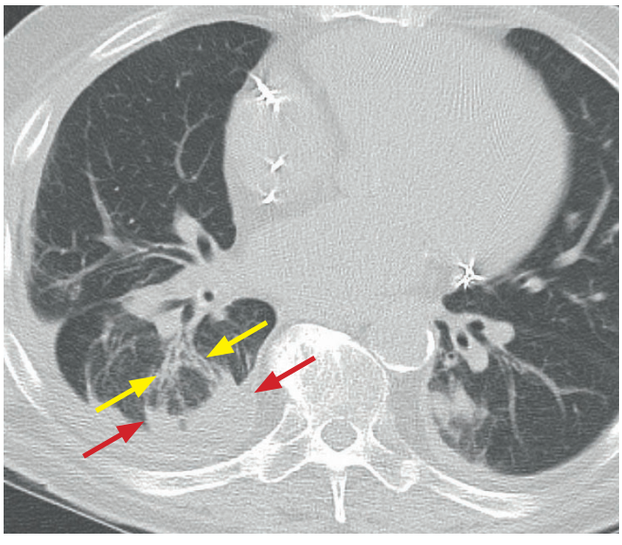
Right middle lobe atelectasis: Frontal chest radiograph shows an indistinct opacity in the right lung with focal silhouetting of the right heart border (arrow). There is elevation of the right hemidiaphragm due to volume loss. The lateral radiograph shows a wedge-shaped opacity (arrow) projecting over the mid-heart representing the collapsed right middle lobe.

Case courtesy Ritu R. Gill, MD, MPH, Brigham and Women's Hospital.

- The findings of right middle lobe atelectasis can be subtle on the frontal radiograph. Silhouetting of the right heart border by the collapsed medial segment of the middle lobe may be the only clue. The lateral radiograph shows a wedge-shaped opacity anteriorly.

Round atelectasis

- Round atelectasis is focal atelectasis with a round morphology that is *always* associated with an adjacent pleural abnormality (e.g., pleural effusion, pleural thickening or plaque, pleural neoplasm, etc.).
- Round atelectasis is most common in the posterior lower lobes.
- All five of the following findings must be present to diagnose round atelectasis:
  1) Adjacent pleura must be abnormal.
  2) Opacity must be peripheral and in contact with the pleura.
  3) Opacity must be round or elliptical.
  4) Volume loss must be present in the affected lobe.
  5) Pulmonary vessels and bronchi leading into the opacity must be curved — this is the *comet tail* sign.

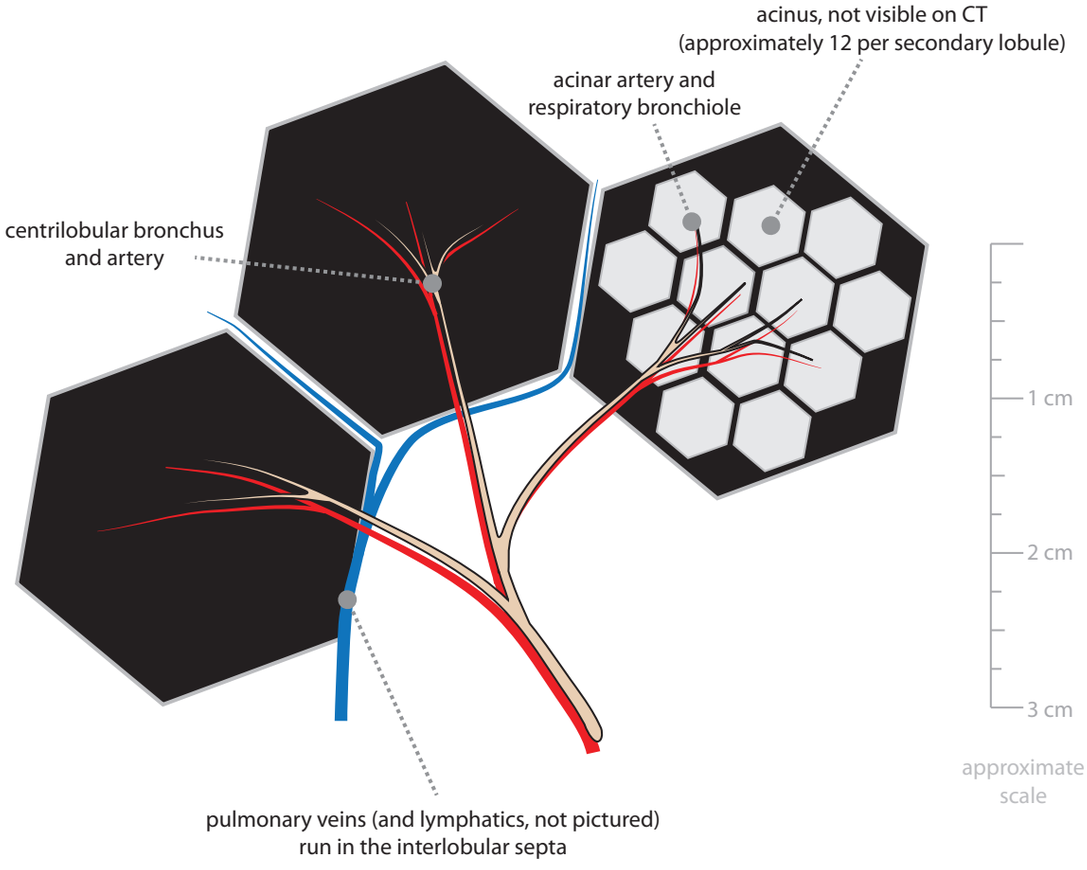


Round atelectasis: Noncontrast CT shows a rounded opacity in the medial right lower lobe (red arrows). This example meets all five criteria for round atelectasis including adjacent pleural abnormality (effusion), opacity in contact with the pleura, round shape, volume loss in the affected lobe, and the *comet tail* sign (yellow arrows) representing curved vessels and bronchi leading to the focus of round atelectasis.

PATTERNS OF LUNG DISEASE

ESSENTIAL ANATOMY

Secondary pulmonary lobule (SPL)



- The secondary pulmonary lobule (SPL) is the elemental unit of lung function.
- Each SPL contains a central artery (the aptly named centrilobular artery) and a central bronchus, each branching many times to ultimately produce acinar arteries and respiratory bronchioles.

  On CT, the centrilobular artery is often visible as a faint dot. The centrilobular bronchus is not normally visible.

  The acinus is the basic unit of gas exchange, containing several generations of branching respiratory bronchioles, alveolar ducts, and alveoli.

  There are generally 12 or fewer acini per secondary lobule.
- Pulmonary veins and lymphatics collect in the periphery of each SPL.
- Connective tissue, called interlobular septa, encases each SPL.

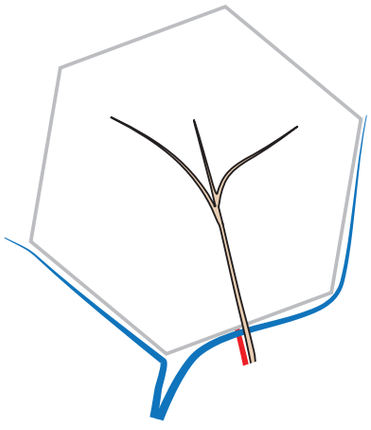
  Thickening of the interlobular septa can be seen on CT and suggests pathologic enlargement of either the venous or lymphatic spaces, as discussed on subsequent pages.
- Each SPL is between 1 and 2.5 cm in diameter.

ABNORMALITIES OF THE SECONDARY PULMONARY LOBULE

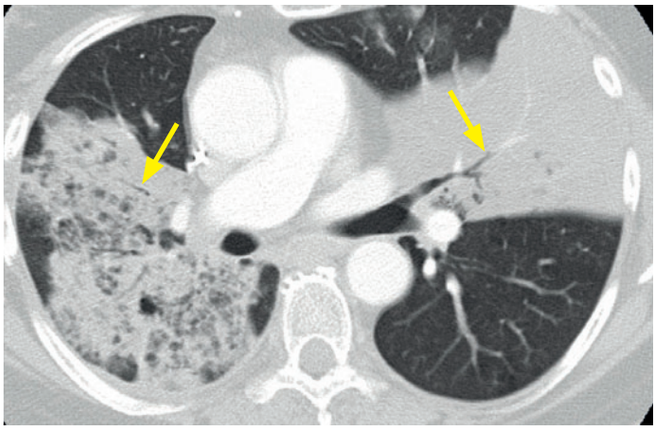
Consolidation and ground glass

- Consolidation and ground glass opacification are two very commonly seen patterns of lung disease caused by abnormal alveoli. The alveolar abnormality may represent either filling of the alveoli with fluid or incomplete alveolar aeration.
- Consolidation can be described on either a chest radiograph or CT, while ground glass is generally reserved for CT.
- Although consolidation often implies pneumonia, both consolidation and ground glass are nonspecific findings with a broad differential depending on chronicity (acute versus chronic) and distribution (focal versus patchy or diffuse).

Consolidation



Schematic demonstrates complete filling of the alveolus with obscuration of the pulmonary vessels. The bronchus is visible as an air bronchogram.



Consolidation: Contrast-enhanced CT shows bilateral consolidative opacities, more densely consolidated on the left. There are bilateral air bronchograms (arrows). Although these imaging findings are nonspecific, this was a case of multifocal bronchioloalveolar carcinoma.

- Consolidation is histologically due to complete filling of affected alveoli with a liquid-like substance (commonly remembered as *blood, pus, water,* or *cells*).
- Pulmonary vessels are **not** visible through the consolidation on an unenhanced CT.
- *Air bronchograms* are often present if the airway is patent. An air bronchogram represents a lucent air-filled bronchus (or bronchiole) seen within a consolidation.
- Consolidation causes silhouetting of adjacent structures on conventional radiography.
- **Acute consolidation** is most commonly due to pneumonia, but the differential includes:

  Pneumonia (by far the most common cause of acute consolidation).

  Pulmonary hemorrhage (primary pulmonary hemorrhage or aspiration of hemorrhage).

  Acute respiratory distress syndrome (ARDS), which is noncardiogenic pulmonary edema seen in critically ill patients and thought to be due to increased capillary permeability.

  Pulmonary edema may cause consolidation, although this is an uncommon manifestation.

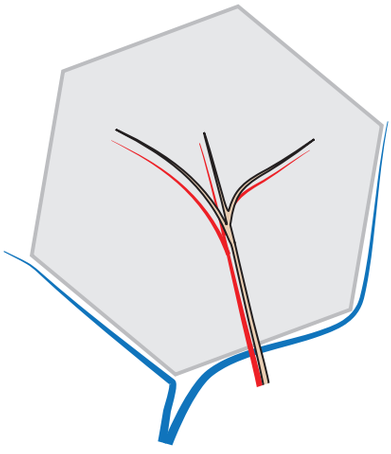
- The differential diagnosis of **chronic consolidation** includes:

  Bronchioloalveolar carcinoma mucinous subtype, a form of adenocarcinoma.

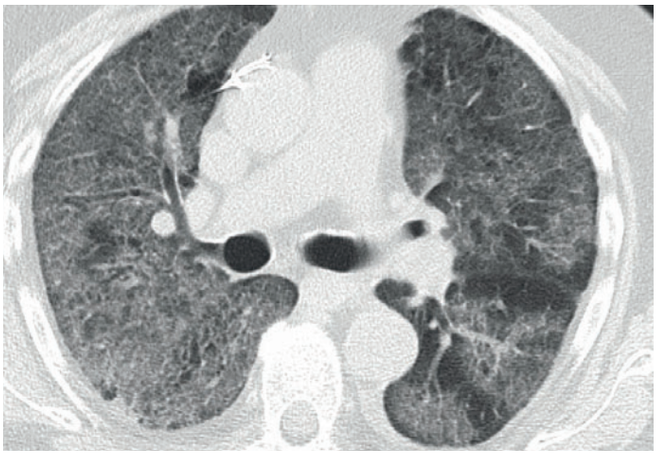
  Organizing pneumonia, which is a nonspecific response to injury characterized by granulation polyps which fill the distal airways, producing peripheral rounded and nodular consolidation.

  Chronic eosinophilic pneumonia, an inflammatory process characterized by eosinophils causing alveolar filling in an upper-lobe distribution.

Ground glass opacification (GGO)



Schematic demonstrates complete hazy filling of the alveolus. The pulmonary vessels are still visible.



Ground glass opacification: Noncontrast CT shows diffuse ground glass opacification (GGO). The pulmonary architecture, including vasculature and bronchi, can be still seen, which is characteristic for GGO. Although these imaging findings are nonspecific, this was a case of acute respiratory distress syndrome (ARDS).

- Ground glass opacification is histologically due to either partial filling of the alveoli (by blood, pus, water, or cells), alveolar wall thickening, or reduced aeration of alveoli (atelectasis).
- Ground glass is usually a term reserved for CT. CT shows a hazy, gauze-like opacity, through which pulmonary vessels are still visible.

  The term ground glass was originally described for unenhanced CT as enhanced vessels are visible in consolidation as well; however, in common practice ground glass is used for any type of CT.
- As with consolidation, air bronchograms may be present.
- **Acute ground glass** opacification has a similar differential to acute consolidation, since many of the entities that initially cause partial airspace filling can progress to completely fill the airspaces later in the disease. The differential of acute ground glass includes:

  Pulmonary edema, which is usually dependent.

  Pneumonia. Unlike consolidation, ground glass is more commonly seen in atypical pneumonia such as viral or *Pneumocystis jiroveci* pneumonia.

  Pulmonary hemorrhage.

  Acute respiratory distress syndrome (ARDS).
- **Chronic ground glass** opacification has a similar but broader differential diagnosis compared to chronic consolidation. In addition to all of the entities which may cause chronic consolidation, the differential diagnosis of chronic ground glass also includes:

  Bronchioloalveolar carcinoma, which tends to be focal or multifocal.

  Organizing pneumonia, typically presenting as rounded, peripheral chronic consolidation.

  Chronic eosinophilic pneumonia, usually with an upper-lobe predominance.

  Idiopathic pneumonias, which are a diverse group of inflammatory responses to pulmonary injury.

  Hypersensitivity pneumonitis (HSP), especially the subacute phase. HSP is a type III hypersensitivity reaction to inhaled organic antigens. In the subacute phase there is ground glass, centrilobular nodules, and mosaic attenuation.

  Alveolar proteinosis, an idiopathic disease characterized by alveolar filling by a proteinaceous substance. The distribution is typically central, with sparing of the periphery.