Lung ultrasonography: Basic principles and clinical applications

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Learning objectives

1. Present the ultrasonographic signs of the normal lung and pleura.

2. Illustrate the sonographic patterns and artifacts related to pleural and pulmonary diseases.

Images for this section:

Fig. 1: Evangelismos Hospital, Athens, Greece.
Background

Ultrasonography (US) was considered a poorly accessible method for visualizing pulmonary and pleural diseases due to the inability of sound to penetrate air-filled lung. Despite its limitations, transthoracic US is becoming an important diagnostic tool in a growing number of pathological situations such as pneumonia, atelectasis, interstitial-alveolar syndrome, pulmonary embolism, pneumothorax and pleural effusion. The technique is particularly suited to bedside use in the intensive care unit, due to low sensitivity of chest X-ray and to the fact that computed tomography (CT) is not easy to perform.

Imaging findings OR Procedure details

Sono transthoracic anatomy

Basic sonographic anatomic landmark for the examination of the lung constitutes the localisation of pleura. Sonographically is described as an intense hyperechoic line that is created by the surface of visceral pleura against the surface of air filled lung and indicates the location of pleura in a normal ultrasound pattern (pleural line) (Fig.1,2). The thoracic wall is recognized by the characteristic posterior shadowing of the ribs. Intercostal muscles are extended between the ribs, creating a useful intercostal sonographic window. Due to the various thickness of the subcutaneous tissue, the ribs constitute the more suitable anatomical landmark on the recognition of the pleura, 0.5-1 cm in depth from the hyperechoic surface of the ribs (Fig.1).

Normal lung signs, points, lines and patterns

Lung sliding

- It is described as a hyperechoic line moving forward and back during the respiration recognisable in B-mode in real time (Fig.2).
- Represents the normal sliding of the two layers of the pleura.

Seashore sign

- It is a dynamic sonographic sign of the normal lung (M-Mode).
- It is described as a complex picture of parallel lines that represents the static thoracic wall above the pleural line and granulous, sandy pattern below the pleural line that represents normal pulmonary parenchyma (Fig.3).
• It is mainly used in cases in which the lung sliding sign is not diagnostic for the presence of pneumothorax.

"A" Lines

• They are horizontal parallel hyperechoic lines, parallel to the pleural line, a basic lung artifact of the normal lung (Fig.1,2).
• They are produced by the intense reflection in the surface of contact of soft tissue and the surface of air-filled lung.

Pathologic lung signs, points, lines and patterns

"B" lines or "comet tail artifacts"

• It is the presence of at least 3 in number hyperecoic lines that are perpendicular to the pleural line.
• The number of these vertical "B" lines depends on the degree of lung aeration loss and their intensity increases with inspiratory movements.
• Their presence excludes the existence of pneumothorax. "Comet tail artifacts" can be single or multiple, localized or disseminated to the whole anterior chest wall.
• They are from each other separated depending on the distance in lines B3 and B7 when the distance is # 3mm and #7 mm respectively. A distance between multiple lines "B" #3 mm (B3 lines) is correlated with ground glass pattern (Fig.4). A separation of artifacts of about 7mm indicates thickening of the interlobular septa (B7 lines) (Fig.5)

Lung point

• It is a specific sonographic sign in the diagnosis of pneumothorax.
• Indicates the point of transition between the pneumothorax pattern (absent lung sliding plus "A" lines) at the expiration phase replaced by a normal lung pattern (lung sliding or patologic comet-tail artifacts) at the expiration phase.
• In normal conditions, in M-mode, lower to the pleural line, the movement of the 2 layers of pleura creates a granulous"pattern". On the contrary, in pneumotorax, the absence of motion of the 2 layers because of the presence of air, is characterized in M-mode by a horizontal pattern.

Lung pulse

• It is a diagnostic dynamic sign of complete atelectasis.
• It is characterized by the absence of lung sliding in B-mode with the simultaneous presence of cardiac pulse in the pleural line in M-mode.
• Presents 93% sensitivity and 100% specificity in the diagnosis of complete atelectasis

**Air broncogramm**

• Sonographic visualization of air broncogramms constitutes an important diagnostic lung artifact in the differential diagnosis between pneumonia and atelectasis.
• It is constituted by hyperechoic punctiform or linear artifacts inside a tissue like pattern of the pulmonary consolidation.
• It is distinguished in dynamic and static. The dynamic air broncogramm is characterized by presence of air inside the bronchi in dynamic movement inside the tissue like pattern (Fig.6). It is a lung artifact that presents 94% and 97% specificity and positive prognostic value and 61% and 43% sensitivity and negative prognostic value in the diagnosis of pneumonia versus resorptive atelectasis. On the contrary, static air broncogramm is an indication of atelectasis and is characterized by the motionless entrappment of air inside the atelectatic region of lung.

**Clinical applications**

**Diseases of the lung**

**Pulmonary consolidation**

• Pulmonary consolidations appears sonographicall as a heterogeneous tissue like pattern resembling the echo-texture of the liver.
• Within the consolidation, hyperechoic punctiform or linear artifacts, corresponding to air broncogramms can be seen (Fig.6)

**Atelectasis**

• Atelectasis is a relatively common condition in the ICU which requires early diagnosis and urgent treatment.
• Passive atelectasis is recognized sonographically by the depiction of atelectatic lung inside anechoic pleural effusion with presence of entrapped air inside the bronchi (Fig.7). A dynamic lung ultrasound sign indicating complete atelectasis is "lung pulse". It is the association of absent lung sliding with the perception of heart activity at the pleural line with a sensitivity of 93% and a specificity of 100% for the diagnosis of complete atelectasis following selective intubation in patients without previous respiratory disorders.
Alveolar interstitial syndrome

- Radiological diagnosis of alveolar interstitial syndrome is based on the chest x-ray while CT represent the gold standard examination which provides accurate information for the differential diagnosis of this heterogeneous group of diffuse pulmonary diseases.
- The radiological equivalence of sonographic B3 and B7 lines (Fig.4,5) with the CT pattern of ground glass and thickened interlobular septa respectively, created new data in the use of lung ultrasound in the study of alveolar interstitial syndrome.
- Alveolar infiltration and thickening of interstitial lung tissue or even their combination, is visualized sonographically with high sensitivity (93,4%) and specificity (93%).
- In a dyspnoic patient, analysis of lines "B" offers direct differential diagnosis between acute pulmonary edema and exacerbation of chronic obstructive pulmonary disease (COPD).
- Chest sonography constitutes a useful tool to differentiate acute cardiogenic pulmonary edema and acute respiratory distress syndrome (ARDS).

Pulmonary Embolism

- An important effort is made in various studies in the diagnosis of pulmonary embolism with the use of transthoracic ultrasound.
- Pulmonary embolism may be recognized as a peripheral wedge shaped hypoechoic region.
- According to the study of Mathis et al, in 194 patients with documented pulmonary embolism, US presented 74% sensitivity, 95% specificity and positive and negative prognostic value 95% and 75% respectively.

Diseases of the pleura

Pneumothorax

- Pneumothorax is defined by the interposition of gas between visceral and parietal pleural layers. It presents as a complication of previous trauma, mechanical ventilation, ARDS, diagnostic and therapeutic thoracentesis and central vein or pulmonary artery catheter insertion.
- Important diagnostic tool in the diagnosis of pneumothorax constitutes transthoracic ultrasonography.
- In various comparative studies, ultrasound presents high rates of sensitivity and speciality.
- Abolition of lung sliding presents 95,3% sensitivity, 91,1% specificity and 100% negative predictive value excluding with precision pneumothorax.
• Presence of lines "A" present 100% sensitivity and negative prognostic value and 60% specificity in the diagnosis of pneumothorax.
• The combination of these two signs, abolition of "lung sliding" and the simultaneous presence of "lines A" present 95% sensitivity and 94% specificity
• Lung point is another specific sonographic sign in the diagnosis of pneumothorax. Present sensitivity between 66% to 79% and 100% specificity The detection of this sign enables a confident diagnosis and approximate evaluation of the extent of the collection.

Pleural effusion

• Pleural cavity constitutes an excellent window for sonographic imaging (Fig.8).
• US is considered as an accurate method for the diagnosis, quantification, and estimation of the nature of the pleural effusion.
• Calculation of volume of pleural effusion is based on the measurement of the maximal distance of the two layers of the pleura, visceral and parietal at the posterior axillary line in end expiration. The amount of pleural fluid can be estimated by the following formula: \( V (\text{ml}) = 20 \times \text{Sep (mm)} \), \( V \) = volume, Sep= maximal distance of the two layers of the pleura. This study was held in mechanically ventilated patients in ICU with mild trunk elevation at 15°. Limitations of this study were small (Sep <10mm) and loculated effusions.
• US also constitutes an important tool in the location of puncture site selection. According to a study at which where compared clinical and US criteria for the puncture site selection, the study elected the necessity of use of US in 15% with reduction of pleurocenetsis complications in the same percentage.
• One of the advantages of use of US is also the determination of the nature of pleural effusions. Transudates were anechoic, whereas an anechoic effusion could be either a transudate or an exudate. According to a study in 127 patients with transudate pleural effusion, the effusion had an anechoic pattern in 45% and a complex non septated pattern in 55%. US is able to depict complex lobulated effusions indicating an exudate in the majority of cases (Fig.9). Studies have comparatively proved the superiority of US in depiction of septa.

Images for this section:
Fig. 1: Sono anatomy of the chest. US appearance of the echogenic subcutaneous tissue and the hypoechoic with multiple echogenic fascia intercostal muscle. Intercostal visualization of pleural line and the horizontal lines parallel to the pleural line, called "A" lines.
Fig. 2: Real-time sonographic view of a normal lung with lung sliding and the presence of "A" lines.
Fig. 3: Seashore sign. Correspondence of pleural line in B-mode and M-mode. In M-mode a complex picture of parallel lines that represents the static thoracic wall above the pleural line and granulous, sandy pattern below the pleural line that represents normal pulmonary parenchyma.
Fig. 4: Multiple comet tail artifacts, perpendicular to the pleural line, with a distance of # 3mm (B3 lines).
Fig. 5: Multiple perpendicular to the pleural line comet tail artifacts with a distance of #7 mm. (B7 lines)
Fig. 6: Pulmonary consolidation with presence of air broncogamms in US.
Fig. 7: Passive atelectasis of left upper lobe with presence of large pleural effusion. TA= Thoracic aorta
Fig. 8: A large anechoic pleural effusion.
Fig. 9: Large pleural effusion with presence of septa.
Conclusion

The use of lung US appears as an attractive alternative to chest radiography and lung CT. It is non-invasive, easily repeatable at the bedside and provides an accurate evaluation of the respiratory status especially in the critically ill patients.

Images for this section:
Fig. 1: National and Kapodistrian University of Athens
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References