How to approach unilateral hyperlucency of the lung?

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Learning objectives

1. To recognize a unilateral hyperlucent lung on chest radiography and computed tomography (CT).
2. To describe the common causes of a unilateral hyperlucent lung on chest radiography and CT and to understand the pathophysiology of certain conditions.
3. To list an appropriate differential diagnosis in case of a unilateral hyperlucent lung and to provide a targeted diagnosis when certain associated radiological signs are seen.
Background

Unilateral hyperlucency of the lung is an uncommon finding arising from a variety of conditions, either congenital or acquired. Since the etiology may vary from benign to potentially life-threatening diseases, an early and accurate diagnosis is needed. Therefore, a systematic diagnostic approach is required to quickly provide a narrow differential diagnosis. Five different categories can be distinguished on whether the abnormality primarily involves the chest wall, lung parenchyma, pulmonary vessels, central airways, or mediastinum. Also, technical factors unrelated to lung disease, which can cause false-positive results, must be considered.

Vascular structures are mainly responsible for the radiologic texture of the normal lung. Any loss of opacity of the lung reflects a change in the pulmonary vascularity.

Therefore, the diagnostic evaluation of hyperlucency is primarily based on the calibre and number of radiologically identifiable vessels per unit area. Hyperlucency can be caused by narrowing or rarefaction of the vascular tree, with oligemia and decreased pulmonary markings as important signs.

An altered patency of the bronchial tree must also be considered. Both air trapping and overinflation, which stretch the vascular structures and reduce their opacity, are important additional clues. Previously existing neoplastic or infectious disease, as well as the patient's age, may also provide important diagnostic information.

In this educational exhibit, a diagnostic strategy to approach a unilateral hyperlucent lung on conventional chest radiography and CT is offered, with a pictorial review of some common and uncommon associated conditions.
1. Technical factors

On chest radiography, unilateral hyperlucency is described as a darker appearance on one side of the thorax, due to increased x-ray transmission. The first step in the evaluation of this finding is to check on radiologic technique, since the most common causes of a unilateral hyperlucent hemithorax do not reflect an intrinsic abnormality of the lung itself. Improper patient rotation is an important cause of unilateral hyperlucency, seen in around 1% of chest radiographs. A slight degree of patient rotation will result in disparity in overall lung opacity on the chest radiograph. The hyperlucency is always on the side towards which the patient is rotated, because of the shorter distance through which the x-ray beam passes. Evaluation of the distance of the medial ends of clavicles from spinous processes helps determine the extent of patient rotation (Fig. 1 on page 10).

Lateral decentering (x-ray tube positioned lateral to the patient's midline) may also cause asymmetric exposure, because the x-ray beam is more intense and perpendicular to the side positioned nearby.

The importance of faulty radiologic technique can generally be considered by checking out the position of mediastinum and the relative exposure of soft tissues in the affected side (especially around the shoulder girdles).

2. Anatomic variations

Besides technical factors, anatomic variations may also result in the appearance of hyperlucent lungs. The best-known example is the patient with a very thin body habitus, which results in an overpenetrated chest film.

Asymmetric absence of soft tissues can likewise result in unilateral hyperlucency. Radical mastectomy is the most common source of this problem, where relative radiolucency is seen on the side of the breast removal (Fig. 2 on page 10).

A similar appearance is noted in congenital abnormalities of the chest wall, such as the Poland syndrome. This condition is characterized by congenital unilateral aplasia of the pectoralis muscles and is associated with ipsilateral syndactyly, brachydactyly, and rib anomalies.

Thoracic spine scoliosis results in alterations to the soft tissues in the path of the x-ray beam and may cause uneven compression of the chest wall against the cassette.
3. Cardiac and pulmonary conditions

When both technical impropriety and chest wall defects are excluded as possible sources, the presence of a decreased blood flow through the lung as cause of unilateral hyperlucency is highly suspected. This may be the result of either vascular disease, primary pulmonary disease, or central airway conditions. These categories can be further subdivided into congenital and acquired conditions. In this section, we will discuss these three main categories, with special emphasis on a few common and uncommon diseases. A small rest group covers mediastinal and pleural space abnormalities. A complete list of causes of unilateral hyperlucency, some of which are not discussed in the text, can be found in Table 1 on page 11.

3.1 Pulmonary vascularity abnormality

**Pulmonary artery hypoplasia** is a rare congenital anomaly that results from incomplete lung development. The condition is radiographically characterized by a hyperlucent lung and a slightly smaller hemithorax on the affected side. There is volume loss, which is indicated by elevation of the hemidiaphragm and mediastinal shift toward the involved side. The affected lung may be hyperlucent due to oligemia. Because of compensatory hyperinflation, the contralateral side may also appear hyperlucent. CT can confirm the diagnosis by showing absence of the main branch of the pulmonary artery.

**Pulmonary embolism** is caused by dislodgement of a thrombus to the pulmonary arterial bed. The chest radiograph is often the first imaging study obtained, but it is neither sensitive nor specific for the diagnosis. Moreover, nearly 50% of thromboemboli do not produce any plain film findings at all. The main role of radiography is to exclude other diseases, such as pneumonia and pneumothorax, that may mimic pulmonary embolism clinically. In case of massive pulmonary emboli, blood flow through the main pulmonary artery is obstructed, producing bilaterally hyperlucent lungs. Fortunately, this is a rare occurrence. A large unilateral embolus can result in a unilateral hyperlucent lung. More localized areas of hyperlucency may result from smaller pulmonary emboli. These "oligemic" lung fields, distal to the occluded vessel, were first described by Westermark, a 20th century German radiologist. Thus, the Westermark’s sign describes a decreased vascularity in the peripheral lung secondary to mechanical obstruction or reflex vasoconstriction in pulmonary embolism. The sign has a low sensitivity (11%), but high specificity (92%) for the diagnosis of pulmonary embolism. When seen, the Westermark’s sign can be very helpful in suggesting further workup for pulmonary embolism in the appropriate patient population. On frontal chest radiographs, an increase in translucency is depicted, representing the collapse of the distal vasculature. CT pulmonary arteriography is currently the most definitive procedure for the diagnosis
of pulmonary embolism. Besides the hypoattenuated peripheral oligemia distal to the occlusive embolus, this modality may show widening and abrupt cut-off of a major pulmonary artery (Fig. 3 on page 12).

3.2 Lung parenchymal abnormality

**Emphysema** is defined as "a group of pulmonary diseases characterized by abnormal permanent enlargement of air spaces distal to terminal bronchioles with destruction of alveolar walls". This definition emphasizes the fact that there are different forms of emphysema, being centrilobular and panlobular emphysema. Panlobular emphysema may be accompanied by bullous lesions, however, bullous emphysema also occurs in an isolated form.

On chest radiography, there are signs of hyperexpansion, such as flattened hemidiaphragms with widened costophrenic angles, increased retrosternal space, horizontal ribs, and a narrow mediastinum.

Emphysema is a very important cause of loss of pulmonary vascularity. Severe cases of emphysema will produce marked attenuation and stretching of peripheral pulmonary vessels. Whereas vascular alterations may be subtle on plain film, high-resolution CT is very sensitive for detection of early emphysema by demonstrating vascular attenuation, areas of hyperlucency and small bullae. Moreover, CT is able to assess the severity and to discriminate between the different types of emphysema. Centrilobular emphysema tends to involve the upper lobes, while panlobular emphysema has a lower lobe predominance.

**The Swyer-James syndrome** or unilateral hyperlucent lung syndrome is a relatively uncommon entity, secondary to infectious obliterative bronchiolitis in infancy or childhood. The injury to the immature lung commonly follows a viral infection, with adenovirus being the most common organism. The affected lung parenchyma shows a variable degree of destruction, and bronchiectasis could be associated. Typically, this disorder is diagnosed in childhood after an evaluation for recurrent respiratory infections. Some patients, however, have little or no sequelae bronchiectasis and may miss their diagnosis until adulthood when abnormal findings are seen on an incidental chest radiograph. The damage to the developing lung results in hypoplasia of the pulmonary artery and its branches, which are reduced in both size and number. Therefore, the Swyer-James syndrome typically manifests with a unilateral hyperlucent lung as characteristic finding. Narrowing of the bronchiolar lumens leads to compensatory hypoperfusion with secondary hyperexpansion of the peripheral airway, which contributes to the hyperlucency.
In conclusion, the radiographic findings of Swyer-James syndrome consist of unilateral hyperlucency, a diminutive ipsilateral hilum with a small pulmonary artery, bronchial wall thickening, and bronchiectasis. The involved lung may show preserved volume, because of the hyperexpansion due to collateral ventilation and air trapping. This air trapping can be confirmed on both exhalational chest radiography and CT, with mediastinal shift toward the contralateral side on expiration.

CT scans are helpful in determining the extent of the disease, because they show above radiographic findings in a more extensive way. Although small, the segmental pulmonary arteries usually can be identified with CT angiography (Fig. 4 on page 12). Sometimes, CT reveals a mosaic attenuation pattern, a result of areas of preserved normal lung.

**Unilateral lung transplantation** is an accepted and increasingly common treatment for end-stage lung disease, such as emphysema, cystic fibrosis, pulmonary hypertension, and a variety of interstitial lung diseases. In case of emphysema and pulmonary hypertension, the native lung is radiolucent relative to the transplanted lung, which receives the bulk of the pulmonary perfusion. Consequently, mediastinal shift and compression of the transplant lung are important additional radiographic findings (Fig. 5 on page 13).

Patients with end-stage lung fibrosis who have single lung transplantation may show hyperlucency of the transplant lung, causing mediastinal shift towards the native lung.

Patients who have had pulmonary resections or who have lobar atelectasis, may show lucency of the residual aerated lung in the involved hemithorax because of compensatory overexpansion.

### 3.3 Central airway abnormality

**Foreign body aspiration** is the most frequent cause of intraluminal airway abnormality in children between 6 months and 3 years of age. The condition may be life-threatening, and patients may present with cough, respiratory difficulty, wheezing, hemoptysis, or recurrent pneumonia. Typically, it is caused by inhalation of food materials, especially peanuts, or toys. Most aspirated foreign bodies are located within the right main-stem bronchus, because of its larger diameter and more vertical course compared with the left main-stem bronchus.

The radiographic appearance of foreign body aspiration depends on size, location, duration and nature of the aspirated material. Most aspirated foreign bodies are nonradiopaque. In such cases, a variety of secondary indirect radiographic signs may indicate a diagnosis of foreign body aspiration. These include obstructive lobar or segmental pulmonary hyperinflation of the lung due to air trapping, hyperlucency due
to air trapping and pulmonary vasoconstriction, and consolidation. A complete bronchial obstruction may lead to total atelectasis of the affected lung. A small percentage (20-35%) of children with foreign body aspiration may have normal chest radiographic findings. If the child is cooperative and the initial chest radiograph is not conclusive, inspiratory and expiratory phase images under fluoroscopic monitoring are recommended to reveal air trapping due to the ball-valve effect of the endobronchial foreign body. On inspiration, the mediastinum shifts to the affected side (Fig. 6 on page 13), whereas the expiratory view demonstrates failure of the affected lung to collapse with mediastinal shift towards the normal contralateral side. In younger, less cooperative children, a lateral decubitus view of the chest with the suspected side down may show lack of collapse of the air-trapped lung. CT may directly identify a foreign body lodged in the tracheobronchial tree (Fig. 7 on page 14) as well as show such secondary changes as retained secretions, hyperaeration, atelectasis, and consolidation. Diagnostic endoscopy must always be performed when the history is compatible with foreign-body aspiration, with or without radiological confirmation.

**Congenital lobar emphysema** represents progressive hyperexpansion of a lobe or one of its segments, based on a congenital bronchial stenosis producing a check-valve mechanism. There are a variety of causes, including deficient bronchial cartilage (bronchomalacia), endobronchial lesions (e.g. mucosal web), and extrinsic bronchial compression (e.g. an anomalous vascular structure or mass). The obstructed lung becomes hyperinflated by collateral air drift. The disease becomes manifest in the first 2-4 weeks of life. The infant presents with dyspnea, tachypnea, tachycardia and cyanosis. In the first week of life, the lobe presents as an opaque mass due to retention of fluid. Later, the fluid is replaced with air and the affected hemithorax becomes hyperlucent on both radiography and CT. Ipsilateral diaphragm flattening and contralateral mediastinal shift may be present, a result of mass effect of the hyperinflated lung. CT can precisely locate the lesion. Furthermore, CT demonstrates hypoattenuated bronchovascular markings in the hyperlucent lobe, permitting exclusion of a pneumothorax.

In adults, the most frequent cause of bronchial obstruction is an **endobronchial tumor**.

A suspected endobronchial mass may result either in bronchial obstruction with atelectasis or bronchial obstruction with air trapping. Atelectasis, distal to bronchial obstruction, is the commonest sign of bronchogenic carcinoma, because most patients have underlying diseases that prevent normal collateral drift. Segments, lobes, or an entire lung are not aerated and collapse partially (dystelectasis) or totally (atelectasis). The affected parts of the lung become smaller and displace the interlobar fissures, mediastinum, diaphragm and the ribs.

Post-stenotic localized hyperexpansion of the lung is found in less than 2% of cases. Here, partial bronchial obstruction permits air to enter the distal lung area, where the air is then trapped, resulting in hyperexpansion and radiographical hyperlucency.
Mediastinal shift to the contralateral side and an enlarged contralateral hilus are additional features. Furthermore, attenuated vascular structures, resulting from pulmonary artery involvement by the tumor, may contribute to the unilateral hyperlucency.

3.4 Mediastinal and pleural space abnormalities

Hilar and mediastinal lesions including adenopathy, fibrosing mediastinitis, and, very rarely, benign masses, such as a bronchogenic cyst, may cause bronchial obstruction and result in a unilateral hyperlucent lung.

A large pneumothorax results in hyperlucency of the ipsilateral hemithorax and can be recognized by observing displacement of the visceral pleural line, absence of lung markings distal to the displaced pleural line, and contralateral shift of the mediastinum.

In some cases of hyperlucent hemithorax, the lucent side is normal and the opposite side is abnormally radiopaque. Diffuse pleural thickening on the more opaque side or pleural fluid layering posteriorly on a supine radiograph are frequent causes.
Fig. 1: Asymmetric patient positioning, leading to a hyperlucent left lung. Note the right-sided position of the trachea and the asymmetric position of the clavicles. When encountered with a unilateral hyperlucent lung, a technical etiology must always be considered.

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Fig. 2: PA chest radiograph of a 62-year-old woman after left mastectomy for breast cancer. Note the presence of a breast shadow on the right and the absence on the left. As a result, the left lung appears relatively hyperlucent compared with the right.

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Table 1: Congenital and acquired causes of unilateral hyperlucent hemithorax. °These conditions are congenital *These conditions may be congenital

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Fig. 3: Acute pulmonary embolism in a 85-year-old woman with known pulmonary hypertension, now presenting with acute chest pain and dyspnea. The CT images demonstrate a complete occlusion of the distal right main pulmonary artery secondary to extensive pulmonary embolism (a). The resulting oligemia of the lung distal to the occluded segment (Westermark's sign) with overall lung hyperlucency is clearly demonstrated (b).

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Fig. 4: Unexpected Swyer-James syndrome in a 67-year-old man with recurrent respiratory distress. Chest radiography (a) shows a hyperlucent left lung with decreased vascularity, most pronounced in the left upper lobe. Axial CT images (b, c) reveal extensive hyperlucency of the left lung with marked decreased overall vascularity and small pulmonary vessels at the left hilar region. The findings remained constant over many years.

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Fig. 5: PA chest radiograph (a) of a 62-year-old woman with a right lung transplant. Both conventional and CT images (b) show the marked hyperlucency of the native left lung due to extensive emphysema. Note the shift of heart and mediastinum to the right, due to the smaller-sized transplant lung with secondary overexpansion of the left native lung.

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Fig. 6: Foreign body aspiration in a 2-year-old girl. The initial chest radiograph shows an asymmetric expansion of the thorax, with a right-sided hyperaeration and shift of the mediastinum to the left side. These findings are suggestive of an obstructive air trapping process on the right mainstem bronchus.

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Fig. 7: The CT image shows the hyperlucent and overexpanded right lung and the mediastinal shift to the left (a). A closer examination of the mediastinal bronchial structures (b) reveals a small mass with soft tissue density in the main right bronchus, responsible for an endobronchial obstruction with consequently air trapping in the right lung.

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Conclusion

In the approach of unilateral hyperlucency, technical factors and chest wall abnormalities are the possible causes to be considered first. A true decrease in pulmonary density may result from a combination of changes in the relative amounts of air, blood, and interstitial tissue. Therefore, the different congenital and acquired conditions are categorized in three major groups, being central airway abnormality, pulmonary vascular abnormality, and lung parenchymal abnormality. Hyperexpansion, with or without air trapping, and alteration in vasculature, are the most important mechanisms in the pathophysiology of a hyperlucent lung.

Unilateral hyperlucency is an occasional finding on chest radiography and CT. Understanding the spectrum and pathophysiology of the numerous possible causes and their associated radiological signs, can permit early and accurate diagnosis. In this educational exhibit, we offered a systematic approach, by which the differential diagnosis may be narrowed to just a few possible causes (Fig. 8 on page 17).
Fig. 8: Flowchart, showing an algorithm to help systematically approach a unilateral hyperlucent lung.

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