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Lung Sonography

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1. Introduction

Lung ultrasonography has come of age and is a well established technique that can be performed quickly at patient's bedside to evaluate for various pathological conditions. This is despite the fact that air is not a favorable medium for transmission of ultrasound waves, and lung being an air filled organ, it was considered not amenable to ultrasonographic evaluation. Dr. Daniel Lichtenstein is one of the pioneers who has developed the field of lung sonography over the last two decades. He has contributed immensely by publishing numerous landmark articles that built the basic concepts of lung sonography. Since then there have been many other groups around the world who have published their findings that have helped to expand this field even further. This chapter will review the utility of lung sonography to evaluate for the following conditions:

1. Pleural effusions
2. Pneumothorax
3. Alveolar interstitial syndromes
4. Acute respiratory distress
5. Peripheral lung masses

2. Basic principle and technique of lung sonography

Body is made up of different biologic media (bone, muscle, fat, air, blood etc). The speed of sound and the acoustic impedance (resistance of a tissue to the passage of ultrasound) varies for different biological media, but the average value is assumed to be 1,540 m/ sec (constant) for most human soft tissues. The difference in acoustic impedances of the two tissues at the interface, determines the extent of reflection and partly the attenuation of ultrasound waves. Greater the difference, more the reflection and attenuation. The speed of sound through air is only 300 m/ sec with very low acoustic impedance. Hence at the tissue-air interface (chest wall-lung) there is a large difference in the acoustic impedance leading to reflection of ultrasound waves. For this reason ultrasonography of lung appears as homogenous amorphous grayness rather than a discrete structural entity. Disease processes that reduce the amount of air in the lung, extend to the periphery, or result in collection of fluid in the pleural space make the ultrasonographic examination of the lung feasible. Because of the difference in acoustic impedance and velocity of ultrasound between tissues, certain artifacts (described in the chapter) arise at the air-tissue-fluid-bone interface. These artifacts

were recognized and described by the pioneers in this field, and form the background of pleura-pulmonary ultrasonography.

3. Equipment

There are many ultrasound machines currently available in the market, and any one of those with 2 dimensional (2D) capability can be used for lung sonography (Photo 1a). Doppler ultrasound is not needed for lung sonography. The new generation machines may contain software and filters to optimize image quality, mainly for echocardiography. The fundamentals of lung sonography have been built on artifacts that were described by the original investigators using a simple 2D machine and probe, without these filters. Some machine may allow the user to override the filter settings. A sector or curved-array transducer with a frequency of 2-5 MHz is suitable for lung sonography. Higher frequency probes can be used to visualize the pleura (Photo 1b). One of the basic principle of sonography is, higher the frequency, lower the depth of penetration, with a higher resolution. The foot-print of the transducer should fit well between the rib spaces to avoid rib artifact. Probe should be in the cranio-caudal orientation with the probe marker towards the head. Radiologists while performing sonography keep the screen marker towards the left side of the screen and cardiologist keep it towards the right. Lung sonography is a new field being developed over the last two decades by intensivists and pulmonologist. It is important to maintain a standard probe orientation and screen marker position. In this chapter the screen marker will be seen on the right side of the screen, with the probe marker towards the head, in the cranio-caudal orientation. Prior to beginning an examination, gain and depth should be adjusted. One can start with a higher depth and then zoom in on nearer structures. Gain should be adjusted to optimize image quality. The gain function

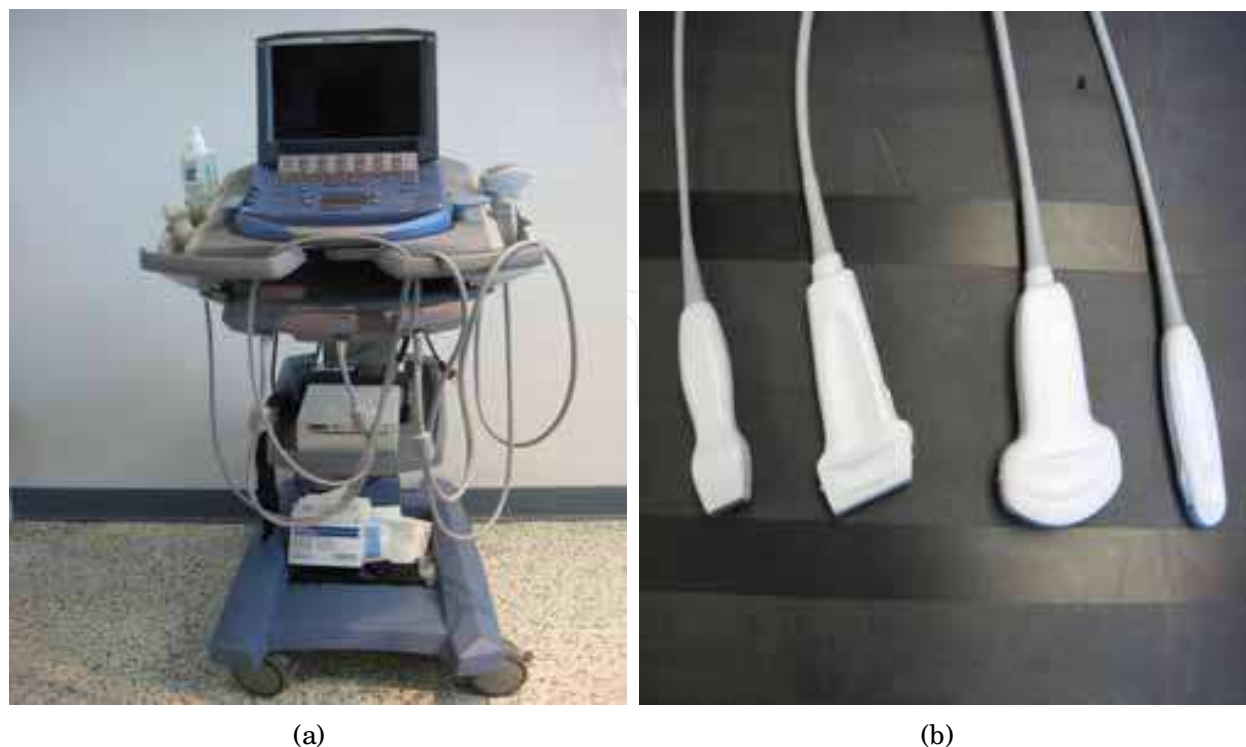


Photo 1. (a) Portable ultrasound machine. (b) Various ultrasound probes

compensates for attenuation (a reduction in sound amplitude) as sound travels deep into the body. The intensity of the returning signals can be amplified by the receiver upon arrival so that the displayed image is brighter and more visible on the screen. Gain can be adjusted for the near field, far field or the entire field (overall gain). If the gain is set too low, the image appears dark. Excessive increase in gain will add "noise" to the image, and make it appear too bright.

4. Ultrasound examination of lung

Depending upon patient's clinical condition and the reason for evaluation, the patient can be in supine, sitting, lateral decubitus, or semi-recumbent position. Critically ill patients in the intensive care unit are usually examined in supine, or partially rotated position. Transducer is in a cranio-caudal direction with the probe marker pointing cranially. The chest is divided into three zones, anterior (between sternum and anterior axillary line), lateral (between anterior and posterior axillary line), and posterior (between the posterior axillary line and spine) (Photo 2). The goal is to perform a complete lung examination by moving the probe along interspaces in a series of longitudinal scan lines. An organized approach is recommended with multiple points of examination in the anterior zone, followed by lateral zone, and if patients clinical condition permits, the posterior zone.



Photo 2. Anterior zone (between sternum and anterior axillary line). Lateral zone (between the anterior and posterior axillary line). Posterior zone (between posterior axillary line and the spine)

With the probe between two rib spaces, in the cranio-caudal direction, the normal ultrasound examination of the lung appears as shown in (Figure 7). Between the acoustic shadows of the two adjacent ribs, a hyperechoic horizontal pleural line is present, approximately 0.5 cm below the origin of the rib shadow. The pleural line is made up of the visceral and parietal pleural surfaces, and represents the interface between chest wall and aerated lung. With respiration pleural surfaces slide against each other, which on 2D mode

appears as a shimmering white line moving in synchrony with respiration. This is called the lung sliding sign, a dynamic sign seen on 2D mode. There is a commonly seen artifact on 2D mode, called the A-line (Figure 13). Presence of A-line with lung sliding indicates the presence of a normally aerated lung. In the absence of lung sliding, their presence is non-specific. A-lines are horizontal artifacts, arising from reverberation of ultrasound waves between the skin and pleural surface. Repetition of this artifact occurs at a distance equal to the distance between the probe head on the skin surface, and the pleural line.

5. Pleural effusions

The utility of ultrasonography for the diagnosis of pleural effusion is well established. Ultrasound can detect pleural effusions as small as 3-5 milliliters (*Grymiski et al., 1976*). Physical examination is less accurate than ultrasonography in detecting a pleural effusion (*Diacon et al., 2003*). It can be difficult to distinguish between pleural thickening, atelectasis, pleural effusion, parenchymal infiltrates or a combination of these findings on a chest radiograph (*Overfors & Hedgecock, 1978; Yu et al., 1993*). Ultrasonography has been shown to be a better imaging modality than chest radiograph in distinguishing between these abnormalities (*Grymiski et al., 1976; Kelbel et al., 1991*). Ultrasonography was shown to have a diagnostic accuracy of 93% when compared with chest computerized tomography (CT) scan in detecting a pleural effusion (*Lichtenstein et al., 2004a*).

Free flowing fluid in the pleural space accumulates in the dependent portion of the thoracic cavity. Depending on patient's clinical condition and comfort, the patient can be in a sitting, supine, semi-recumbent or in a lateral decubitus position (Photo 4). The goal should be to examine as much of the hemithorax as possible to be able to detect even small or loculated pleural effusions.

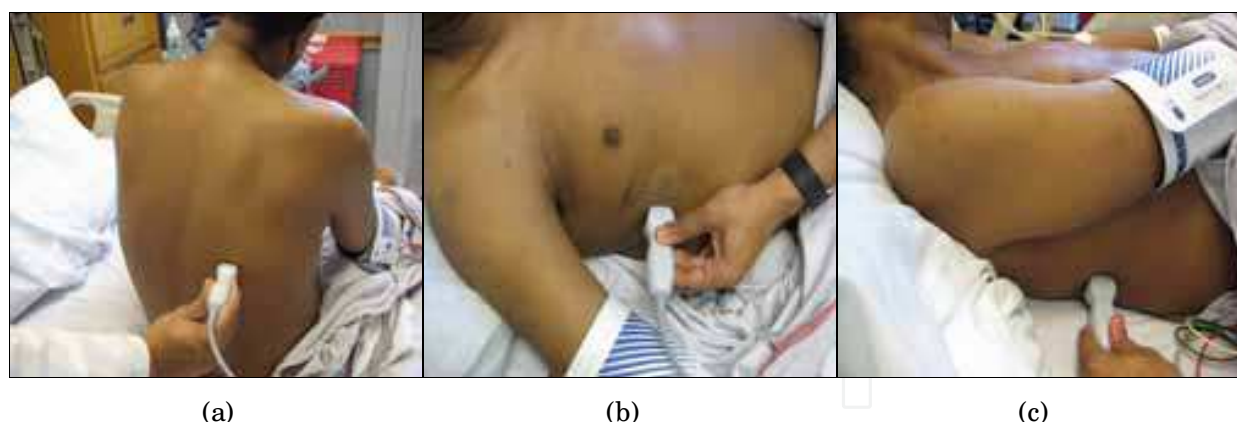


Photo 4. Patient in (a) sitting, (b) supine, and (c) slightly rotated position

There are three important findings that are useful in diagnosing a pleural effusion with the help of an ultrasound (Figure 1):

1. Anatomic boundaries of pleural effusions: the chest wall, the diaphragm, the lung and the subdiaphragmatic organs.
2. The presence of an anechoic space (black) between the visceral and parietal pleura.
3. Dynamic changes.

The probe should be in the cranio-caudal direction and the examiner needs to be aware of the position of the probe marker on the ultrasound screen for proper orientation. The first step is to identify the diaphragm as a curvilinear hyperechoic structure that moves with respiration. Pleural fluid in general is visualized as a hypoechoic or an anechoic collection above the diaphragm (Figure 1).

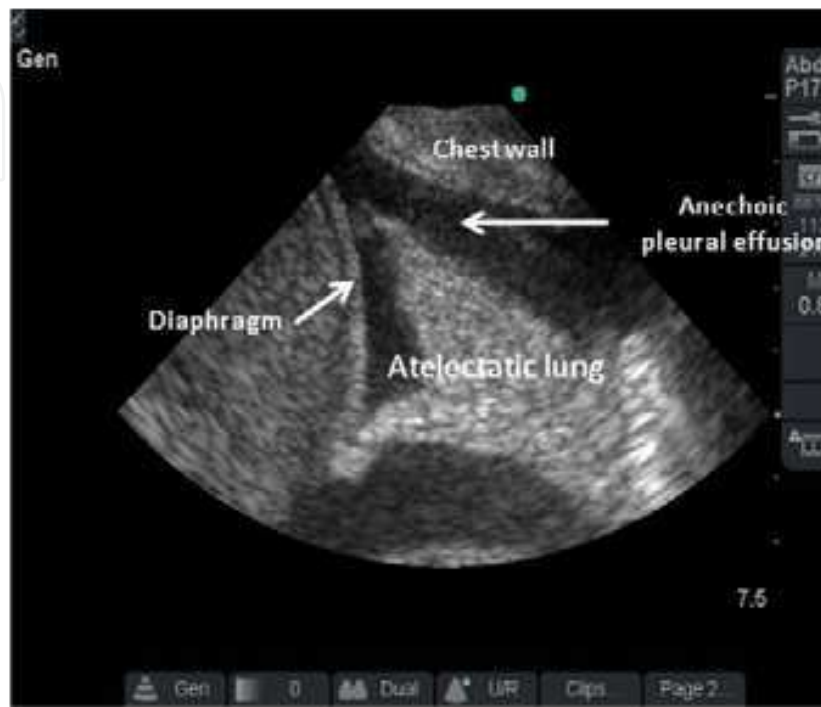


Fig. 1. Pleural effusion is present as an anechoic space with anatomic boundaries made up of chest wall, diaphragm and atelectatic lung

In the presence of moderate to large pleural effusions, the adjacent lung may become atelectatic and appears as tissue like structure flapping in the pleural effusion (flapping lung or the jellyfish sign). The compressed lung has an echogenicity similar to that of the liver, and this is termed as sonographic hepatization of the lung (Figure 1). Aerated lung may be seen moving over the pleural effusion with respiration. This is called the curtain sign. The movement of visceral pleural towards or away from the chest wall with inspiration and expiration creates a sinusoidal waveform pattern on M mode ultrasound (Figure 2). The sinusoid sign is a dynamic sign and is very specific for the diagnosis of pleural effusion, and can be helpful in distinguishing small pleural effusions from pleural thickening. Cellular or proteinaceous debris in the pleural fluid can be agitated by respiratory or cardiac motion creating a swirling pattern, which is called the plankton sign. Fibrin strands may be present and seen floating in the effusion or connected to each other in a lattice like pattern. Cellular debris in the effusion may settle down due to gravity, this creates an echogenic layering effect (hypocellular hypoechoic top layer with a cellular hyperechoic bottom layer) called the hematocrit sign.

Sonographic characteristics of the pleural fluid have been used to distinguish transudates from exudates. Effusions can have one of the following sonographic patterns, (1) anechoic: echo-free (black) space between the visceral and parietal pleura (2) complex non septated:

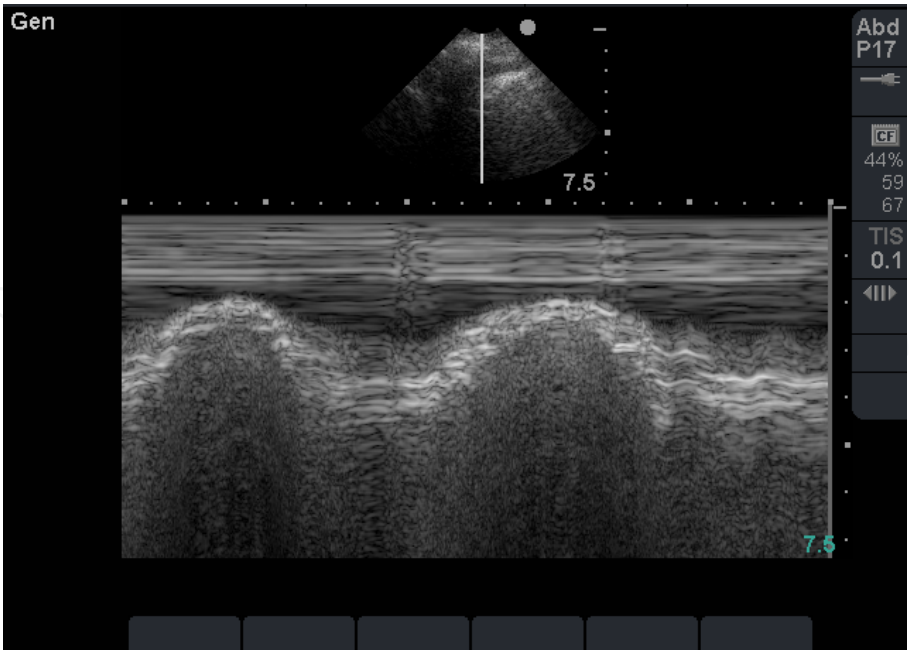


Fig. 2. Sinusoid sign on M mode (arrows)

echogenic material is present in a non homogenous pattern without septations (Figure 3). (3) complex septated: floating fibrin strands or septae in a lattice like pattern are present (Figure 4). This can be seen in parapneumonic effusions, empyemas, and malignant effusions. Ultrasonography has been shown to be superior to CT scan in detecting septations in pleural effusions (*McLoud & Flower, 1991*), and (4) homogeneously echogenic: very cellular echogenic material is strewn homogeneously in the effusion, as in an empyema or hemorrhagic effusions (Figure 5). Transudates are almost always anechoic (*Yang et al., 1992*). Exudates on the other hand can have any of the four patterns.



Fig. 3. Complex non septated pleural effusion



Fig. 4. Complex septated pleural effusion



Fig. 5. Homogeneously echogenic pleural effusion

Additional findings on sonography may be helpful to assess the etiology of pleural effusions. Echogenic swirling patterns or the presence of pleural nodules are suggestive of malignant effusions (*Chian et al., 2004*). The presence of adjacent consolidated lung with mobile hyperechoic air bronchograms indicates an effusion of infectious origin (Figure 6).

Loculated pleural effusions may be missed if the entire hemithorax is not examined, as they can be in non dependent areas. They do not change with body position, can be circular or elongated, with thick pleural linings.

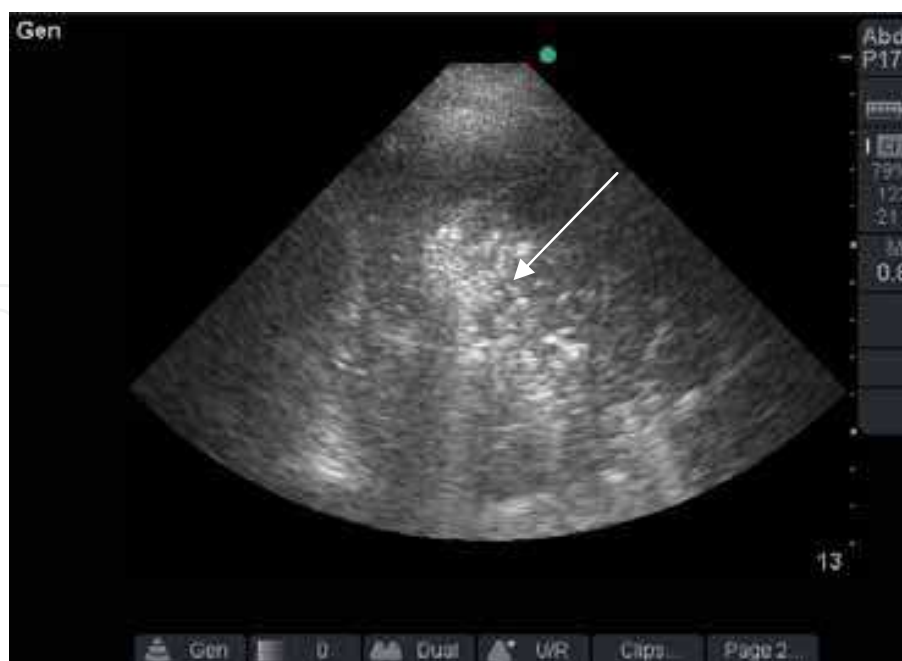


Fig. 6. Consolidated adjacent lung (arrow), suggesting a parapneumonic effusion

Many methods have been described to estimate the volume of pleural fluid (*Balik et al., 2006; Eibenberger et al., 1994*), and are reasonably accurate. It is best to classify the effusion as small: seen in one probe range, moderate: seen in two probe range and large: greater than two probe range.

Thoracentesis is a routinely performed procedure, although considered safe, the incidence of pneumothorax has been reported to be as high as 20 to 39% (*Grogan et al., 1990*). Several studies have shown that ultrasound guided thoracentesis has lower complication rates. In one study there was a significant reduction in pneumothorax rate when ultrasound was utilized for identification of needle placement (0% vs approximately 29%) (*Grogan et al., 1990*). A similar reduction in the rate of pneumothorax was reported in another study (18% vs 3%) (*Raptopoulos et al., 1991*). The procedure can be performed with real-time guidance for needle insertion with ultrasound, or the puncture site can be identified and marked. If the latter approach is used, it is important not to change patient's position, or delay the procedure, as this may displace freely flowing pleural fluid.

6. Pneumothorax

Early detection of pneumothorax is extremely important, especially in trauma patients and critically ill patients on mechanical ventilation. CT scan of chest is the gold standard test, but cannot be done immediately, may not be available in certain settings, and requires transport of patient to the radiology unit. Hence it is not an ideal test for a potentially life threatening situation such as pneumothorax. Chest radiographs are widely available, can be done relatively quickly and are routinely performed to evaluate a patient for pneumothorax. However, supine chest radiographs are not reliable, and have a high rate of misdiagnosis (*Chiles & Ravin, 1986; Tocino et al., 1985*). Ultrasonography can be performed quickly at patient's bedside, and has been shown to be very effective for rapidly ruling out pneumothorax (*Lichtenstein 1995, 1999, 2000, 2003, 2005*). Certain procedures, such as,

thoracentesis, central line placements, lung biopsies etc carry a high risk of iatrogenic pneumothorax. Performing an ultrasound examination before and after the procedure can immediately rule out, or confirm a pneumothorax.

Lung sonography to detect pneumothorax should be performed with the transducer in cranio-caudal orientation. Free air in the pleural space collects in the non dependent anterior chest, making supine position ideal for evaluation for a pneumothorax (Photo 5). Between the acoustic shadows of the two adjacent ribs, a hyperechoic horizontal pleural line is present, approximately 0.5 cm below the origin of the rib shadow (Figure 7). The pleural line is made up of the visceral and parietal pleural surfaces, and represents the interface between chest wall and aerated lung. With respiration pleural surfaces slide against each other, which on 2D mode appears as a shimmering white line moving in synchrony with respiration. This is called the lung sliding sign, a dynamic sign seen on 2D mode. Air movement during respiration cause the lung to expand and contract, this sign indicates the presence of an expanded lung, with visceral pleural in contact, and sliding against parietal pleura. Detection of lung sliding at multiple sites of the chest virtually rules out a



Photo 5. Supine position is ideal for the evaluation of pneumothorax. Multiple anterior and lateral points should be evaluated



Fig. 7. Between the two ribs (vertical arrows), 0.5 cm below, shimmering white pleural line (horizontal arrow) is located

pneumothorax (*Lichtenstein & Menu, 1995*). Absence of lung sliding on the other hand can be seen in many other circumstances besides a pneumothorax. Conditions that prevent air movement into the lung (airway occlusion with mucous plug, tumor, foreign body), or inflation of the lung (ARDS, pneumonia, apnea) will abolish lung sliding. Pleural effusion from inflammatory or neoplastic processes will also abolish sliding. Therefore the absence of lung sliding is not very useful.

Lung sliding, a dynamic sign on 2D mode can be recorded as a static sign on M mode. In the presence of lung sliding, the characteristic pattern observed is the seashore sign (Figure 8). The pleural surface is the boundary, above it there is a wave like pattern (motionless chest wall), and below it is a granular or sandy beach like pattern (air filled lung). In the absence of lung sliding the pattern observed is called the stratosphere sign, also called the bar code sign (Figure 9). The granular or sandy beach pattern below the pleural line is replaced by horizontal lines.

There are two more dynamic findings, lung pulse (*Lichtenstein et al., 2003*) and comet-tail artifacts (B-lines) (*Lichtenstein et al., 1999*), seen on 2D mode, that rule out a pneumothorax. With lung pulse, the force of cardiac pulsation causes synchronous movement of the pleural line. Even in the absence of lung sliding in conditions that cause obstruction of air entry (mucous plug, airway tumor etc), lung pulse may be observed, indicating the presence of an expanded lung. B-lines, also called comet tail artifacts, are vertical artifacts that arise from the visceral pleura (Figure 10). They are well defined, do not fade, look like a laser beam, and move with lung sliding. Multiple B-lines indicate the presence of an interstitial syndrome. B-lines 7 mm apart, indicate thickened interlobular septa, an ultrasound equivalent of Kerly B-lines. B-lines 3 mm apart, correlate with ground glass opacities. Since B-lines originate from visceral pleura, their presence rules out pneumothorax.

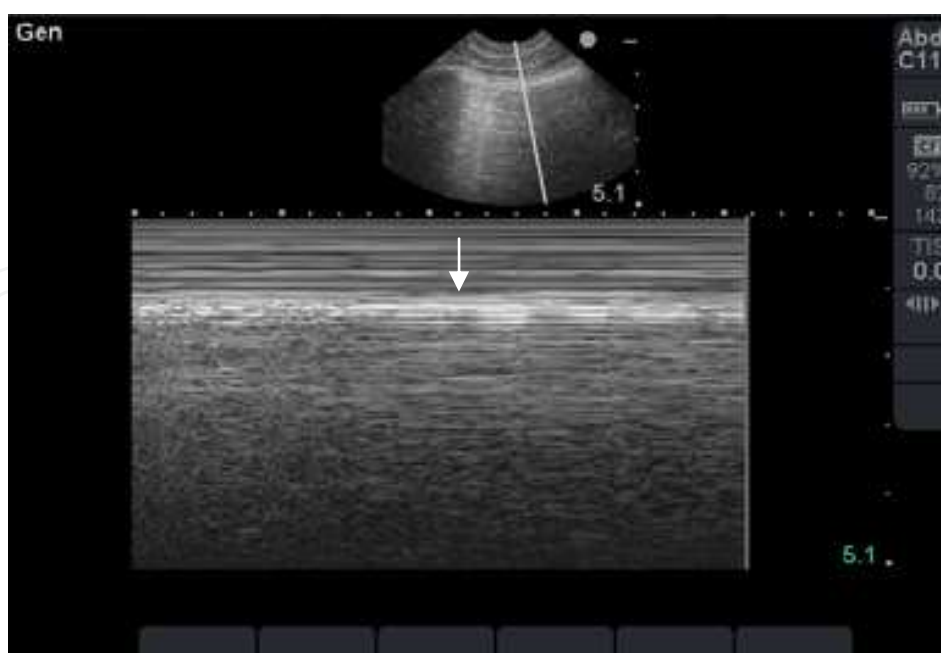


Fig. 8. Seashore sign on M mode, consistent with lung sliding. Above the pleural line (arrow), there is a wave like pattern created by the motionless chest wall. Below the pleural line is the granular, sandy beach like pattern, created by the air filled lung

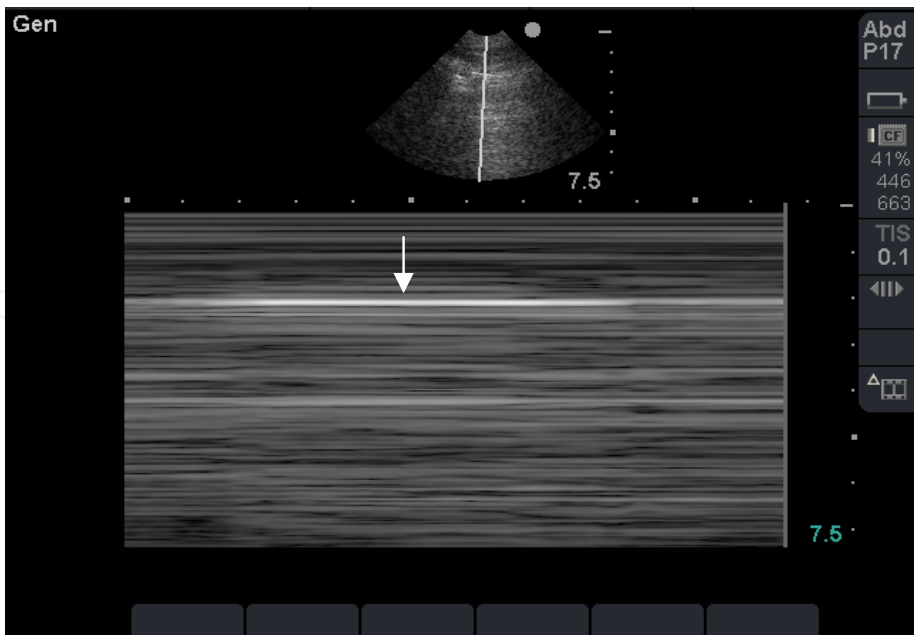


Fig. 9. Stratosphere sign on M mode, consistent with absent lung sliding. Horizontal lines above and below the pleural line (arrow), also called the barcode sign



Fig. 10. B-lines (arrow). Vertical, laser like, hyperechoic, do not fade, arise from the visceral pleural, and move with lung sliding

There is one dynamic sign on 2D mode that confirms the presence of a pneumothorax, the lung point sign (*Lichtenstein et al., 2000*) (Figure 11). Partially collapsed lung is in contact with the chest wall at some point, where the visceral and parietal pleura are in contact, and slide against each other with respiration. A thorough examination may reveal this point where the pleura slides in with inspiration as the lung expands, but during expiration as the lung contracts, lung sliding disappears. This sign is 100% specific for pneumothorax, but has low sensitivity (*Lichtenstein & Menu, 1995*). Low sensitivity could be due to multiple reasons,

operator skills, completely collapsed lung with no chest wall contact, incomplete examination, or the rib and sternum could be obscuring visualization. This sign can be recorded on M mode (Figure 12).

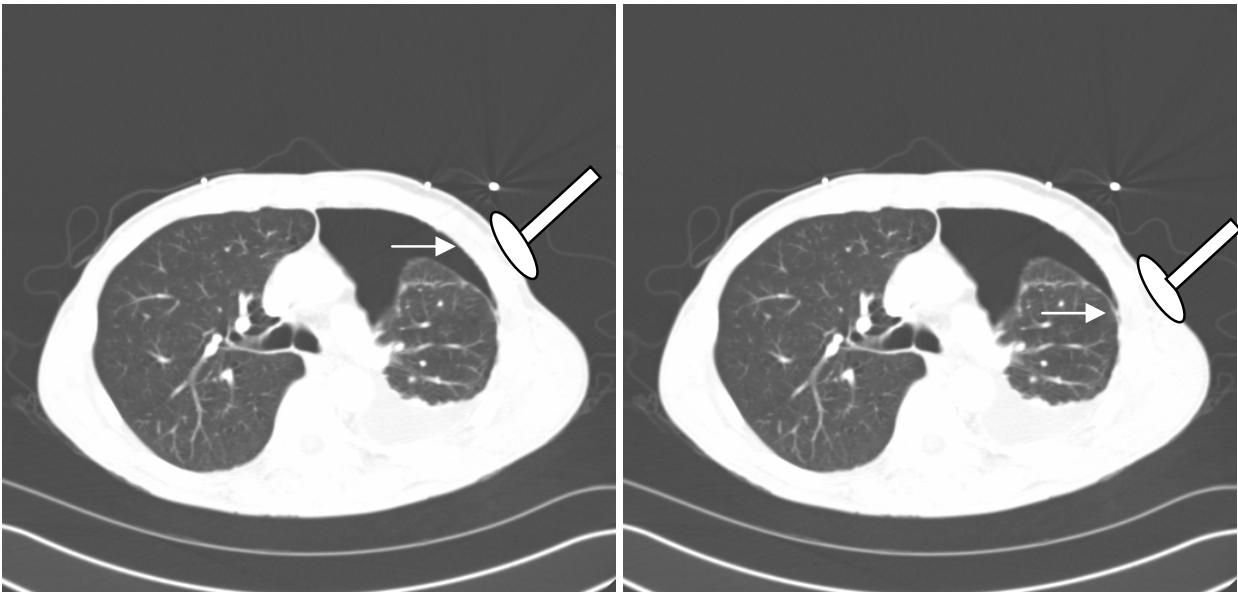


Fig. 11. Lung point sign. With the probe at this point, during expiration (1), the lung contracts, air comes between the pleural space (arrow). During inspiration (2), lung expands and slides in the ultrasound plane (arrow)

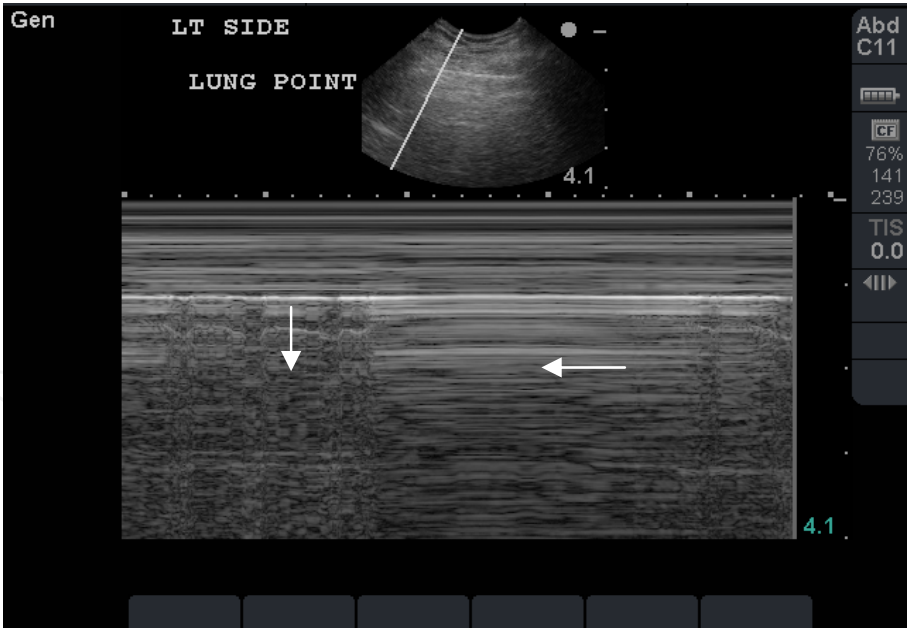


Fig. 12. Lung point sign on M mode. Alternating seashore sign (indicating lung sliding) (vertical arrow), with stratosphere sign (indicating absent lung sliding) (horizontal arrow)

There is another artifact commonly seen on 2D mode, called the A-line (Figure 13). The presence of A-line with lung sliding indicates the presence of a normally aerated lung. In the absence of lung sliding, their presence is non-specific, and can be seen with or without a pneumothorax. A-lines are horizontal artifacts, arising from reverberation of ultrasound

waves between the skin and pleural surface. Repetition of this artifact occurs at a distance equal to the distance between the probe head on the skin surface, and the pleural line.

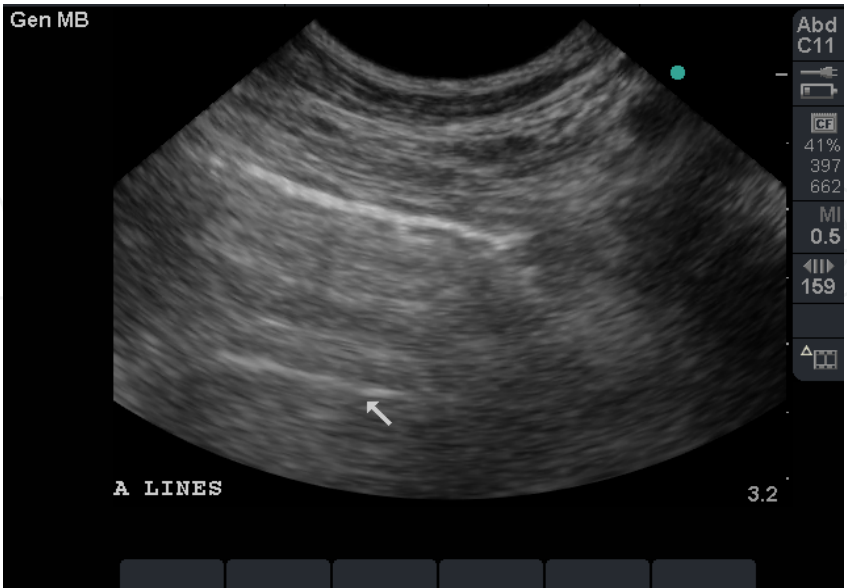


Fig. 13. Normal appearance of lung: A-line. Horizontal reverberation artifact, repetitive at a distance equal to the distance between the skin, and the pleural line

7. Alveolar consolidation

There are many causes of alveolar consolidation (pneumonia, ARDS, atelectasis etc), and its location can vary depending on the etiology. However 98.5% of cases of alveolar consolidation about the pleura (*Lichtenstein et al., 2004b*), an important requisite for its detection by ultrasonography (Figure 14). Consolidated lung has a tissue like density on ultrasound with

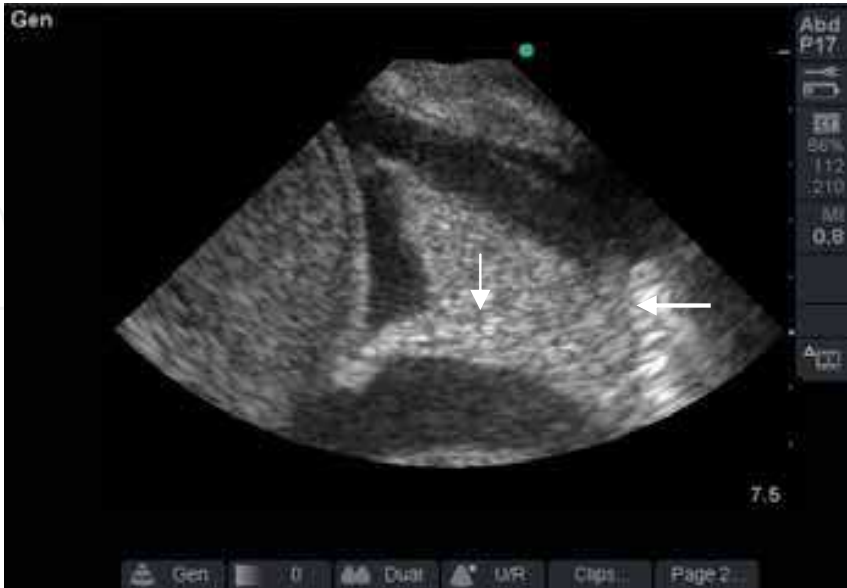


Fig. 14. Consolidated lung with tissue like density. The echogenicity is similar to that of the liver. Punctiform air bronchograms (vertical arrow) are present as hyperechoic artifacts, and the deep boundary is irregular, representing the shred sign (horizontal arrow)

an echogenicity similar to that of the liver, hence the term, sonographic hepatization of the lung. The deep interface between consolidated and aerated lung is irregular, called the shred sign. Air bronchograms when visualized, appear as punctiform or linear hyperechoic artifacts within the consolidated lung. When the centrifugal inspiratory movement of the air bronchogram is $> 1\text{mm}$, it is called a dynamic air bronchogram. The presence of dynamic air bronchogram indicates patent bronchi, with air bubbling within the bronchi with inspiration, and has a 94% specificity and a 97% positive predictive value for diagnosing pneumonia, and distinguishing it from resorptive atelectasis (*Lichtenstein et al., 2009*). Abscesses and necrotizing areas within the consolidated lung too can be detected with ultrasonography. Compared to CT scan, ultrasound has a sensitivity of 90% and a specificity of 98% for detecting alveolar consolidation (*Lichtenstein et al., 2004b*).

8. Alveolar-interstitial syndrome

The alveolar-interstitial syndrome (AIS) includes several heterogenous conditions, both chronic (pulmonary fibrosis) and acute (ARDS, cardiogenic pulmonary edema, interstitial pneumonia). Lung sonography is very useful in detecting AIS, and is an easy technique to learn. The patient should be examined in supine position with the probe in a cranio-caudal direction. Ideally the ultrasound examination should be performed by placing the probe in four discreet areas, two anterior and two lateral per hemithorax. Sonographic findings of AIS include multiple B-lines (comet tail artifact or lung rockets, described earlier) in a single view, disseminated diffusely over the antero-lateral thorax. Correlating with CT scan findings, B-lines 7 mm apart, indicate thickened interlobular septa, an ultrasound equivalent of Kerly B-lines. B-lines 3 mm apart, correlate with ground glass opacities. It is important to know that isolated B-lines, or confined to the last intercostals space above the diaphragm can be seen in healthy subjects and are of little clinical significance. It is critical to be able to distinguish B-line from two other vertical artifacts: the E-line and the Z-line. E-lines do not arise from the pleural line, and are seen in subcutaneous emphysema. The Z-lines arise from the pleural surface, are frequently seen artifacts without any clinical significance. They are ill-defined, fade away at a short distance, independent of lung sliding, and do not erase A-lines.

Finding of diffuse comet tail artifacts has a 93% sensitivity and 93% specificity for the diagnosis of diffuse interstitial syndrome, compared with radiography (*Lichtenstein et al., 1999*). The finding of AIS by lung sonography is not very specific as many conditions can cause the sonographic pattern seen in AIS. *Prosen & Klemen, 2011* showed that in patients with acute dyspnea, the combination of comet tail artifacts and a elevated N-terminal pro-brain natriuretic peptide (NT-proBNP) level $> 1000\text{ pg/ml}$ had a 100% sensitivity and specificity in differentiating acute heart failure from COPD and asthma. *Copetti et al., 2008* described pleuroparenchymal patterns seen on sonography that can differentiate ARDS/ALI from acute cardiogenic pulmonary edema. In their study on critically ill patients, the ultrasound finding of dyshomogeneous AIS with spared areas, pleural line modifications and lung consolidations were strongly predictive, in an early phase, of non-cardiogenic pulmonary edema. Lung sonography, looking at B line pattern of AIS has been shown to be of use in monitoring cardiogenic pulmonary edema (*Volpicelli et al., 2008*), effectiveness of hemodialysis in removing extravascular lung water (*Nobel et al., 2009*), and antibiotic failure in patients with ventilator associated pneumonia (*Bouhemad et al., 2010*).

9. Lung sonography in acute respiratory failure

Rapid evaluation for a diagnosis in patients presenting with acute respiratory failure is important, in order to institute proper management. Physical examination and chest radiography have limitations (Lichtenstein et al., 2004a). Chest CT scans involve time delays, risk of transport of unstable patients, and radiation exposure. Lichtenstein & Meziere, 2008 showed in their study that lung ultrasound can immediately provide a diagnosis of acute respiratory failure in 90.5% of cases. They provide an algorithm, “Bedside Lung Ultrasound in Emergency- the BLUE protocol”, to evaluate patients with acute respiratory distress (Figure 15). In their study, they assessed for (1) Lung sliding: present or absent (2) Artifacts: A or B-lines (Figure 16) (3) Alveolar consolidation and/ or pleural effusion: absent or present, and (4) Deep venous thrombosis.

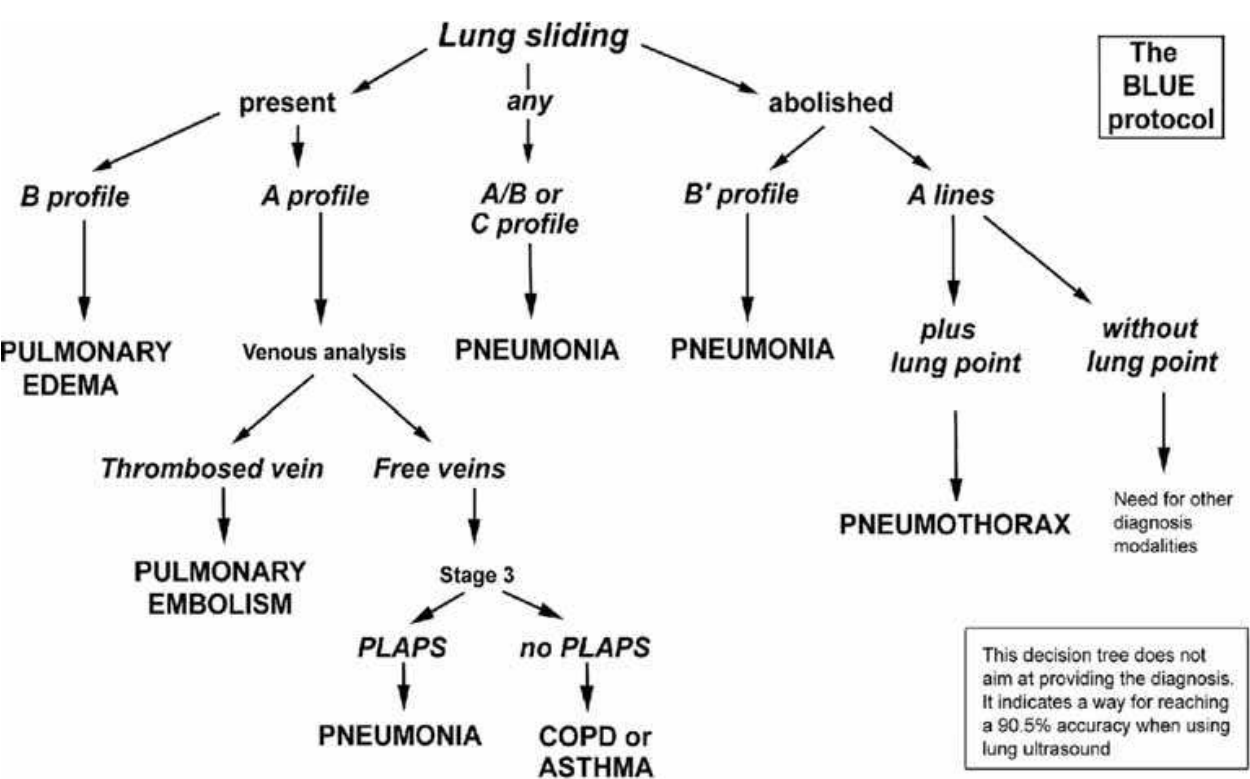


Fig. 15. A decision tree utilizing lung ultrasonography to guide diagnosis of severe dyspnea

Using this algorithm one can rapidly evaluate patients with acute dyspnea, in the emergency room, intensive care unit, or in rapid response team-events, at their bedside. Repeated examinations can be done, if needed, with a high diagnostic accuracy.

10. Peripheral lung masses

Peripheral intra-thoracic nodules and masses are (Figure 17) frequently encountered by pulmonary physicians and pose a diagnostic challenge, as the yield of bronchoscopy and sputum cytology is low for such lesions. Diagnostic options include percutaneous biopsy with image guidance (CT scan, fluoroscopy, and ultrasound), video-assisted thorascopy, or limited thoracotomy. Percutaneous image guided biopsy has a high diagnostic yield for malignant, compared with benign lesions. Ultrasound guided percutaneous biopsy of

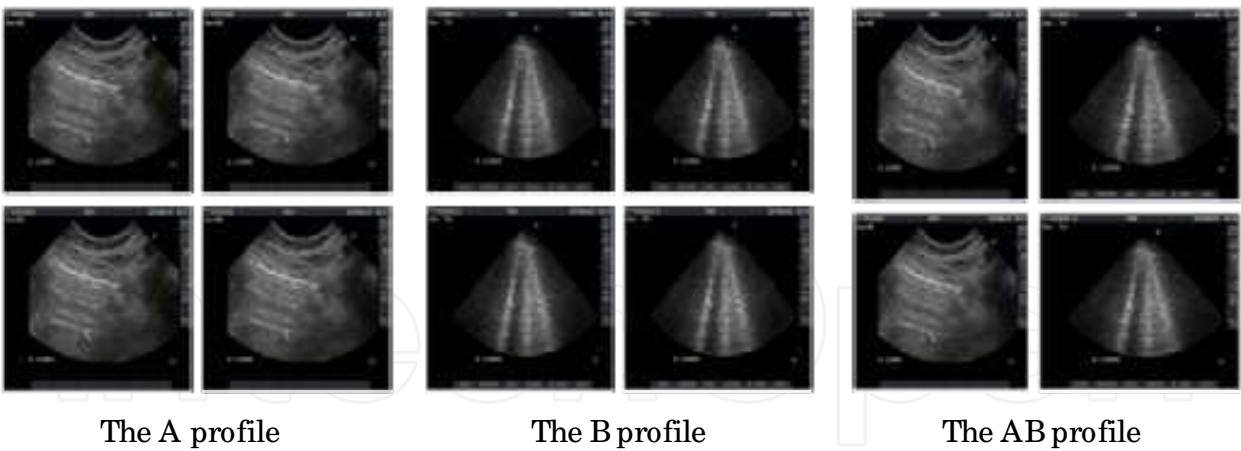


Fig. 16. Ultrasound profiles. Left panel: The A profile is defined as predominant A-lines plus lung sliding at the anterior surface in supine or half-sitting patients. This profile suggests COPD, embolism, and some posterior pneumonia. Pulmonary edema is nearly ruled out. Middle: The B profile is defined as predominant B +lines. This profile suggests cardiogenic pulmonary edema, and nearly rules out COPD, pulmonary embolism, and pneumothorax. Right panel: an A/ B+ profile, massive B-lines at the left lung, A-lines at the right lung. This profile is usually associated with pneumonia

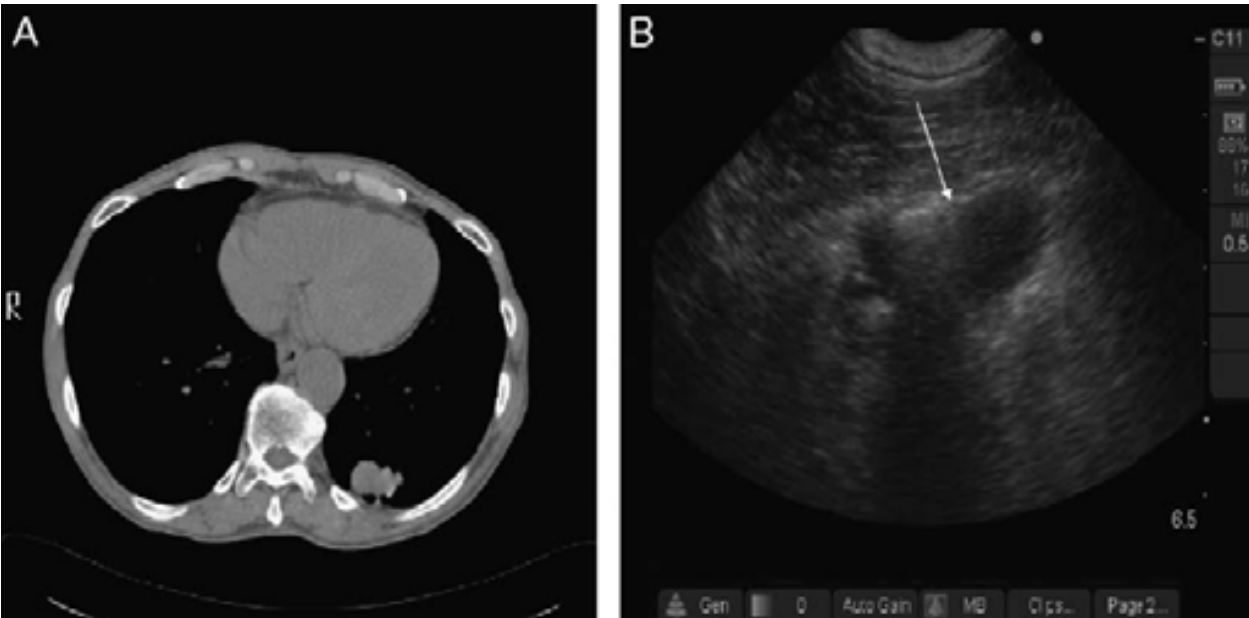


Fig. 17. (A) Transverse computed tomography scan of the chest in a 70-year-old male smoker with weight loss reveals 2.5 x 3 cm pleural-based left lower lobe mass. (B) Ultrasound examination of the mass shows a hypodense mass not invading the pleura (white arrow)

malignant peripheral pulmonary lesions has been shown to have a diagnostic accuracy (Khosla et al., 2009, higher than fluoroscopically guided biopsy and comparable to CT scan guided biopsy (Liao et al., 2000). Malignant lesions appear as hypoechoic or moderately echogenic, round or oval, inhomogeneous structures. They have well defined margins, which may be serrated with finger like projections into the lung tissue. Ultrasound guided biopsy of pleural-based intra-thoracic masses offers several advantages compared with CT

guided procedure. There is no radiation exposure. Ultrasound is portable, allowing for performance of the procedure at bedside if needed. It is less expensive, less time consuming, and more readily available than CT scan. The procedure can be performed with the patient and physician in a comfortable position; and the physician does not have to wear a lead jacket which allows for greater freedom of movement. A significant advantage of ultrasound is real-time guidance that allows for dynamic evaluation of the target lesion, monitoring of the needle tip throughout the procedure, and fine adjustments that can be made quickly and precisely. Also, necrotic areas in the lesion and blood vessels can be avoided with real-time guidance. As small peripheral lesion may only be visible in one phase of the respiration, real-time guidance allows for the biopsy to be conducted in the respiratory phase, during which the lesion is most accessible with breath holding. Ultrasound examination allows for assessment of invasion of the chest wall by the tumor and has been reported to be superior to CT scan (*Bandi et al., 2008*). On ultrasound, reliable criteria for infiltration of the chest wall include: direct visualization of the infiltration on chest wall structure and rib destruction. Other indications include, interruption of the pleural line, and/ or limited respiratory excursion of the mass.

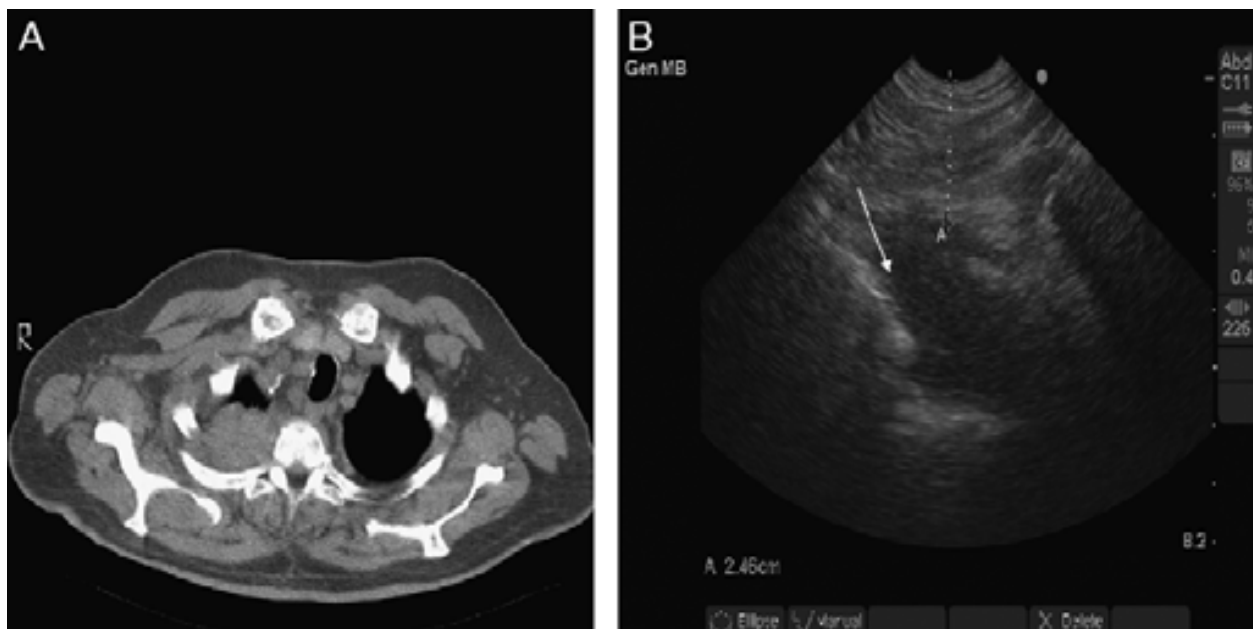


Fig. 18. (A) Transverse computed tomography scan of the chest in a 75-year-old male smoker with right shoulder pain reveals a 4 x 5 cm pleural-based right upper lobe mass. (B) Ultrasound examination of the mass from the right supraclavicular fossa shows a hypodense mass. The mass is approximately 2.5 cm from the skin surface and is extending into the chest wall (white arrow)

11. Conclusion

Lung sonography has come of age and it is now a well established tool in the armamentarium of pulmonologists and intensivists. It has tremendous clinical utility, and provides rapid information at patient's bedside. It performs better than a chest radiograph in many clinical scenarios, and decreases the need for transporting critically ill patients for sophisticated, costly tests. The ultrasound probe is the stethoscope of the future (Photo 6).



Photo 6. Pocket size ultrasound

12. Acknowledgment

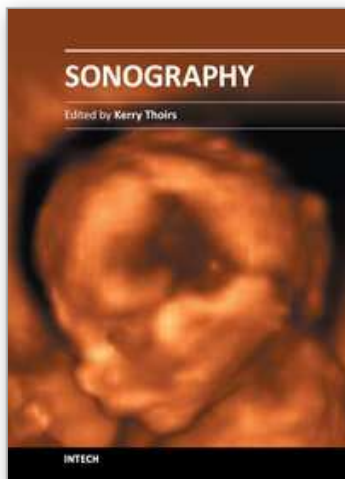
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Medical sonography is a medical imaging modality used across many medical disciplines. Its use is growing, probably due to its relative low cost and easy accessibility. There are now many high quality ultrasound imaging systems available that are easily transportable, making it a diagnostic tool amenable for bedside and office scanning. This book includes applications of sonography that can be used across a number of medical disciplines including radiology, thoracic medicine, urology, rheumatology, obstetrics and fetal medicine and neurology. The book revisits established applications in medical sonography such as biliary, testicular and breast sonography and sonography in early pregnancy, and also outlines some interesting new and advanced applications of sonography.

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