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A Systematic Approach to Demystifying the Unilateral Hyperlucent Lung

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After participating in this educational activity, the radiologist should be better able to identify the cause of a unilateral hyperlucent lung.

Category: General Radiology
Subcategory: Chest
Modality: CT, Radiography

Key Words: Unilateral Hyperlucent Lung, Imaging of Unilateral Hyperlucent Lung, Causes of Unilateral Hyperlucent Lung

Causes of the unilateral hyperlucent lung consist of technical factors and congenital and acquired conditions. The goal of this article is to document the causes of the unilateral hyperlucent lung to increase the radiologist's familiarity with each of these conditions, ensure proper diagnosis, and help to guide appropriate treatment.

After excluding technical factors that cause unilateral hyperlucent lung (patient positioning is the most common),[1] the radiologist should consider congenital and acquired causes, which include vascular, airway, parenchymal lung, pleural/mediastinum, and chest wall entities.[2-5] The clinical implications of some of the causes of the unilateral hyperlucent lung, such as pneumothorax, can result in high mortality and require emergent treatment. Therefore, proper recognition of these entities with chest radiography and CT correlation can ensure correct diagnosis and guide appropriate treatment.[2-5]

Approach to the Unilateral Hyperlucent Lung

In evaluating unilateral hyperlucent lung, the first consideration is to check for patient positioning, which is the most common cause of this finding in a chest radiograph, accounting for about 1% of all radiographs.[1] Typically, the lung will be hyperlucent on the side of the patient rotated toward the x-ray beam, because the x-ray beam travels a shorter path through the body on the rotated side, resulting in greater transmission. Conversely, the beam takes a longer path through the nonrotated side, thereby resulting in beam attenuation of the x-ray in the latter instance.[2] Additionally, lateral decentralization of the beam can result in unilateral hyperlucent lung because of a more intense beam on one side.[6] Scoliosis also can manifest with this finding due to spine curvature and axial rotation with asymmetric absorption of x-rays.[6] Proper alignment and positioning of a patient can be assessed by centralization of thoracic spinous processes and ensuring symmetric distance of the medial portions of the clavicles to the spinous process.[4]

After excluding artifacts associated with patient positioning and scoliosis, the flow chart shown in Figure 1 can serve as a useful algorithm to assess the various causes that can lead to the unilateral hyperlucent lung.[2-5] The select causes can be grouped into vascular, airway, lung/parenchymal, pleural/mediastinum, and chest wall entities. These are discussed in the following sections.[2-5]

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In Memoriam

Robert E. Campbell, MD

CDR's longtime Editor-in-Chief Robert E. Campbell MD, died on February 2, 2020, at the age of 88. The following remarks are excerpts from a tribute to Dr. Campbell delivered at his memorial service.

I have known Bob as a radiology colleague and a close friend for over 35 years. I would like to share some of my many wonderful memories of Bob and of our friendship.

First, let me tell you about Bob's professional life. Readers of *Contemporary Diagnostic Radiology* know his editorial work, and many of you knew him as Chairman of the radiology department at Pennsylvania Hospital. But I want all of you to know that Bob Campbell was one of the most outstanding radiologists of our time. Bob believed "to whom much is given, much is required." It was his responsibility to give back to his profession—and he did so in spades. I cannot list the multitude of international, national, regional, and local organizations to which Bob contributed his time and talents. As an example, though, I will highlight one organization that was most dear to his heart: the Radiological Society of North America (RSNA) and its companion Research and Education Foundation.

RSNA is the world's largest radiology association, with members from 136 countries. Bob became involved in the mid-1970s, when the annual meeting was held in the Palmer House in Chicago. Back then, it was truly a "mom and pop" operation. It is said that Bob and his wife, Nancy, personally handed out tickets to attendees when he was Chairman of the Refresher Course Committee! That meeting is still in Chicago, but now it is held at the Convention Center with an international attendance of more than 50,000 people. Over many years, Bob served as Chair of every important RSNA committee and as President in 1988–89.

Bob's most important contribution to RSNA was helping to start its Research and Education Foundation. The Foundation supports pilot research grants and programs to train the next generation of researchers. Established in 1984, it now has an endowment of $88 million and has provided over $60 million to support research efforts and educational programs.

Robert and Nancy Campbell in Antarctica, 2019.

I want to say a few words about Bob, the person. First and foremost, he loved his family: Nancy, the love of his life; his four children, and his eleven grandchildren. Just ask him how they were doing and he would recite the recent score of his grandson's lacrosse game or how well a granddaughter was doing in college . There was always such pride in his voice.

Bob was highly sought out to lead projects. Nothing was done half way. You could have guessed that he was a perfectionist from his handwritten notes. Yes, Bob wrote notes—his handwriting was exquisite. It looked like he had printed it with a special "Campbell" font.

Bob never met anyone he did not like, and everyone liked him. When he talked to you, he was also listening. You had his undivided attention. Bob had a great sense of humor and an infectious laugh—I can hear it today!

The bottom line—Bob loved life! He was a very special person, and we were all privileged to count him as a friend. I will miss walking with him on the trails at Cape Cod, pounding the pavement in the halls of the RSNA meeting in Chicago, and shuffling through the sandy beaches of Hawaii. But he has left me with many fond memories, and my life has been greatly enriched by knowing him.

—C. Douglas Maynard, MD

The continuing education activity in *Contemporary Diagnostic Radiology* is intended for radiologists.

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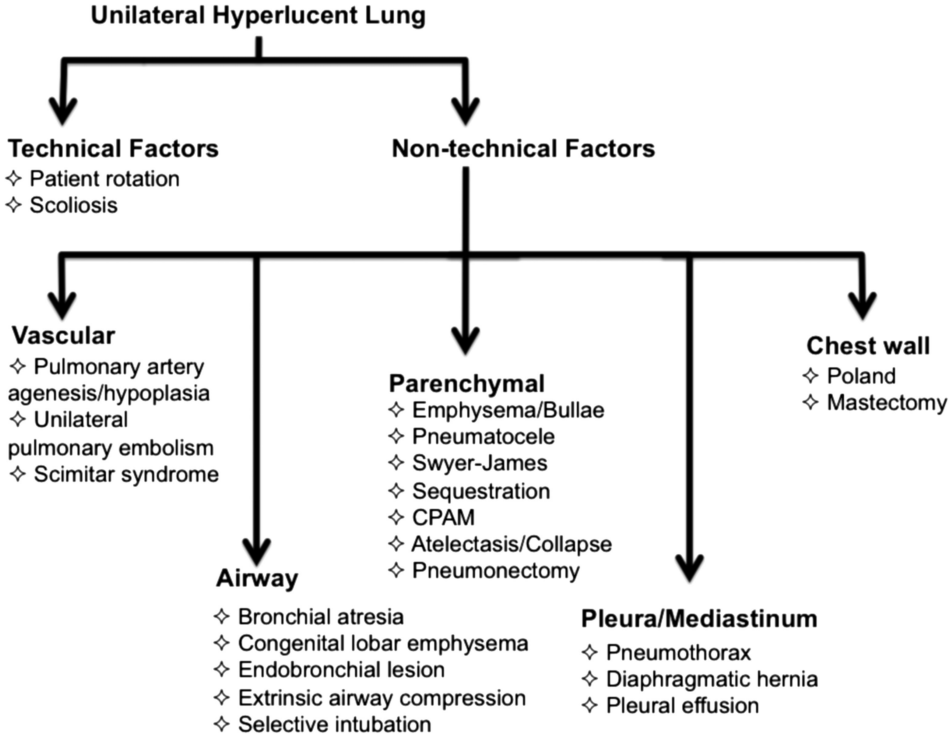


Figure 1. Schematic representation of select causes of the unilateral hyperlucent lung. After technical factors of patient rotation and scoliosis have been excluded, the nontechnical causes of the unilateral hyperlucent lung can be grouped into vascular, airway, parenchymal, pleural/mediastinum, and chest wall entities.

Vascular Causes

Unilateral Absent or Hypoplastic Pulmonary Artery

In unilateral absent or hypoplastic pulmonary artery, the lung and the airway on the side of the absent or hypoplastic pulmonary artery do not develop or are rudimentary respectively. This results in the contralateral lung being hyperexpanded, hyperlucent, and herniated toward the affected side, with mediastinal shift to the side of volume loss.[3] Left unilateral pulmonary agenesis is more common than right, but patients with absent right lung have a worse prognosis.[7] Nonetheless, some patients with unilateral pulmonary artery agenesis can be asymptomatic to adulthood.[7] Figure 2 shows a hypoplastic left pulmonary artery with underdeveloped left lung with cystic changes and hyperinflated right lung, and with herniation of right lung into the left hemithorax and leftward mediastinal shift.

Pulmonary Embolism

Pulmonary embolism can occur unilaterally or bilaterally. In unilateral pulmonary embolism, vasoconstriction of the pulmonary arteries distal to the clot results in oligemia, which can present as hyperlucency of the affected segments when compared with the normal lung. This is known as the Westermark sign,[5] which can be subtle on radiography, but may be seen with CT. Additionally, peripheral infarcts (Hampton's hump) from segmental pulmonary artery embolism may be appreciated on CT scans.

Scimitar Syndrome

In scimitar syndrome, there is partial anomalous pulmonary venous return of the right pulmonary veins via a scimitar vein, which could drain into the inferior vena cava (IVC), portal system, coronary sinus, or right atrium.[3] The right lung is hypoplastic compared with the normal hyperexpanded and hyperlucent left lung (Figure 3), and there could be mediastinal shift to the right. There is left-to-right shunting of blood, and the severity is dependent on the degree of shunting.[4]

Airway Causes

Bronchia Atresia

Bronchia atresia results in the congenital obliteration of proximal to segmental airways without connection to the central airways, and may manifest with mucoid impaction in the remnant airways on the afflicted side.[3] The resultant air trapping in the affected region results in hyperlucency (Figure 4) and may be more apparent on CT than on radiographs based on the size of the affected region.

Congenital Lobar Emphysema

Congenital lobar emphysema is a disorder of the lower airways with air trapping via a "ball-valve" mechanism, whereby inspired air enters[3,4] but cannot leave (Figure 5) and results in hyperlucency. In order of decreasing incidence, the left upper lobe is most commonly affected, followed by the right middle lobe, the right upper lobe, and the lower lobes.[3,8] Most affected children are symptomatic with respiratory distress by 6 months.[3]

Endobronchial Obstruction

A partially obstructive endobronchial lesion (foreign body or mass) also may act as a "ball-valve" mechanism resulting in air trapping within the lung supplied by the affected airway. This lung is hyperexpanded and hyperlucent when compared with the normal lung (Figure 6). Foreign body aspiration commonly occurs in children between 6 months to 3 years of age, and this diagnosis can be challenging as the aspirated object may be radiolucent, and only about 60% of the diagnosis are recognized within 24 hours.[3] However, the finding of a unilateral hyperlucent lung on a frontal radiograph, with that side remaining hyperlucent when a patient lies down on that side (lateral decubitus position), is highly suggestive of

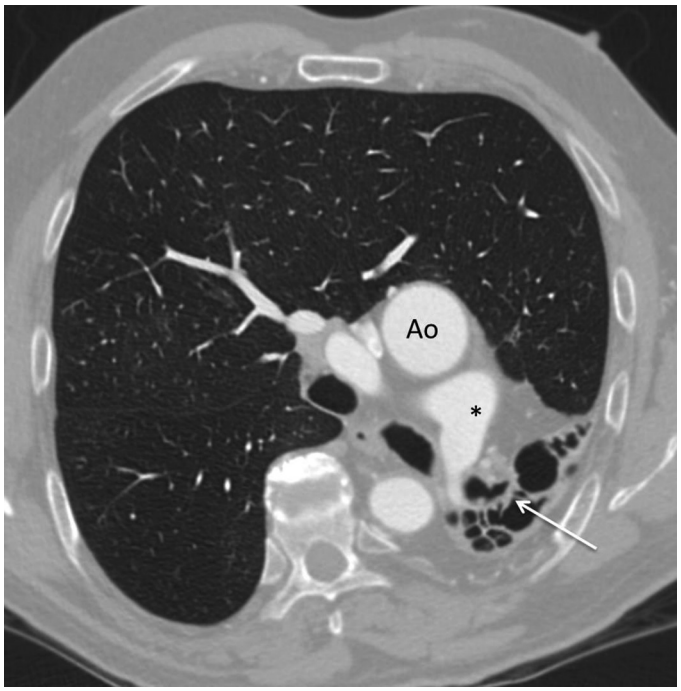


Figure 2. Hypoplastic left pulmonary artery. Axial CT scan shows hypoplastic left pulmonary artery with underdeveloped and cystic-appearing left lung (*arrow*) with hyperexpanded and hyperlucent right lung, with herniation of the right lung into the left hemithorax with concomitant left mediastinal shift. Ao, aorta; *, hypoplastic left pulmonary artery.

air trapping and obstruction of the bronchi supplying that side of the lung.[3] Unilateral extrinsic compression of the mainstem bronchus by a bronchogenic cyst, mediastinal mass or lymphadenopathy, also can lead to obstruction of that airway and hyperlucency of that side of the lung.[3]

Selective Bronchial Intubation

Selective intubation of the endotracheal tube tip in a unilateral mainstem bronchus will result in ipsilateral hyperlucent lungs on the side of intubation.[3,4]

Lung Parenchymal Causes

Blebs/Bullae/Emphysematous Changes

Blebs and bullae are cystic lung diseases without airway or blood supply connection to the affected cystic lung spaces and can occur between normal lung parenchyma.[3,4] Blebs are thin-walled areas less than 1 cm in diameter, whereas bullae are larger, measuring at least 1 cm in diameter. Blebs can coalesce to form bullae. Multiple bullae in a lung region result in emphysematous changes. Because of the paucity of blood vessels and airways in these regions, they appear hyperlucent when compared with normal lung (Figure 7). Pneumatoceles are thin-walled cystic structures that form as a postinfectious or posttraumatic sequela, hydrocarbon exposure, or barotrauma; are similar to bullae; and manifest as regions of hyperlucency in the affected lung.[4]

Swyer-James Syndrome

Swyer-James syndrome is a condition whereby the remote destruction of distal small airways from childhood respiratory viral disease results in hyperexpanded and hyperlucent affected lung zones.[9] These regions show decreased density of bronchovascular components, air-trapping, and

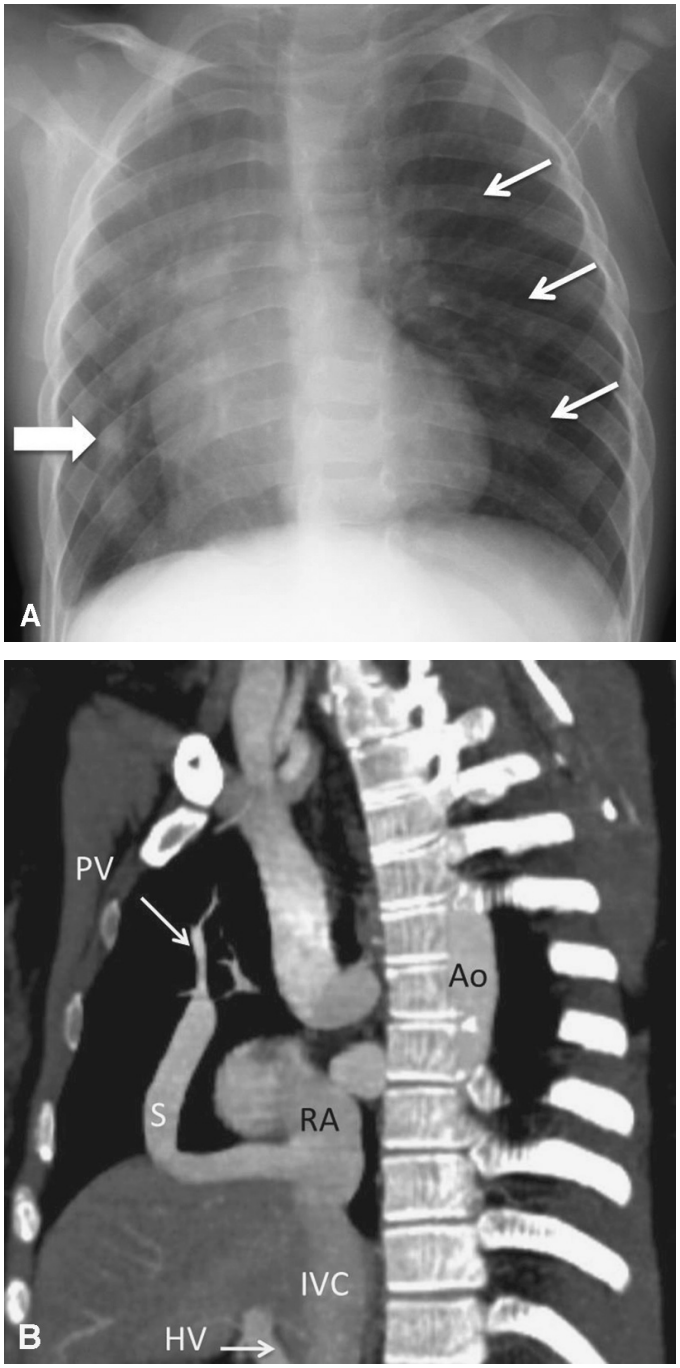


Figure 3. Scimitar syndrome. *A*: Frontal radiograph of a child demonstrates the hypoplastic right lung compared with the left, with increased hyperlucency of the left lung (*small arrows*) as compared with the right lung. The scimitar vein is seen as a curvilinear opacity (*large arrow*). *B*: The scimitar vein (S) is better seen in the oblique coronal plane 3D rendition of an adult patient, where it drains the right upper lobe pulmonary vein (PV) through the right atrium (RA) into the IVC. Ao, descending thoracic aorta; HV, hepatic vein.

hyperlucency (Figure 8). Patients with this condition frequently have a history of multiple recurrent episodes of respiratory infection and present with dyspnea, cough, and shortness of breath.[3]

Pulmonary Sequestration

Pulmonary sequestration refers to a portion of lung tissue that is supplied by systemic arterial blood supply but not pulmonary blood supply. This lung tissue does not communicate with the tracheobronchial tree. The sequestered

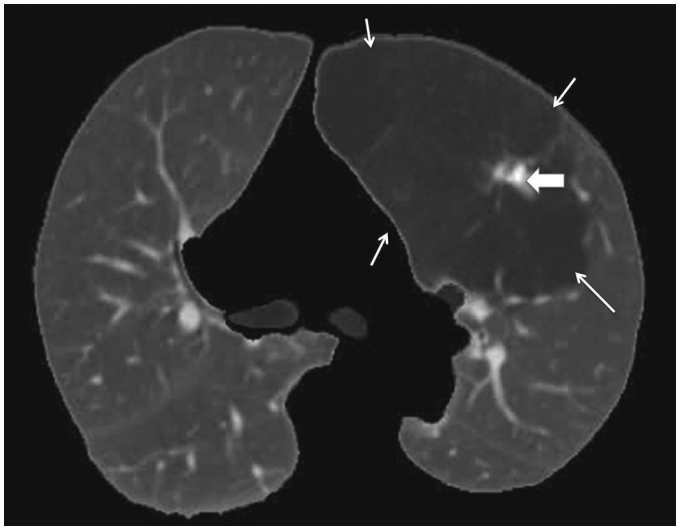


Figure 4. Bronchial atresia. Axial CT section of a patient with left upper lobe hyperlucency (*small arrows*) with paucity of bronchovascular components. An atretic bronchiole is impacted by mucus, known as a mucocele (*large arrow*).

lung can drain to the systemic (extralobar sequestration) or pulmonary (intralobar sequestration) venous system. Intralobar sequestration is more common than extralobar sequestration. Intralobar sequestration can manifest as cystic changes due to chronic inflammation and hyperlucency (Figure 9), with air trapping from collateral air drift from the adjacent lung, and it occurs most in the left lower lobe.[10] Pulmonary sequestration, however, most often presents as consolidation, masses, or structures with air-fluid levels.[10] Pulmonary sequestration is usually treated by surgery during infancy when discovered. Complications arising from failure of treatment include vascular shunting, hemorrhage, chronic infection, and malignancy.

Other Lung Parenchymal Conditions

Other lung parenchymal conditions include congenital pulmonary airway malformations in infants and children, which can appear hyperlucent, and unilateral lung atelectasis/collapse with contralateral lung hyperexpansion and hyperlucency. Additionally, pneumonectomy on one side

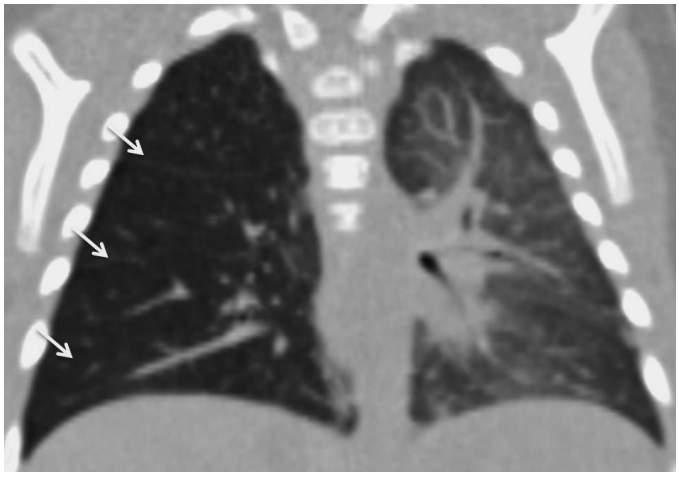


Figure 5. Congenital lobar emphysema. Coronal CT scan showing hyperlucency and expansion of the right lung in an infant with a paucity of bronchovascular components (*arrows*) as compared with the left lung.

Figure 6. Endobronchial obstruction. Coronal CT minimum intensity projection scan shows distal tracheal/proximal right mainstem bronchial mass (*arrow*), which was determined to be adenoid cystic carcinoma, results in air trapping and hyperexpansion and hyperlucency of the right lung as compared with the left lung.

results in volume loss, fluid accumulation, and fibrothorax formation on that side, with compensatory hyperinflation and hyperlucency in the contralateral normal lung.[3]

Pleural/Mediastinum Causes

Pneumothorax

Air in the pleural space results in hyperlucency of the affected side.[3] As the volume of air in the pleural cavity increases, the air exerts mass effect on the lung, resulting in atelectasis and collapse. This results in mediastinal shift to

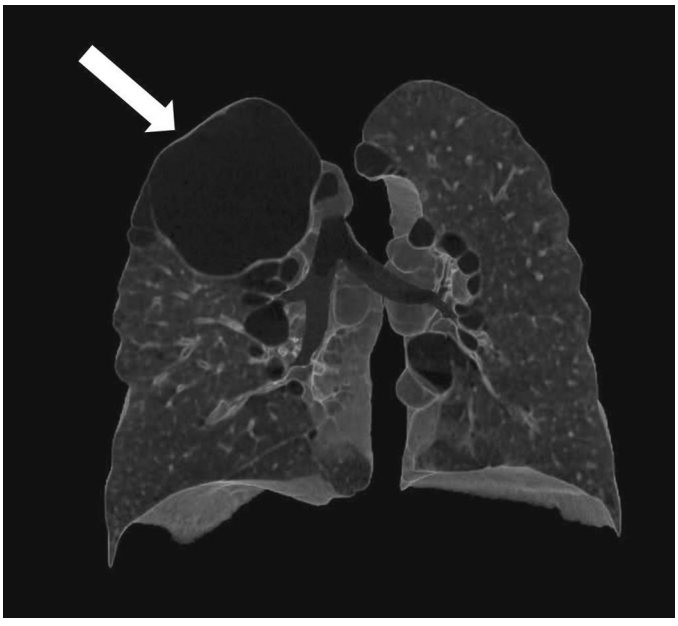
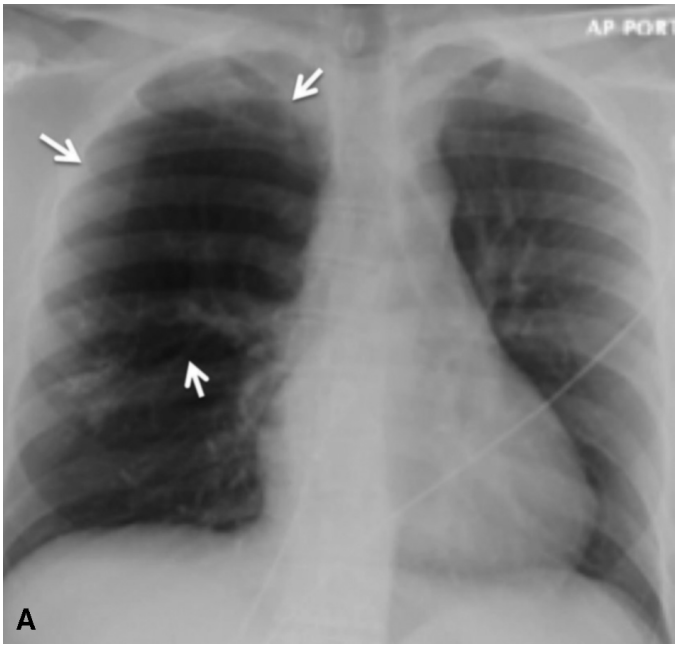


Figure 7. Bulla. Hyperlucent right upper lobe due to a large bulla (*arrow*), with thin wall and no bronchovascular elements in a 3D rendition from a coronal CT chest image. Pneumatoceles have a similar appearance and are a sequela of posttraumatic or postinfectious events, hydrocarbon exposure, or barotrauma. Smaller blebs and bullae are seen along the medial aspects of the bilateral lungs.



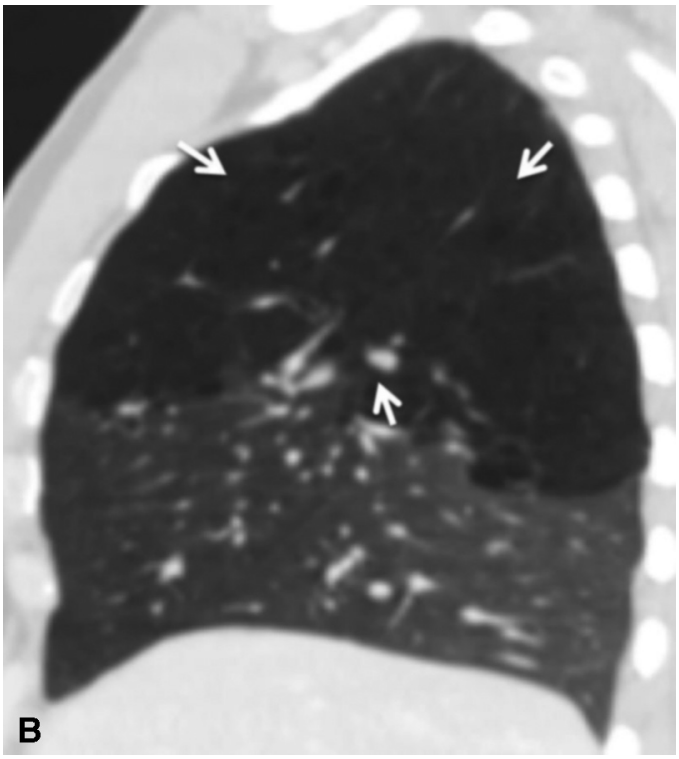


Figure 8. Swyer-James syndrome. *A*: Hyperlucent right mid- to upper lung zone (*arrows*) seen on a radiograph of a patient with Swyer-James syndrome. *B*: The hyperlucent right upper anterior and superior segments of the right lower lobe are better seen in axial and sagittal CT images. There is paucity of bronchovascular components, air trapping, and hyperlucency (*arrows*).

the contralateral side if the pneumothorax is large enough (tension pneumothorax, Figure 10). Emergent needle thoracostomy at the second intercostal space in the midclavicular line is required to prevent compression of the great vessels and to allow venous blood return to the heart. The main airways are usually patent, but the airway leading to the atelectatic lung can be collapsed. Causes of pneumothorax include spontaneous rupture of blebs/bullae in thin, tall individuals or smokers; and iatrogenic and traumatic events from chest wall injuries.

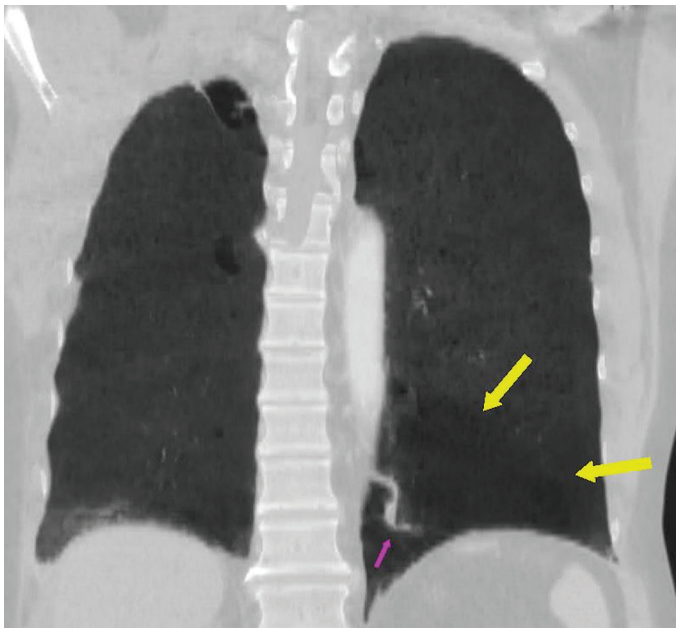


Figure 9. Left lower lobe sequestration. Coronal CT scan of the chest demonstrates a hyperlucent left lower lobe sequestration with cystic changes (*yellow arrows*) with systemic arterial branch from the thoracic aorta supplying this segment (*pink arrow*). A sequestrated segment has blood supply but does not communicate with the tracheobronchial tree and can demonstrate air trapping and hyperlucency, most likely from chronic inflammation. Air trapping is attributable to collateral air drift from the adjacent lung.

Diaphragmatic Hernia

In diaphragmatic hernia, whether traumatic or congenital, herniation of abdominal viscera such as stomach and bowel into the affected hemithorax through a diaphragmatic defect can result in hyperlucency due to the gas-containing stomach and bowel loops displacing the lung. There can be a mediastinal shift to the contralateral side if the herniation is large enough (Figure 11). Depending on the size of the diaphragmatic hernia, the airways may or may not be affected.

Other Pleural/Mediastinal Causes

Opacification of a unilateral hemithorax by pleural fluid, mass, or consolidation or lung collapse results in hyperexpansion and hyperlucency of the contralateral hemithorax and lung.

Chest Wall Causes

Poland Syndrome

In Poland syndrome, the congenital absence of the pectoralis major or minor muscles[3] can occur with or without rib, nipple, or breast abnormalities. Absence of muscle tissue reduces beam attenuation on the affected side, making that lung appear hyperlucent because of greater x-ray beam penetration (Figure 12). As always, it is important to ensure that technical factors such as patient rotation or scoliosis have been excluded before making this diagnosis.

Mastectomy

In patients who have undergone mastectomy, the absence of breast tissue decreases soft tissue attenuation, which results in relative lung hyperlucency on the affected side.[5] The presence of surgical clips and a history of breast cancer[5] or breast reduction should hint to this possibility.

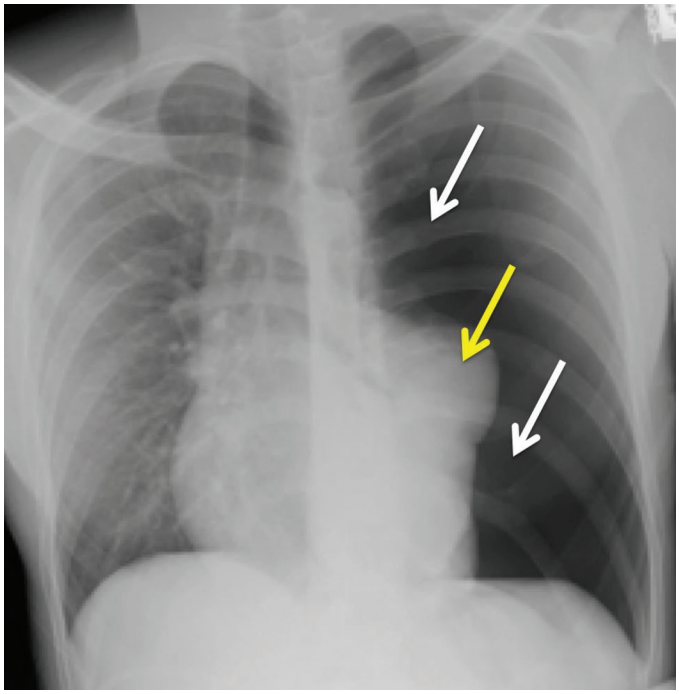


Figure 10. Tension pneumothorax. Chest radiograph shows hyperlucent left lung due to a large left pneumothorax (*white arrows*), resulting in medially collapsed lung (*yellow arrow*), with tension component and rightward mediastinal shift. This is an emergent situation requiring needle thoracostomy at the left second intercostal space in the midclavicular line.

Conclusion

Before making the diagnosis of a unilateral hyperlucent lung, it is important to exclude technical factors like patient positioning and scoliosis.[1,2,6] Only after these conditions have been excluded can the radiologist entertain the idea of a truly unilateral hyperlucent lung. The use of a systematic approach and a thorough understanding of select common and less common causes of the unilateral hyperlucent lung are critical for the radiologist to arrive at the correct diagnosis. The improved diagnostic acumen of radiologists also ensures that patients receive timely and appropriate treatment to reduce mortality.

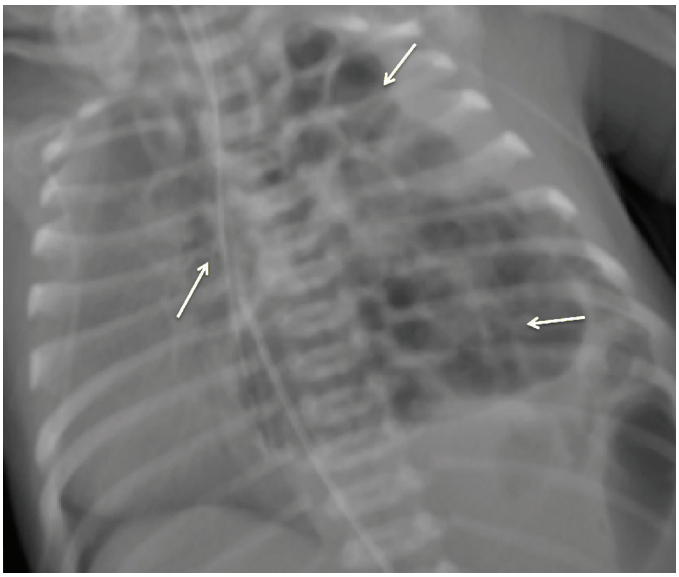
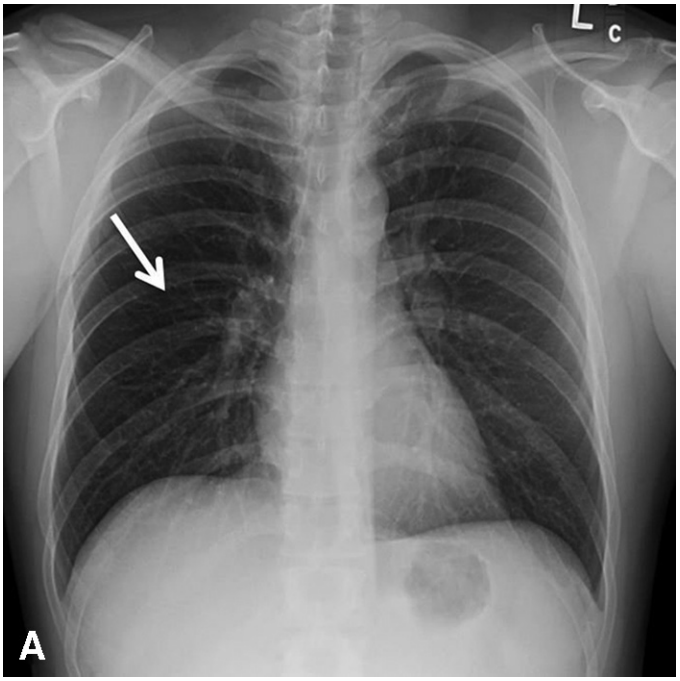


Figure 11. Congenital diaphragmatic hernia. Chest radiograph shows herniation of gas-distended small bowel loops (*arrows*) into the left hemithorax, with resultant rightward mediastinal shift and decreased right hemithorax volume from collapsed right lung, and this results in relative left lung hyperlucency as compared with the right lung, compatible with congenital diaphragmatic hernia.



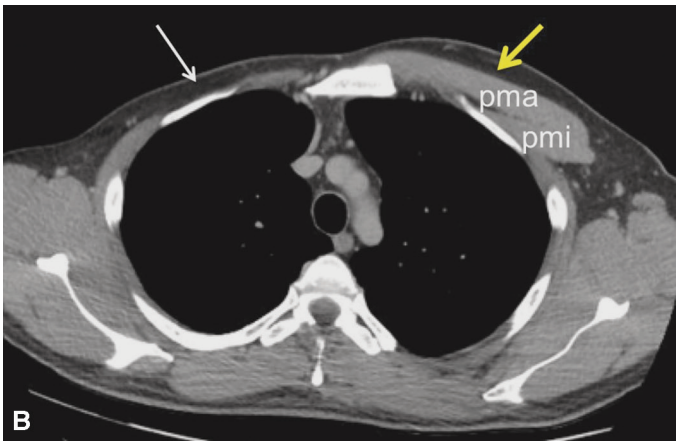


Figure 12. Poland syndrome. *A*: There is apparent asymmetric hyperlucency of the right lung (*arrow*) in this chest radiograph due to congenital absence of the right pectoralis major and minor muscles on the right, which better seen in the CT scan (*white arrow* in *B*). Note the presence of left pectoralis major (pma) and pectoralis minor (pmi) muscles in the normal left chest wall (*yellow arrow*).

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1. Which one of the following entities is the *most* common cause of a unilateral hyperlucent lung?
- **A.** Patient rotation
- **B.** Congenital lobar emphysema
- **C.** Unilateral pulmonary embolism
- **D.** Scimitar syndrome
- **E.** Swyer-James syndrome

2. Which one of the following entities can be a posttraumatic sequela?
- **A.** Bronchial atresia
- **B.** Swyer-James syndrome
- **C.** Pneumatocele
- **D.** Mastectomy
- **E.** Poland syndrome

3. Manifestation of which one of the following entities on a side of the lung will result in contralateral lung hyperlucency?
- **A.** Congenital lobar emphysema
- **B.** Pulmonary sequestration
- **C.** Bulla
- **D.** Scimitar syndrome
- **E.** Bronchial atresia

4. Airway causes of the hyperlucent lung include all of the following, *except*
- **A.** bronchial atresia
- **B.** endobronchial lesion
- **C.** Swyer-James syndrome
- **D.** selective intubation
- **E.** congenital lobar emphysema

5. Which one of the following statements regarding pulmonary embolism is *false*?
- **A.** It is a condition that can manifest unilaterally or bilaterally.
- **B.** It is a condition that always results in hyperlucency in the contralateral lung.
- **C.** A clot in a segmental pulmonary artery results in vasoconstriction distally.
- **D.** It is a condition that can result in peripheral airspace opacities (Hampton's hump).
- **E.** The Westermark sign refers to oligemia distal to the pulmonary artery clot.

6. Which one of the following conditions is *most* frequently associated with a mucocele?
- **A.** Diaphragmatic hernia
- **B.** Pneumothorax
- **C.** Poland syndrome
- **D.** Mastectomy
- **E.** Bronchial atresia

7. Which of the following statements is *false*?
- **A.** Tension pneumothorax is a life-threatening condition that requires emergent treatment.
- **B.** The pattern of venous drainage of intralobar sequestrations is to the pulmonary veins.
- **C.** Poland syndrome is a condition due to the congenital lack of pectoralis major and minor muscles.
- **D.** In unilateral pulmonary artery agenesis, the lung on the contralateral side fails to develop.
- **E.** A patient rotated to the right will show hyperlucency of the right lung.

8. Which one of the following is the *most* common lobe affected in congenital lobar emphysema?
- **A.** Right lower lobe
- **B.** Left lower lobe
- **C.** Right middle lobe
- **D.** Left upper lobe
- **E.** Right upper lobe

9. In Figure 13, which one of the following letters indicates the scimitar vein?
- **A.** A
- **B.** B
- **C.** C
- **D.** D

Figure 13.

10. If present, any of the following abnormalities would result in ipsilateral hyperlucent lung, *except*
- **A.** diaphragmatic hernia
- **B.** Poland syndrome
- **C.** mastectomy
- **D.** pneumonectomy