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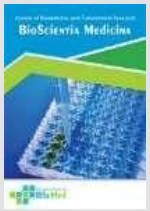

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Thoracic Ultrasound: A Narrative Literature Review

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A B S T R A C T

Ultrasonography (USG) is useful in diagnosing abnormalities in the thoracic area, such as pleural effusion, pneumothorax, consolidation, atelectasis, pulmonary edema, etc. The advantages of thoracic ultrasound are low cost, non-radiation, non-invasive, easy to carry, short examination time, and a dynamic aspect that can be seen during the examination. Thoracic ultrasound can be used to guide thoracentesis procedures, chest tube placement, and aspiration of lung abscesses. Ultrasound can be substituted as a computed tomography scan (CT-Scan) as a guide for aspiration and biopsy of the lung parenchyma, pleura, and chest wall. Portable and compact ultrasonography provides the opportunity for ultrasound examinations to become a routine part of an examination, like a stethoscope. Ultrasonography also has limitations in patients with subcutaneous emphysema, peripheral edema, and obesity. Ultrasound examination is very dependent on the experience and abilities of the operator.

1. Introduction

Ultrasonography (USG) has been a tool to help diagnose disease since the 1940s. However, the use of ultrasound in the field of lung disease is still minimal. Xirouchaki et al. stated that ultrasound cannot pass through air-filled tissue, but ultrasound is very good at depicting the thoracic wall, pleura, and lung tissue adjacent to the pleura and thoracic wall.[1] This weakness is not an obstacle in establishing a diagnosis of several thoracic disorders, such as pleural effusion, pneumothorax, consolidation, atelectasis, and pulmonary edema.[2] The use of thoracic ultrasound is not as common as the use of ultrasound in other tissues. The last ten years of the use of thoracic ultrasound have shown significant developments in lung and pleura examination, especially in emergency cases.[3]

Thoracic ultrasound examination can also be used to guide invasive interventions such as thoracentesis, biopsy of the thoracic wall, pleura, and lung tissue, and the installation of a chest tube.[4,5] Low cost, non-radiation, non-invasive, easy to carry, short examination time, and dynamic aspects that can be seen during the examination are the advantages of thoracic ultrasound.[6] Thoracic ultrasound examination is safer than chest X-ray examination. Computed tomography scan (CT scan) and magnetic resonance imaging (MRI) because it does not use a strong magnetic field.[7]

The transducer is an important part of ultrasound, which produces sound waves with a frequency between 2 and 18 megahertz (MHz). Transducers (probe) also function as sensors to capture reflected waves after penetrating certain tissues. Sound waves that pass through the network will experience

reflection and propagation of the waves, thus affecting the quality of the resulting image.[1,5] The ultrasound modality is portable, practical, and can be used repeatedly but has side effects, namely allergies to the jelly. Jelly is used to improve the propagation of sound waves emitted by the transducer. Side effects of ultrasound waves themselves have never been reported.[6,7] The purpose of this literature review is to explain the basic techniques and applications of ultrasound in diagnosing thoracic disorders and interventions.

Ultrasonography

The discovery of the ultrasound device began around 1920, namely the discovery of ultrasonic waves, which began to be applied in the medical field for therapy, not to diagnose disease. In the early 1940s, ultrasonic waves were also used as a tool to diagnose disease.[4,6] In 1986, dr. Daniel Lichtenstein served in the section intensive care unit (ICU) and found that ultrasound could be used as a guide to examine patients with pleural effusion before taking pleural fluid. This continued to develop until, in 1992, guidelines for the use of ultrasound in the lung field were introduced throughout the world.[1,5-7] Initially, ultrasound was not used to evaluate lung disease because the principle of ultrasound is the result of reflections or ultrasonic waves transmitted by the medium through which it passes. The lungs are air-filled organs that inhibit waves. Therefore, the use of ultrasound is limited in evaluating pleural masses or effusions. The development of thoracic ultrasound is able to diagnose pneumonia with a sensitivity of 85%-95% and a specificity of 75%-90%, pulmonary edema with a sensitivity of 87.6% and a specificity of 96.2%, pulmonary thromboembolism with a sensitivity of 46.2% and a specificity of 100% and pneumothorax with a sensitivity of 71.4% and a specificity of 100% and pleural effusion and empyema with a sensitivity of 100% and a specificity of 99.7%.[1,7,8-14]

Normal thoracic ultrasound interpretation

Pleural line and lung sliding

The normal anatomy of the chest wall appears as layers of soft tissue echogenic, which shows images of muscles and fascia. The ribs appear as curvilinear structures with acoustic shadows. The surface of the lungs contains a layer of visceral pleura it looks thicker and sticks together with the parietal pleura, forming a pleural line in normal people. Normal pleural lines appear <1 cm below the rib line. Hyperechoic and horizontal are called pleural lines (Figure 1).[1,15] The two layers of the pleura appear to move toward each other during the so-called inspiratory and expiratory phases of lung sliding. The image will look like marching ants or marching ants with moving black lines and white dots. Lung sliding will not be seen in conditions where the visceral and parietal pleura do not stick together or rub together, such as pneumothorax, post-pleurodesis, extensive atelectasis, pulmonary bullae, or apnea.[6,15,16]

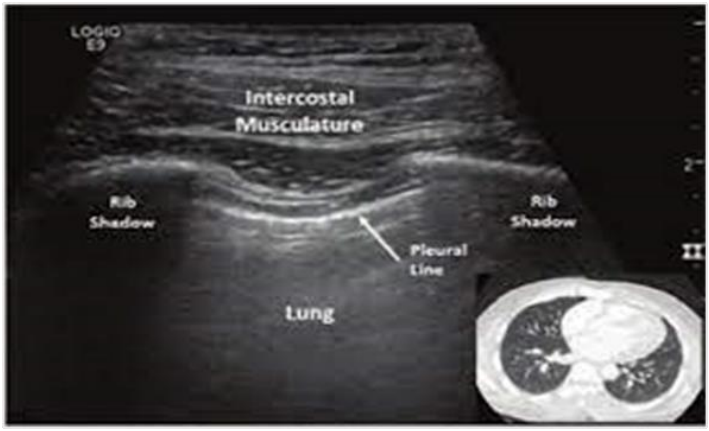

Figure 1. Pleural line.

A-lines and B-lines

A-lines is a horizontal line that does not move parallel to the skin and pleural lines and depicts the distribution of the pleural lines. A-lines It can be seen completely or only partially depending on the presence or absence of air below the pleural line. B-lines is a hyperechoic vertical line that resembles a laser originating from the pleural line inward without a fading image. The pleural lines will move in sync with lung sliding. B-lines are called comet tails or lung rockets (Figure 2). Normal lung ultrasonography is absent, or there are < 3B lines per field look. B-lines can be found in 37% of elderly people and 10% of young people with normal lungs.[18,19,20]

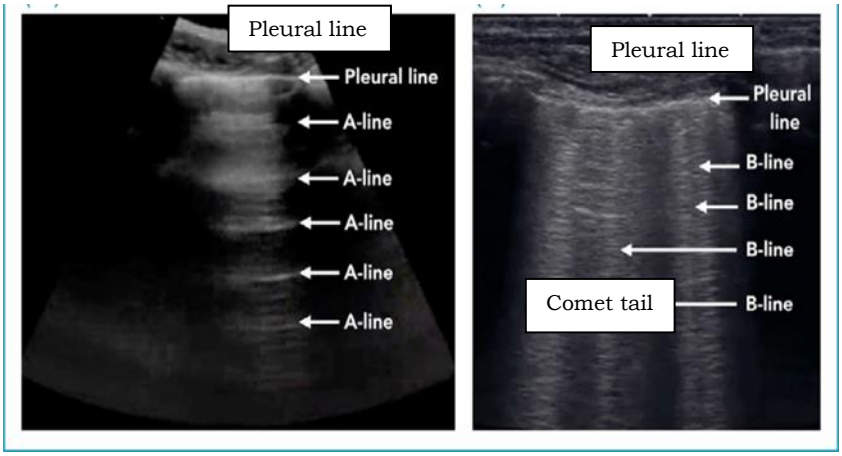

Figure 2. A-lines and B-lines.

Interpretation of thoracic ultrasound in thoracic abnormalities

Pleural effusion

Ultrasonography is more sensitive in detecting pleural effusion compared to lateral decubitus chest radiography. Pleural effusion detected on a chest X-ray requires 150 ml of pleural fluid, whereas on an ultrasound examination, it is only 5 ml. The image of pleural effusion on ultrasound generally shows an anechoic and homogeneous area between the two layers of the pleura with the appearance of lung collapse, which looks like a tongue-shaped structure in the shadow of the pleural effusion. Ultrasonography can also see images of pleural thickening and estimate the type of pleural fluid, whether transudate or exudate. When suspecting pleural effusion, the operator can position the patient semi-fowler or sit. This is because the fluid will be easier to identify when the patient is in that position due to the effects of gravity.[13,19,21] Several studies explain that ultrasound consistently shows 100% sensitivity and 99.7% specificity in diagnosing pleural effusion. A meta-analysis study conducted by Grimberg et al. concluded that the sensitivity and specificity of ultrasound in diagnosing pleural effusion was 93% (with a 95% confidence interval of 89-96%) and 96% (with a 95% confidence interval of 95-98%).[15] The ultrasound appearance of pleural effusion depends on its nature, cause, and chronicity. Based on the level of reflected echoes, four types of images are obtained on ultrasound, namely anechoic, complex and non-separated, separated complex, and homogeneously echogenic (Figure 3).[1,13,18,22]

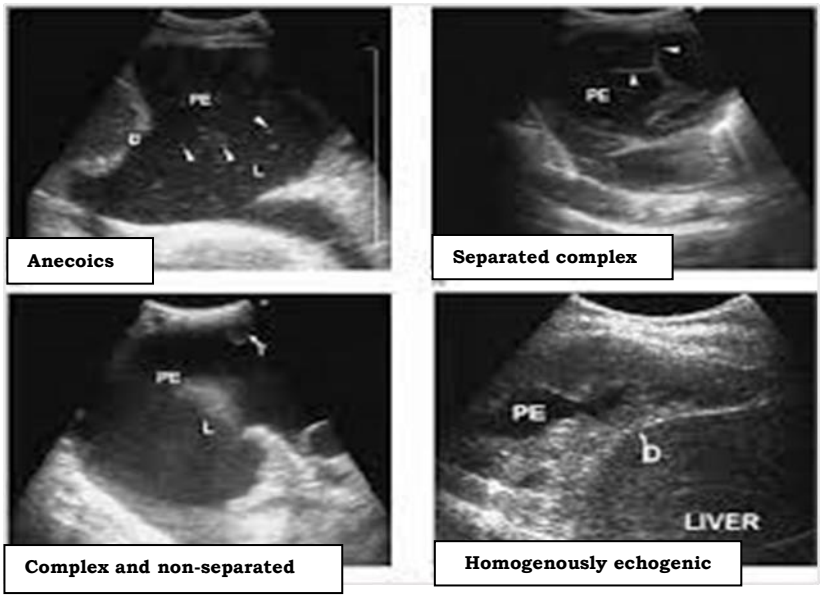

Figure 3. Ultrasound image of pleural effusion.

Signs that are noticed when ultrasound examination in patients with pleural effusion are a quad sign and sinusoid sign. A quad sign is a static image consisting of 4 border lines of the pleural effusion area, including the rib shadow, parietal, and visceral pleura, which is visible when the effusion occurs in small amounts with an anechoic image. The sinusoid sign is a picture of pleural effusion using M-mode as an image of visceral pleura movement during inspiration and expiration and forming sinusoidal waves, which are generally in empyema. Nodular pleural thickening may be found in a small proportion of malignant pleural effusions.[3,13,19,20]

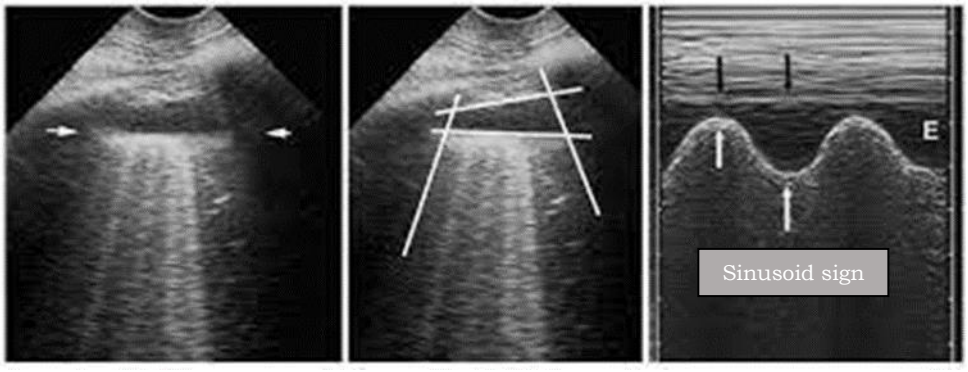

Figure 4. Quad sign and sinusoid sign.

Ultrasonography is able to predict the type of pleural fluid, whether transudate or exudate. The description of the transudate is anechoic, non-separated, and free-flowing. The description of the exudate is hyperechoic, partitioned, and complex. Malignant pleural effusion gives an anechoic ultrasound appearance even though the fluid is an exudate accompanied by pleural thickening (swirling patterns).[22-26] The ultrasound appearance of effusion due to inflammation is in the form of strings of

echogenic and insulating material and relatively little mobility during breathing and heart rate. Empyema is seen as an echogenic effusion, which resembles a solid pleural lesion, and on M-mode ultrasound, there is a sinusoidal appearance. Azam et al. proposed a scoring system to differentiate transudate and exudate. During an ultrasound examination, if the score reaches >4, it is predicted that the effusion is transudative (Table 1).[1,19,24,25]

Table 1. Ultrasound scoring system to differentiate transudate and exudate.

Sign	Score
Bilateral pleural effusion	1
No localized fluid	1
Anechoic fluid	1
The pleura is not thickened	1
Hepatic congestion	1
The inferior vena cava is not collapsed	1

Estimation of pleural effusion volume by ultrasound

The volume of pleural effusion is estimated qualitatively and quantitatively via ultrasound. The qualitative volume of pleural effusion is minimal, slight, moderate, and massive. The minimum is the obstacle-free area (black) coinciding with the corner costophrenicus, with an estimated volume of ≥ 100 ml. Slight, namely an echo-free area larger than the costophrenicus angle with an estimated volume of 100-500 ml. Moderate, echo-free area exceeds the range of one transducer, with an estimated volume of 500-1,500 ml. Massive, namely an echo-free area greater than the range of two or more transducers, estimated volume > 1,500 ml. Examination Quantitatively measured with a transducer curvilinear 3-5 Mhz at the end of expiration, namely by measuring the horizontal distance from the most cranial diaphragm at the mid-axillary line to the nearest segment. The distance (in cm) is then multiplied by 20 to estimate the amount of effusion fluid (in ml) (Figure 5).[3,13,27,28]

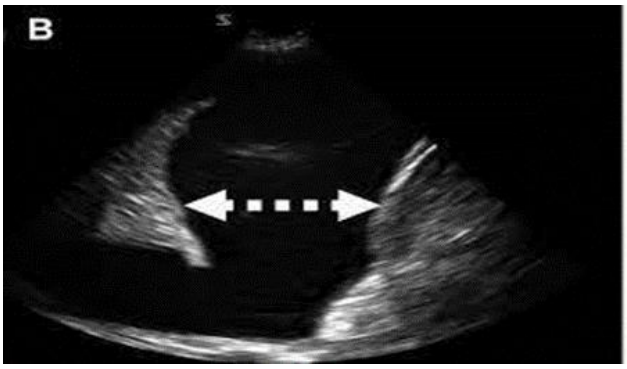

Figure 5. Calculation of the predicted volume of pleural cavity fluid.

Another formula used for quantitative pleural effusion volume measurement is the formula Goecke in 2 ways. Goecke 1, the volume of effusion fluid [ml] (EV) is obtained by the craniocaudal distance of the chest wall in centimeters [cm] (H) multiplied by 90 (constant). On Goecke 2, the volume of effusion fluid is obtained by calculating the craniocaudal distance of the chest wall on the screen in cm (H) plus the distance from the lung to the center of the diaphragm (D) and then multiplying by 70 (constant). The Goecke 2 method better represents the actual fluid volume (Table 2).[1,14,27]

Table. 2 Coecke's formula 1 and Coecke.

Goecke 1	Goecke 2
EV (Ml) = H x 90	EV (Ml) = (H + D x 70)

Apart from the sitting position, quantitative calculation of pleural effusion volume can also be done in a lying position, especially in patients who cannot sit upright. The patient is in a lateral decubitus position in the direction of the disease or to be examined so that fluid can collect in only one place. Two methods that can be used in lying position patients are Eibenberger method and the Reverse method. The formula of Eibenberger method is that the the estimated effusion volume is obtained from the results of measuring the perpendicular distance between the lung surface and the posterior chest wall at the time of maximum inspiration, multiplied by a constant of 47.6, then subtracted by 837. When examining the transducer in the transverse position. The second method that can be used is the Reverse method, namely, volume calculations are carried out by measuring the distance between the visceral pleura and parietal pleura at the end of expiration (Table 3).[1,28]

Table 3. Eibenberger and Reverse formulas.

Eibenberger	Reverse
Maximum inspiration	End of expiration
Transverse position	Transverse position
Postrodorsolateral	Posterior axillary line
EV = X x 47.6 - 837	EV = Sep x 20

Pleural thickening

The thickness of the visceral and parietal pleura is normal 0.2-0.3 mm. Pleural thickening is a focal lesion originating from the visceral or parietal pleura with a thickness of more than 3 mm with irregular borders. Pleural thickening occurs due to conditions such as fibrosis, empyema, and pleurisy. Pleural thickening on ultrasound shows widening of the pleura without fluid or relative movement of the pleura against the thoracic wall. Pleural thickening appears hypoechoic, but sometimes, there is increased echogenicity with focal shadowing, which indicates the classification so that it appears anechoic in B-mode. All movements of body fluids can be described using the color Doppler. However, when the pleura is thickened, no detectable color picture is visible. Pleural effusion accompanied by thickening of the parietal pleura (> 10 mm), pleural nodules, and thickening of the diaphragm (> 7 mm) is suggestive of malignancy (Figure 6).[14,15,29]

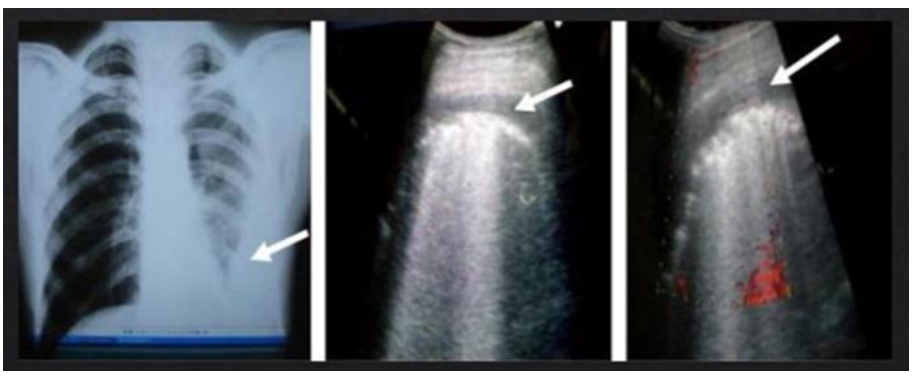

Figure 6. Pleural thickening.

Pleural tumors

Benign pleural tumors on ultrasound will appear in the form of a round mass with various variations in echogenicity, both in the parietal pleura and visceral pleura, such as fibroma or lipoma. Malignant pleural tumors are characterized by irregular pleural thickening, taking the form of a nodular mass, and are often accompanied by pleural effusion that invades the chest wall with less defined boundaries. Tumor metastases appear as diffuse thickening of the parietal pleura and a small amount of visceral pleura (Figure 7). Color Doppler examination of malignant pleural tumors provides a picture of neovascularity with irregular vascularization.[16,17,30]

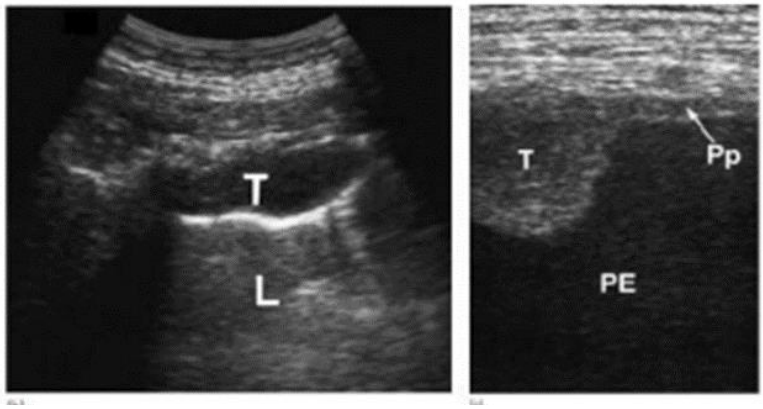

Figure 7. Pleural tumors.

Pneumothorax and hydropneumothorax

The role of ultrasound in diagnosing pneumothorax shows a sensitivity of 86% and a specificity of 97%, while a chest x-ray has a sensitivity of 28% and a specificity of 100%. Sonographic signs in pneumothorax consist of soundbar code sign, loss of image lung sliding, and loss of artifacts-comet tail as well as lung point. M-mode in the ultrasound image is a horizontal line image on the entire ultrasound screen called a barcode sign or stratosphere sign, while the normal situation is in the form of a seashore sign. Hydropneumothorax on ultrasound examination appears air-fluid level, which moves during inspiration and expiration, giving rise to an image in the form of a curtain sign. This is because the air in the pleura covers the effusion during respiration (Figure 8).[20,31-33]

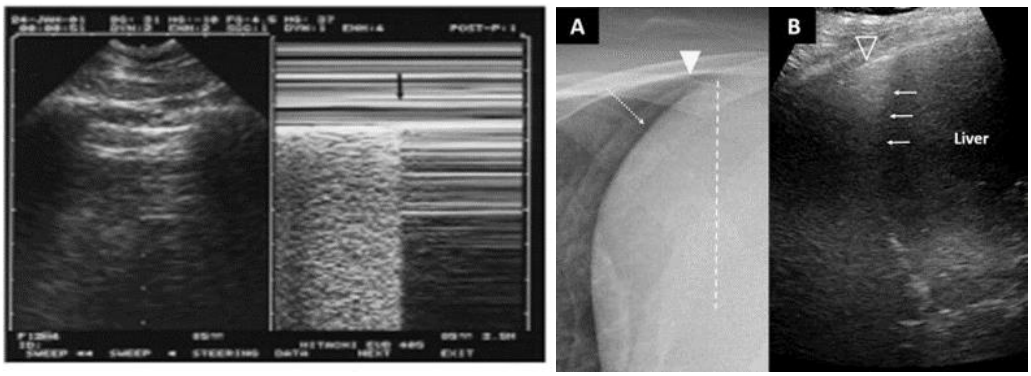

Figure 8. Pneumothorax and hydropneumothorax.

Lung parenchymal disorders

Normal lung parenchyma contains air, so it cannot be detected using ultrasound. Lung parenchyma has different acoustic impedances, the distance between the chest wall and the air in the lung parenchyma. Abnormalities in the lung parenchyma in the form of lesions that extend to adhere to the surface of the pleura can provide a clear picture of the disorder because air is not obstructed. Several lung parenchymal abnormalities detected using ultrasound include lung consolidation, pneumonia, lung abscess, lung cancer, tumor metastasis in the lung, and pulmonary embolism and pulmonary edema.[34,35]

Pneumonia and lung abscess

Typical signs on ultrasound examination of consolidation are lung hepatization and air bronchogram (Figure 9). Consolidation will produce a picture similar to liver tissue, so it is known as lung hepatization. Lung consolidation is found in the lower right part of the hemithorax, so the lung will be shaped like the liver, whereas if consolidation occurs in the lower left part, it will resemble the spleen. Pulmonary consolidation appears as a wedge-shaped hypoechoic tissue structure that is difficult to assess. Its size does not change with respiratory movements.[18,36,37]

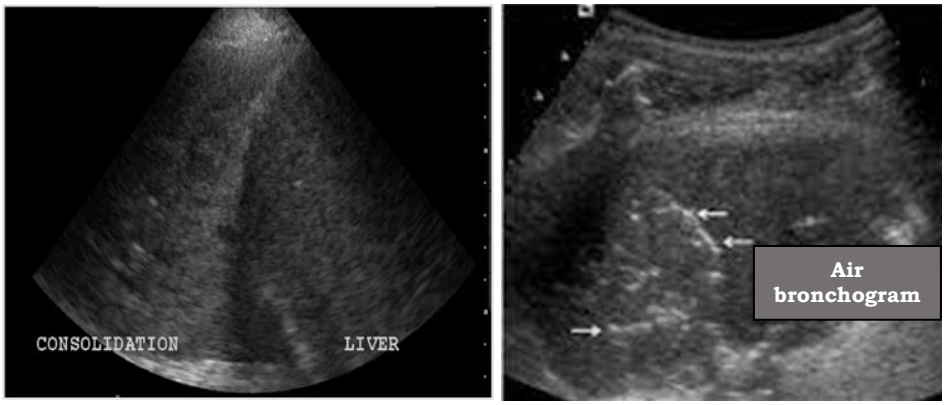

Figure 9. Pulmonary consolidation on ultrasound.

An air bronchogram is a picture of the bronchi that looks hyperechoic or hypoechoic because there is an accumulation of fluid in the alveoli that surround the bronchi. Hyperechoic indicates there is an accumulation of air, while hypoechoic indicates the presence of fluid, which is specifically a sign of pneumonia. Lung abscesses that extend to the pleura on ultrasound can appear as hypoechoic lesions with firm and irregular borders. In the central area of the abscess, an anechoic image will appear, but septa may also be visible. Abscess picture with air-fluid level on a chest X-ray, a picture can be seen of curtain sign on ultrasound (Figure 10).[18,21,38]

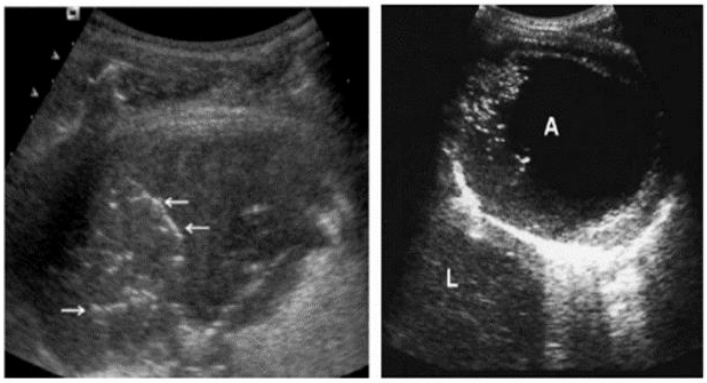

Figure 10. Lung abscess on ultrasound.

Lung cancer and tumor metastasis in the lungs

Peripheral lung tumors and Pancoast tumors can be detected by ultrasound if there is contact with the pleura, giving the appearance of a homogeneous, well-defined, hypoechoic, or slightly echogenic mass with a sensitivity of 69.2% and a specificity of 72.4%. Color Doppler ultrasound is able to distinguish whether a lung mass is malignant or benign. Malignant marked neovascularity with low-impedance flow. Tumor metastases in the periphery can be detected by ultrasound in the form of multiple sub-pleural echogenic nodules with a diameter of between 1-2 cm accompanied by high vascularity.[16,18,39,40]

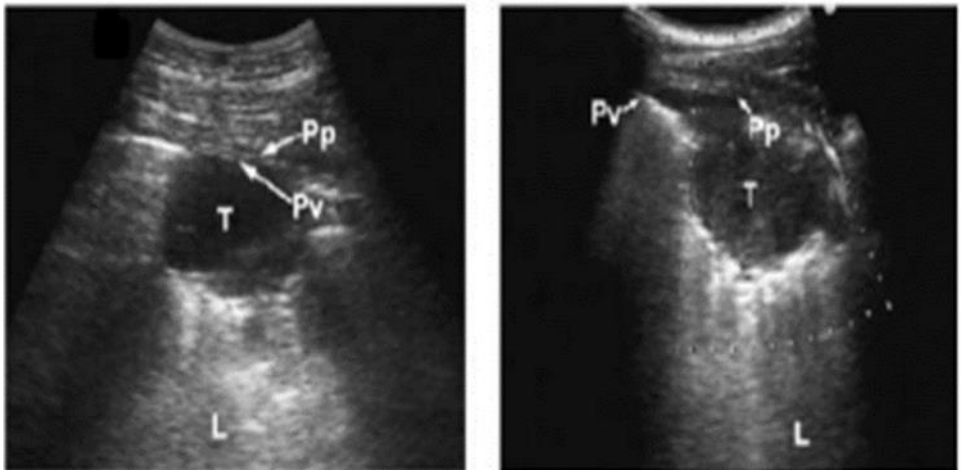

Figure 11.Lung cancer and tumor metastasis in the lungs.

Chest wall abnormalities

Abnormalities on the chest wall soft tissue disease such as lipoma, sebaceous cyst, hematomas, and abscesses on the ultrasound image appear according to whether they contain fluid or a mass. Abnormalities of lymph nodes in the axilla and suprasternal can be caused by inflammation, malignancy, or lymphoma. Lymph nodes are caused by inflammation. The ultrasound image is triangular in shape and is echogenic with fatty hilum and increased vascularization. Lymph nodes caused by malignant appearance in the form of irregular, hypoechoic, and round lesions fatty hilum disappear. Lymphoma is a round, hypoechoic, and well-defined lesion. Fracture costal trauma in ultrasound shows a gap accompanied by a hematoma and soft tissue swelling. Diaphragmatic disorders in the form of diaphragmatic paralysis show paradoxical diaphragmatic movements during respiration.[18,45]

Ultrasound-guided intervention

Ultrasonography is used to guide action in thoracic abnormalities, including thoracentesis diagnostics, closed tube drainage, biopsy of the pleura and thoracic wall, as well as biopsy of lung tumors that invade the pleura or thoracic wall with a diagnostic success rate of up to 97%. The method of attaching a biopsy needle to an ultrasound transducer is called freehand technique, which is better than conventional techniques. The limitation of conventional techniques is that they must first provide a mark on the target area, but there can be a relative shift in the location of the target due to skin movement due to changes in position. It is not recommended for the examination to move the patient who will undergo thoracentesis after an ultrasound has been performed and after marking on the skin, especially for minimal pleural effusion, because this will cause a shift in the location of the fluid and marks on the skin, even if there is little movement.[3,21,22] Chest tube placement can be guided

by ultrasound, such as thoracentesis, catheter pig-tail in patients with parapneumonic effusion, or loculated empyema, especially in patients in the ICU and pleural biopsy with an Abrams needle in pleural effusion patients. In certain circumstances, namely minimal pleural effusion, some operators prefer to perform pleural drainage in real-time (ultrasound-guided technique) (Figure 12). The use of ultrasound as an action guide is also carried out in the tissue sampling procedure using the endobronchial ultrasound (EBUS) method and transthoracic biopsy by ultrasound transbronchial needle aspiration (TBNA) and transbronchial lung biopsy (TBLB). The use of ultrasound in thoracic interventions has a lower risk of complications and is useful in guiding more specific needle insertion locations.[46-48]

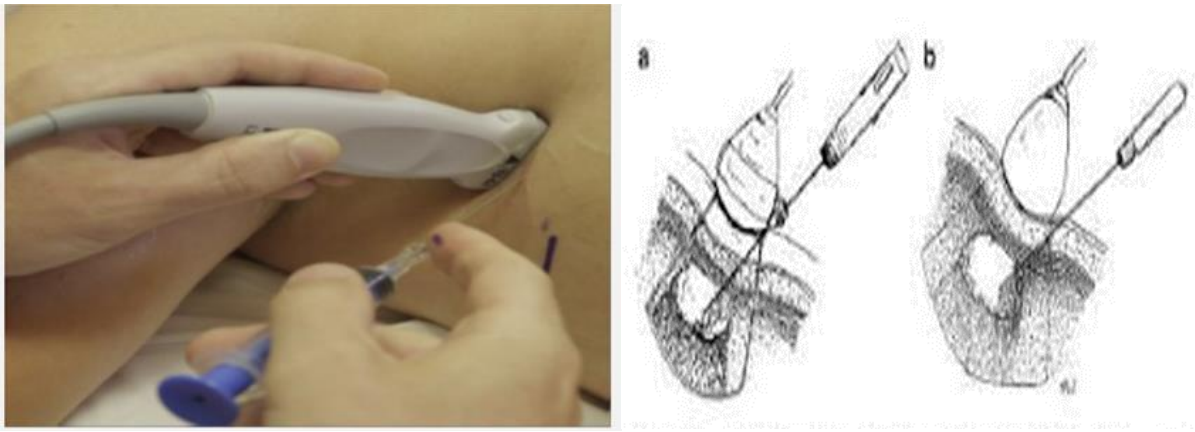

Figure 12. Real-time ultrasound guidance techniques.

Biopsy using endobronchial ultrasound had a diagnostic yield of 89% and a sensitivity of 91%. EBUS transbronchial needle aspiration is used in the diagnosis of lung cancer with central lesions, namely in the inner 1/3 of the hemithorax. Meanwhile, EBUS-transbronchial lung biopsy for diagnosing lung cancer in peripheral lesions with a sensitivity of 96% and a specificity of 100%. Complications that often occur during biopsy are pneumothorax and hemoptysis, with an incidence rate of 4%.[46] Contraindications for intervention with ultrasound guidance consist of absolute contraindications, namely arteriovenous malformations with pulmonary artery pressure, while relative contraindications include patients who are uncooperative, unable to be positioned, unable to suppress coughing and catch their breath, pneumonectomy, bleeding disorders, pulmonary hypertension, and pulmonary fibrosis.[47,48]

2. Conclusion

Ultrasonography is very useful in diagnosing thoracic abnormalities such as pleural cavity abnormalities, lung parenchymal abnormalities, and chest wall abnormalities. Thoracic ultrasound can be used as a guide in interventional procedures for thoracic abnormalities. The advantages of thoracic ultrasound are low cost, non-radiation, non-invasive, easy to carry, short examination time, and a dynamic aspect that can be seen during the examination. Thoracic ultrasound can be used as a guide in interventional procedures for thoracic abnormalities.

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