Eurasian J Pulmonol 2015; 17: 1-9

Transthoracic Ultrasonography for Clinicians

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Abstract

Transthoracic ultrasonography (US) has become an essential tool for respiratory, emergency, and critical care physicians. It can be performed with basic equipment and by personnel with minimum training as a modality for the evaluation of a wide range of thoracic pathologies. Its advantages include immediate application at the point of care, low cost, and lack of radiation. The main indications for transthoracic US are the qualitative and quantitative assessment of pleural effusions, pleural thickening, diaphragmatic pathology, as well as chest wall and pleural tumors. Transthoracic US is also useful in visualizing pulmonary pathologies that abut the pleura, such as pneumonic consolidation and interstitial syndromes, including pulmonary edema. Transthoracic US is more sensitive than the traditional chest radiograph in the detection of pneumothoraces, and it is useful in diagnosing skeletal abnormalities such as rib fractures. It is the ideal tool to guide transthoracic procedures, including thoracocentesis and pleural biopsy. Moreover, transthoracic US-guided procedures can be performed by a single clinician with no sedation and minimal monitoring. Transthoracic US-guided fine needle aspiration and/or cutting needle biopsy of extrathoracic lymph nodes and lesions arising from the chest wall, pleura, peripheral lung, and mediastinum are safe to perform and have a high yield in the of hands of experienced clinicians. Transthoracic US can also potentially guide the aspiration and biopsy of diffuse pulmonary infiltrates, consolidations, and lung abscesses. Moreover, transthoracic US may be used in the detection of pulmonary embolism.

Keywords: Pleural disease, transthoracic, ultrasonography

INTRODUCTION

It has taken approximately half a century for respiratory physicians to appreciate the potential impact of transthoracic ultrasound (US) on patient safety and diagnostic yield in managing chest diseases. Transthoracic US is becoming increasingly utilized in respiratory medicine and as its usage increases, its applications are expanding (1, 2). The renewed interest in transthoracic US is partly because of the ease of use at the point of care, as well as the lack of ionizing radiation associated with conventional radiography, which is a potential major cause of cancer (3, 4). Transthoracic US has become an essential tool in both critical care and emergency departments, and in 2004, the American Institute of Ultrasound in Medicine reported that the concept of an "ultrasound stethoscope" was becoming a reality (1, 5-7).

By nature, transthoracic US is a user-dependent technology, and therefore, competence should be ensured and its appropriate use should be defined. This review aims to give an overview of some technical aspects of transthoracic US and to explore its diagnostic use for both imaging and assisting in diagnostic procedures.

TECHNICAL ASPECTS

Basics: Physics and Principles

Ultrasound generates digital images by transmitting sound waves from a transducer to human tissues and recapturing the reflected sound waves (or echoes)that are then converted back into electrical impulses and processed into images (8, 9). The frequency of diagnostic ultrasound is in the millions of Hertz (MHz) and ranges from 2 to 10 MHz for transthoracic US (8-10). The distribution and intensity of the US image on the screen is determined by three characteristics: 1) the direction and 2) intensity

Received Date: 27.10.2014
Accepted Date: 14.11.2014
Available Online Date: 13.02.2015

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DOI: 10.5152/ejp.2014.03511

• Available online at www.eurasianjpulmonol.com

of the captured echoes, and 3) the time elapsed from emission to capture (8-10). Different tissues have different densities and therefore conduct these waves differently. Echogenicity is the ability to reflect an echo, and the echogenicity of any tissue or lesion is defined relative to that of the normal liver, which is arbitrarily considered isoechoic (9). Sound waves propagate well though liquids (e.g., pleural effusions) and through tissues with a high fluid content (e.g., consolidated lung, tumors, and liver) (8, 10, 11). Tissues that have higher echogenicity are called "hyperechoic" and are usually represented with lighter colors. In contrast, tissues with lower echogenicity are called "hypoechoic" and are usually represented with darker colors. Areas that lack echogenicity are called "anechoic" and are usually displayed as completely dark (e.g., fluid). Solid organs have variable echogenicity depending on the content of fluid and fraction of reflected waves. However, when a significant difference in density between tissues is encountered, the sound waves are reflected in a phenomenon called "acoustic impedance." This is readily seen when imaging gas (e.g., normal lung or a pneumothorax) or solid tissue (e.g., bone) (10, 11). Thus, the anatomy beyond the visceral pleura is not discernible in healthy individuals.

Hardware and Controls

Most modern US units also offer motion-mode (M-mode) and color flow Doppler scanning, in addition to conventional 2D ultrasound. Transthoracic US can be performed using the most basic equipment. Different probes have different purposes. A low frequency curvilinear probe (2–5 MHz) provides a better depth of ultrasound penetration into tissues at the expense of a lower resolution. This probe is ideal for initial screening of superficial and deeper structures. A high frequency linear probe (5–10 MHz) provides excellent image resolution but is unable to penetrate deeply into tissues and is best used for refined assessment of an abnormal chest wall or pleura (8-10). Some US units have default settings: "abdominal" being low frequency and "thyroid" being high frequency. The images should be optimized using the "depth" and "gain" functions on the US unit in real time (8, 9). The depth function is comparable with a digital zoom and defines the section of the scanned image displayed on the monitor at a certain magnification, with the scale displayed on a vertical axis. Ideally, the depth should be adjusted so that the area of interest fills the screen. By adjusting the gain, the amplification of the echoes and therefore, the brightness of the image can be adjusted to maximize the contrast between tissues.

Conducting a Study

When conducting a study, correct positioning of the patient is essential because it aids in obtaining high quality images (8, 11). If available, it is advisable to study the available images [chest X-ray and computed tomography (CT) scan] prior to performing a thoracic US scan because this aids not only in the positioning of the patient but also in the identification of the area of interest and in shortening the study procedure time. The posterior chest is best scanned with the patient sitting in an upright position, whereas the lateral and anterior chest wall can be examined with the patient in either the lateral decubitus or supine position. The superior sulcus pathology can be apically visualized with the patient in the supine or sitting position.

By convention, a probe orientation marker is placed on the left side of the screen (opposite to echocardiography) and orients the left side of the screen as cephalad. Emergency medicine and intensive care specialists most often scan patients in the supine position and hold the transducer in a longitudinal plane (i.e., parallel to the spine) with the transducer indicator in a cephalad position (12). Although this technique has advantages (e.g., greater sensitivity for pneumothoraces), the visualization of peripheral tumors and consolidated lung is best achieved by examining in line with the intercostal spaces and is the technique preferred by many respiratory physicians. The distance between the intercostal spaces can be increased by raising the arm above the patient's head in either erect or recumbent positions, allowing better visualization (8).

Liberal application of gel and a reduction in ambient lighting allow better image visualization and are the final steps prior to scanning. The US probe should be held like a pen in the operator's dominant hand, with the outer part of the hand in contact with the skin to allow probe stabilization. The operator should focus on the screen while the probe is moved over the area of interest, and the non-dominant hand should optimize the digital image quality on the US unit by adjusting the depth and gain. The patient's contralateral side may be used as a "normal control" prior to imaging the area of interest (8).

DIAGNOSTIC TRANSTHORACIC US

Ultrasound of the Normal Chest

The point where the US probe makes contact with the skin is viewed from the top of the screen by convention, below which a series of echogenic layers are visualized. These comprise skin, muscle, and fascial planes (7-9) (Figure 1). Ribs are seen as convex structures with posterior shadowing on transverse (vertical) scanning, and when viewed longitudinally, the anterior cortex appears as a continuous echogenic line. The combined visceral and parietal pleura appear as a single highly echogenic pleural line approximately 5 mm deep in the rib cortex and no more than 2 mm in width, and they represent the pleuropulmonary interface (7-9). On

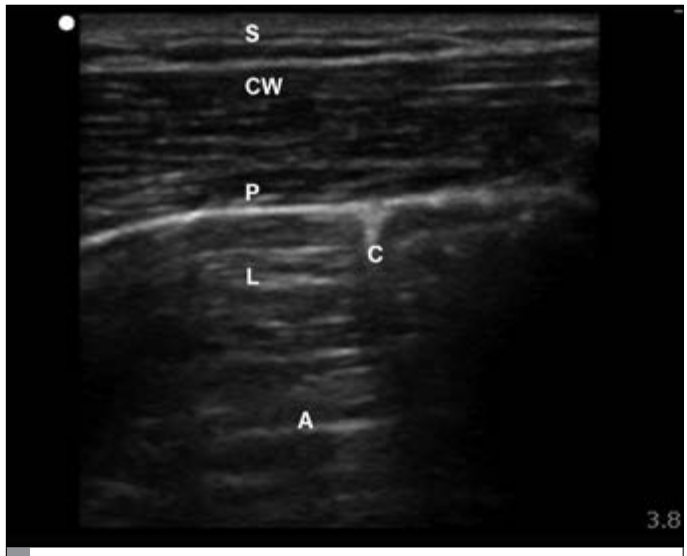

Figure 1. The typical appearance of a normal chest on high frequency ultrasound (transverse image through the intercostal space). The normal chest wall comprises a series of echogenic layers, including skin, muscle, and fascial planes. The visceral (more echogenic) pleura slide over the parietal pleura during respiration. A-lines are reverberation artifacts beneath the pleural line. "Comet-tail" artifacts are short, vertical lines seen at the pleura-lung interface in normal individuals
S: skin; CW: chest wall; P: pleura; L: lung; A: A-line; C: comet-tail artifact

high resolution scanning, the parietal and visceral pleura can be seen as two distinct echogenic lines, with the former seemingly thinner and the latter more echogenic (8). These two layers glide over each other during normal respiration, giving rise to the so-called "lung sliding" sign, which is best seen on longitudinal (vertical) real-time scanning (7, 8).

Because of the presence of air and major acoustic impedance, a normal lung cannot be visualized on US; however, the pleura–lung interface causes artifacts that can be described as "the ABC's" of thoracic US (7-9). "A-lines" or reverberation artifacts are seen as a series of echogenic parallel horizontal lines equidistant from one another, and they diminish in intensity with increasing distance from the pleural surface (7, 8, 13). "B-lines" are longer, vertical artifacts that obliterate A-lines, move synchronously with lung sliding, and are considered pathological (7, 8, 14). "Comet-tail" artifacts are short, vertical lines seen at the pleura-lung interface in normal individuals, particularly at the lung bases, and are possibly caused by fluid-filled subpleural interlobular septa (7-9, 14).

The diaphragm is best studied in the supine position (15). On the right, the liver is used as a window to view the diaphragm (the spleen is used on the left), and it appears as an echogenic curved line that is 1–2 mm thick which contracts with inspiration (7-9). At the costophrenic angle, an aerated lung can variably obscure underlying structures, and this is termed the "curtain sign" (8, 9).

Lymph Node, Chest Wall, and Skeletal Pathology

Ultrasound may aid in distinguishing reactive from malignant pathology in accessible lymph nodes (cervical, supraclavicular, or axillary) (8). Inflammatory lymph nodes are said to have an echogenic fatty hilum with an oval or triangular shape, whereas malignant nodes usually show loss of the fatty hilum leading to a hypoechoic appearance. Irregular borders also suggest extracapsular spread (8, 9, 16).

Chest wall masses are best visualized with high frequency probes and can have variable echogenicity, which is too non-specific to differentiate between etiologies (8, 9).

Malignant metastases to the ribs appear as hypoechoic masses that replace the normal echogenicity of the rib and cause disruption of the cortical line (17). Rib fractures cause interruption and shifting of the cortex (8).

PLEURAL PATHOLOGY

Pleural Effusion

A pleural effusion appears as an anechoic, homogeneous space between parietal and visceral pleura that changes shape during respiration. Adhesions between the two pleural surfaces may result in the absence of lung motion above the effusion, and an atelectatic lung is often seen in large effusions (7-9).

Sonographic estimates of pleural volume correlate well with actual effusion volumes, and in some studies have been shown to be superior to volumes estimated by radiographic measurement (18, 19). The size of an effusion can be described as minimal, if the echo-free space is confined to the costophrenic angle; small, if the space is greater than the costophrenic angle but still within the range of the area covered with a 3.5 MHz curvilinear probe; moderate, if the space is greater than a one-probe range but within a two-probe range; and large, if the space is bigger than a two-probe range (8, 9).

The ultrasonographic appearance of pleural effusions can vary depending on their etiology and chronicity and can be classified according to their echogenicity as anechoic, complex non-septated, complex septated, or homogenously echogenic (7-9).

Transudates invariably give rise to anechoic, non-septated, free-flowing effusions (Figure 2), whereas complex, septated, or echogenic effusions (Figure 3) are typically exudates (20). Malignant effusions vary, but clues to diagnosis can be found in the appearance of the pleura. Nodularity and thickening (>10 mm) of the parietal pleura and thickening of the visceral pleura or diaphragm (>7 mm) are highly suggestive of a malignancy and have both high specificity and positive predictive values (6, 21). Other US findings suggestive of pleural malignancy include diaphragmatic nodularity and hepatic metastases (21).

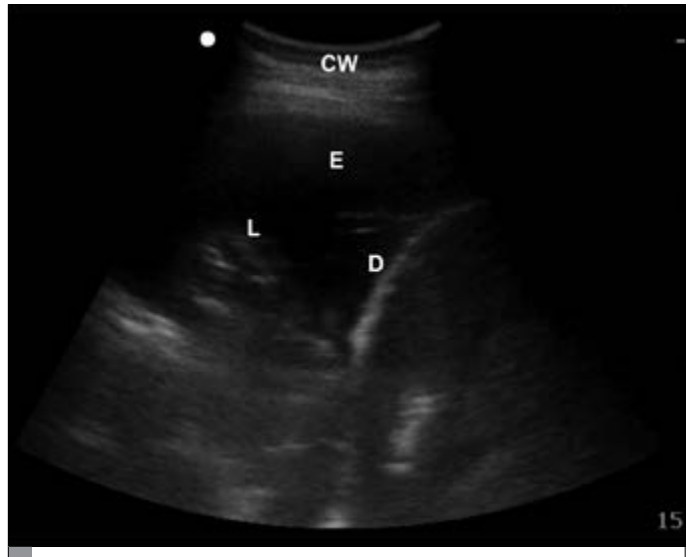

Figure 2. This low frequency US image was obtained from a patient with an uncomplicated pleural effusion. Note the large free-flowing pleural effusion (anechoic area) (E), atelectatic lung (L), chest wall (CW), and diaphragm (D)

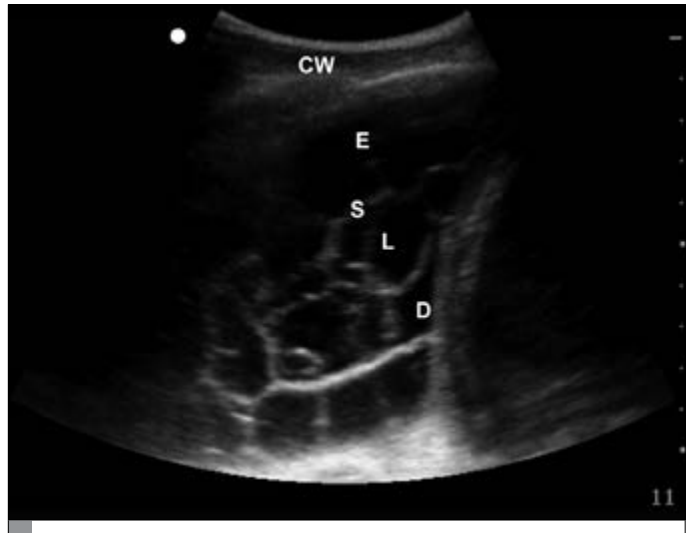

Figure 3. A low frequency US of a complex septated effusion with septa (S) and loculations (L)
CW: chest wall; E: pleural effusion; D: diaphragm

Pleural Thickening

Pleural thickening is defined as a focal lesion arising from the visceral or parietal pleura that is greater than 3 mm in width with or without an irregular margin. These can be difficult to distinguish from small effusions as both may appear hypo-or anechoic on US. Pleural thickening neither displays movement relative to the chest wall during respiration nor contains movable strands or echo densities (22). In a pleural effusion, transmitted motion during respiratory or cardiac cycles causes a color signal on Doppler known as the "fluid color sign." This sign, being both sensitive and specific, can be used to differentiate a small effusion from pleural thickening (23).

Pneumothorax

Ultrasound has become an essential tool in the emergency and intensive care units. Prompt and accurate diagnosis of a pneumothorax in the management of a critical patient can prevent progression to a life-threatening situation. US not only allows for a rapid evaluation of an unstable patient at the bedside but also has a higher sensitivity than the traditional upright chest radiography for the detection of a pneumothorax (5, 24, 25). A variety of methods are available to detect pneumothoraces. Firstly, the absence of normal lung sliding can be seen at the interface between the parietal and visceral pleura. The presence of lung sliding reliably excludes the presence of a pneumothorax (i.e., high negative predictive value), whereas its absence implies lack of contact between the two pleural surfaces (8, 9, 26). Secondly, using the M-mode, normal lung sliding produces the characteristic "waves on a beach" or "seashore" sign (Figure 4). This is created by the relative lack of motion of the superficial (soft tissue) layers during respiration, which gives rise to multiple horizontal lines ("waves"), whereas the structures deeper than the pleural line appear as granular ("sea shore"), reflecting the relative motion of the lung during respiration. In the presence of a pneumothorax, the granularity of the lung with respiration is lost, giving rise to the "bar-code" sign. Diaphragmatic paralysis, pleural adhesions, and emphysema may decrease the sensitivity of US for the detection of a pneumothorax (7, 12, 27).

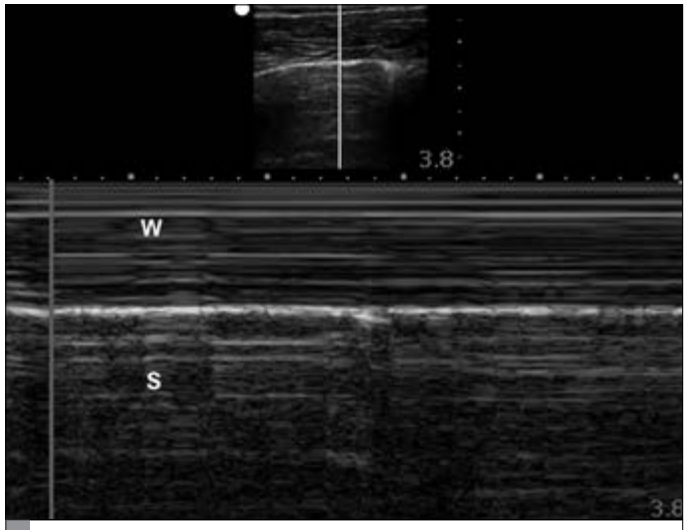

Figure 4. This is a high frequency US image, using the M-Mode of a patient with a normal chest wall and lung. Normal lung sliding produces the characteristic "waves on a beach" or "seashore" sign. This is created by the relative lack of motion of the superficial (soft tissue) layers during respiration, which gives rise to multiple horizontal lines ("waves"; W), whereas the structures deeper than the pleural line appear as granular ("sea shore"; S), reflecting the relative motion of the lung during respiration

Thirdly, the "lung pulse," caused by a subtle transmission of the cardiac pulsation to the parietal pleura (best seen in the M-mode and more prominent in the left lung) also disappears when the pleural surfaces are separated by air (7). Fourthly, a "lung point," demonstrated while scanning from anterior to lateral in a supine patient, is the particular location on the chest wall where a clear transition between normal lung sliding and static lung is seen, and it is caused by air collecting anteriorly in the pleural space. If present, it can be used to delineate the boundaries of the pneumothorax (7, 8, 28). Finally, A-lines are accentuated by the presence of intrapleural air, whereas B-lines vanish if the pleural surfaces are not in apposition.

Diaphragmatic Pathology

Both thickness and excursion need to be evaluated during the study of the diaphragm. A high frequency transducer (7–18 MHz) is used to evaluate diaphragm thickness. This is best done in the anterior axillary line with a sagittal image at the intercostal space between the 7th and 8th or 8th and 9th ribs. Average thickness of the diaphragm is 0.22–0.28 cm in healthy volunteers and 0.13–0.19 cm in a paralyzed diaphragm (28). A thickness <0.2 cm measured at the end of expiration has been proposed as a cut-off to define diaphragm atrophy. These values apply when assessing the neuromuscular status of the diaphragm in patients with chronic obstructive pulmonary disease (COPD) (29). Excursion is best measured in the M-mode, and the normal range of motion from the resting expiratory position to full inspiration is 1.9–9 cm in adults with higher values reported in deep breathing or sniffing. A diaphragmatic excursion >2.5 cm is used to exclude severe diaphragmatic dysfunction in adults, and a diaphragmatic inspiratory amplitude <2.41 cm correlates with a 50% decrease in vital capacity (30).

Pulmonary Pathology

Pulmonary pathology can be divided into two groups: lung consolidation and an interstitial syndrome (7, 8). Ultrasonographic lung consolidation is seen as a subpleural echo-poor region resembling tissue and has many causes, including infection, pulmonary embolism, lung cancer and metastasis, compression atelectasis, obstructive atelectasis, and lung contusion. An interstitial syndrome is marked by the presence of multiple B-lines, which have been described as "discrete laser-like vertical hyperechoic reverberation artifacts that arise from the pleural line, extend to the bottom of the screen without fading, and move synchronously with lung sliding" (7).

Pneumonia

Pneumonia appears as a hypoechoic area with an irregular shape in contact with the pleural line. The area of consolidation may be surrounded by multiple, closely spaced B lines, representing inflammatory perilesional edema, whereas the adjacent pleural line is hypoechoic and lung sliding is reduced or absent. Branching echogenic structures are often visible within the consolidation, representing "air bronchograms." When there is fluctuation with respiration and intrinsic movement, the term "dynamic air bronchogram" is used, which also rules out atelectasis (31). Air trapped in the small airway creates multiple millimetric hyperechogenic spots within the lesion (Figure 5) (32). "Fluid bronchograms" are fluid-filled airways and give rise to anechoic tubular structures that may be associated with bronchial obstruction

or extensive pneumonic consolidation (8). In mechanically ventilated patients, lung US should be considered as it may be more accurate than portable chest radiography in the detection of consolidation (7).

Lung Tumors

Lesions originating from the pleura, the chest wall, the anterior mediastinum, as well as peripheral lung lesions with pleural contact, can be visualized with US. Tumors are discernible as hypoechoic regions with posterior acoustic enhancement (Figure 6) (8, 33). The depth of these lesions is accurately measured using US; however, sonagraphic rib shadowing can prevent the accurate determination of their size in the longitudinal axis (Figure 7). Color Doppler may aid in distinguishing benign from malignant masses, with around two-thirds of malignant masses demonstrating a color Doppler signal (low-impedance flow) because of increased vascularity (34, 35). A pulsatile or triphasic flow pattern is often observed in either benign or malignant mass lesions, whereas a constant flow pattern correlates better with malignancy (37). The detection of chest wall invasion by malignant lesions is superior with US compared with CT; therefore, US can be effectively used to distinguish between T2 and T3 lung cancers (TNM staging) (36).

Pulmonary Embolism

Pulmonary infarction can be seen as a peripheral wedge-shaped hypoechoic region, frequently accompanied by a pleural effusion (37). Pulmonary embolism is considered to be present when two or more characteristic triangular or rounded pleural-based lesions are visualized, and the diagnosis is possible if one typical lesion with a corresponding small pleural effusion is present (37). Hemorrhages and incomplete infarctions mainly occur in the lower lobes of the lung, which when combined with their subpleural location is helpful in ultrasound imaging (37). In a recent meta-analysis of five trials (n=650), the sensitivity and specificity of US in detecting pulmonary embolism was 80% and 93% respectively, and US may depict a larger number of and smaller lesions than CTPA (38). A screening, point-of-care US protocol may predict the need for CTPA, thereby reducing the indiscriminate use of CTPA and unnecessary radiation and contrast exposure (39).

Interstitial Syndrome

Multiple B-lines are the sonographic sign of lung interstitial syndrome and are due to sub-pleural thickened interlobular septa as

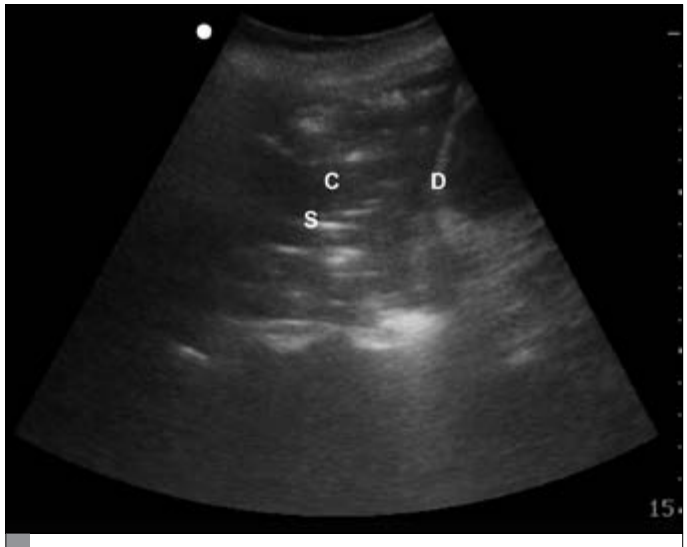

Figure 5. A low frequency US image of a patient admitted to the ICU with multilobar pneumonia. Seen here are multiple millimetric hyperechogenic spots (S) within the area of consolidation (C) created by air trapped in the small airways. Diaphragm (D)

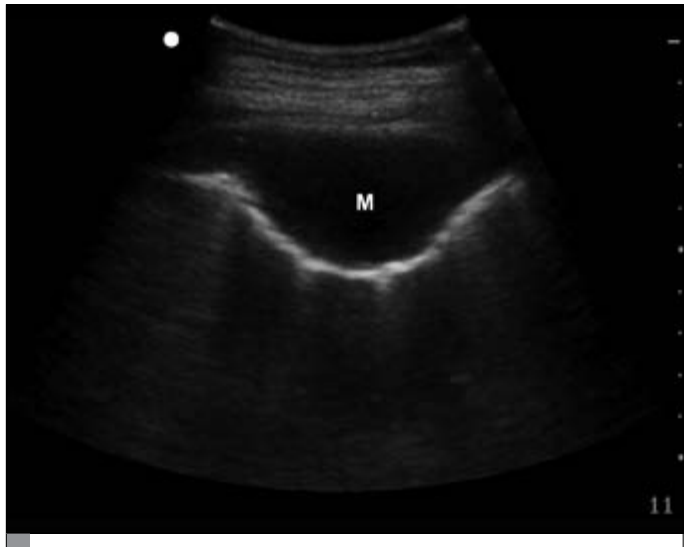

Figure 6. This low frequency US of a patient with bronchogenic carcinoma shows a mass (M), a hypoechoic region with posterior acoustic enhancement, abutting the pleura. The scan was done to localize the mass and obtain a cytological diagnosis by means of a US-guided transthoracic needle aspiration (TTNA)

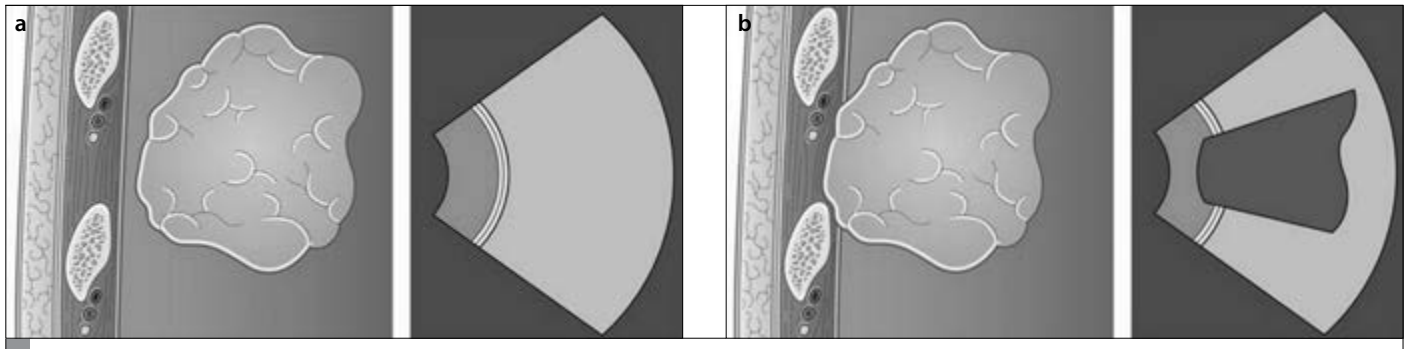

Figure 7. a, b. A peripheral lung lesion is shown schematically on the left, without (a) and with (b) pleural contact. The corresponding sonar images recorded with a sector scanner appear on the right. Only the lesion with pleural contact is visible on US. Note that the acoustic window is too narrow to demonstrate the circumference of the lesion but that it allows the determination of its full depth

well as subpleural areas of ground-glass attenuation (Figure 8) (2, 14). The following are the causes of interstitial syndrome: pulmonary edema of various causes, interstitial pneumonia or pneumonitis, and diffuse parenchymal lung disease (pulmonary fibrosis). Clinically, screening for B-lines can help distinguish between cardiogenic pulmonary edema and exacerbation of COPD (when not due to pneumonia) (40). Acute respiratory distress syndrome usually presents with more patchy involvement and a nonhomogeneous distribution of B-lines, and anterior subpleural consolidation as well as reduced or even absent lung sliding with an irregular thickened pleural line may be seen (7). Multiple B-lines in a diffuse and nonhomogeneous distribution may also be observed in patients with diffuse parenchymal lung disease, and the distribution of B-lines correlates with CT evidence of fibrosis (7). Diffuse parenchymal lung disease may additionally result in a fragmented pleural line with subpleural echo-poor areas (7).

Other Pulmonary Pathology

Pulmonary arteriovenous malformations that extend to the pleura appear as distinct hypoechoic lesions with posterior acoustic enhancement and high vascularity on Doppler (41). Rounded atelectasis may be visualized as a pleural-based mass with associated pleural thickening and extrapleural fat (42). Pleural and pulmonary cysts that abut the chest wall (e.g., hydatid cysts) can be visualized as large, round anechoic lesions (8).

ULTRASOUND-GUIDED INTERVENTIONAL PROCEDURES

General Principles

Ultrasound has become the standard for guiding various transthoracic procedures. It potentially increases the success rate and minimizes the risk compared with blind procedures because a more accurate and safe insertion site can be selected. Even in the absence of pleural effusions, ultrasound-guided biopsies have been shown to be safe (8, 43).

Real-time US guidance of needle biopsies is performed using specifically designed reusable probes, which are commercially available, although many clinicians use the "freehand" image-assisted technique (8). With this technique, the patient is suitably positioned, the area of interest identified, and the overlying skin marked. Having ascertained all the relevant information from the preceding scan, the procedure is then performed paying careful attention not to reposition the patient (8).

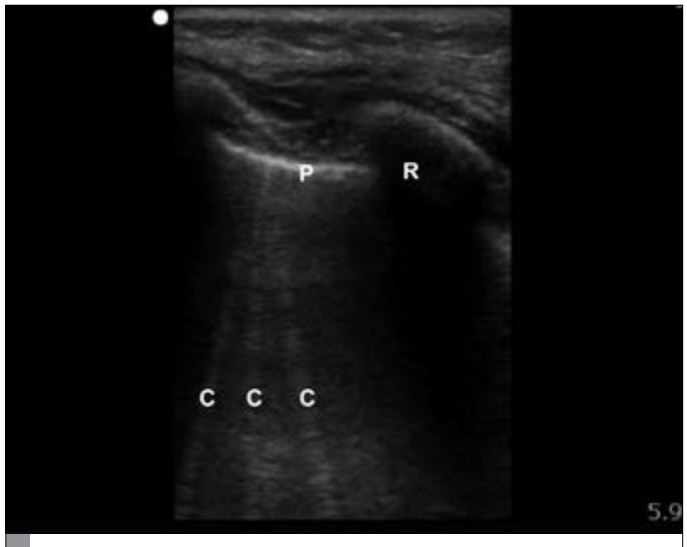

Figure 8. An example of an interstitial syndrome. This is a low frequency US of a patient with pulmonary edema. Note the B-lines (C), as well as the pleura (P) and Rib (R)

Thoracocentesis

Ultrasound-guided pleural aspiration has been shown to increase the yield and reduce the risk of complications, particularly pneumothoraces and inadvertent organ puncture (43). This may be particularly important when a safe procedure is mandatory, e.g., in mechanically ventilated patients and patients with a bleeding diathesis (8).

Diagnostic Biopsies of the Pleura

The most efficient and cost-effective approach to the management of pleural exudates that remain undiagnosed despite pleural fluid analysis is controversial (44, 45). Thoracoscopy and image-guided biopsies are the two modalities most commonly used.

Image-guided closed biopsy offers a rapid, more accessible, and cheaper alternative to thoracoscopy, albeit at the cost of a marginally lower yield (46). The choice between US and CT as the preferred imaging modality may be dictated by local expertise and the need to perform the biopsies outside the radiology unit (46). Ultrasonographic guidance allows for the biopsy of overtly abnormal pleura or for the use of other devices (e.g., cutting needles) to biopsy "dry" mesothelioma while decreasing the risk of visceral lacerations (46). Ultrasound guidance has also been shown to increase the likelihood of obtaining pleural tissue and diagnostic yield independent of pleural thickening (47). Moreover, pleural biopsy close to the diaphragm can be safely performed under image guidance, which is important as malignant deposits are more frequently located near the midline and diaphragm (46). The diagnostic yield of ultrasound-guided pleural biopsy ranges from 77% to 88% for metastatic malignancy and mesothelioma, 80% for "dry" mesothelioma, and 80%–100% for mesothelioma with a solid tumor mass >3 cm (43, 48, 49).

Tube Thoracostomy

Current guidelines strongly recommend the routine use of US guidance for all pleural fluid drainage, and it remains the ideal technique for identifying the optimal site for safe and effective intercostal drainage (ICD) (50). US may be particularly relevant in loculated parapneumonic effusions, where thickened parietal pleura, adhesions, or loculations can complicate insertion (8, 9). US is able to detect pleural septations with greater sensitivity than CT and may guide further decisions regarding the need for further interventions in addition to tube drainage and antibiotics. US is also used to decide when it is safe to remove the thoracostomy tube (51).

Transthoracic Biopsy of Chest Wall and Pulmonary Tumors

Chest wall tumors and pulmonary masses in contact with the chest wall are detectable by US and are suitable for transthoracic US-assisted biopsy because no aerated lung needs to be traversed during biopsy (5, 7, 8). Transthoracic fine needle aspiration (TTFNA) is performed under local anesthesia, ideally with a 22-gauge injection-type or spinal needle (8). US-assisted TTFNA and CNB have a combined yield of almost 90% in pleural-based lesions of the lung, chest wall, or pleura itself (52). US-guided TTFNA has been shown to

be significantly superior to CNB in confirming a diagnosis of bronchogenic carcinoma, whereas CNB is superior in other lesions (52). The reported pneumothorax rate of US-assisted TTFNA is approximately 1% and CNB is in the order of 4% (52).

"Drowned lung" is a radiological term often used to describe areas of pulmonary collapse (resorptive atelectasis) and postobstructive pneumonitis secondary to proximal lung tumors. Drowned lung is considered to represent accumulated secretions and is typified on US by fluid bronchograms, provided it extends to the pleura (8). US-assisted TTFNA of a drowned lung can be diagnostic in almost 75% of cases, and it may represent a viable alternative to bronchoscopy in selected cases (53, 54).

Transthoracic Biopsy of Mediastinal Masses

Yang et al. (55) have reported a diagnostic yield of 88.9% for mediastinal masses by means of US-guided needle biopsies. The same investigators pioneered the supraclavicular approach for US-guided biopsies of superior mediastinal tumors (56). However, US-assisted mediastinal biopsy has not gained popularity among clinicians, presumably because investigators generally utilized only CNB and were almost exclusively interventional radiologists (57). The complication rates of the various studies range from 1% to 6%, with pneumothoraces, hemothoraces, and hemoptysis the most common serious complications.

When US-assisted TTFNA is combined with CNB, close to 94% of patients are diagnosed (combined yield) by this sequential single-session approach without the aid of a radiologist or thoracic surgeon (54). US-assisted biopsy of mediastinal masses appears to be safe even in the setting of superior vena cava (SVC) syndrome, with minor hemorrhage seen in <5% of patients following TTFNA and 19% following CNB (58).

Basic Competency in Ultrasonography

Transthoracic US remains an operator-dependent modality, and image acquisition and interpretations occur simultaneously (8, 52). There have been recent renewed calls for formal instruction of basic US skills and certification in basic US competency. The Critical Care Network of the American College of Chest Physicians, in partnership with La Société de Réanimation de Langue Français, has identified pleural and lung US as two core areas in their consensus statement on competency in critical care US (59). They suggest that basic knowledge and skills are required in the following five principle areas: 1) basic ultrasound physics; 2) knowledge of machine controls and transducer manipulation; 3) knowledge of normal and abnormal anatomy and the pathophysiological consequences of observed abnormalities; 4) knowledge of image interpretation, clinical application, and limitations of US; and 5) knowledge of when the examination is beyond the technical or interpretive capability of the clinician (59).

The accreditation process in Europe and UK recognizes three levels of training and expertise (60). Level 1 competency includes 1) recognizing the normal anatomy of the pleura and diaphragm; 2) identifying the heart, liver, and spleen; 3) recognizing a pleural effusion and estimating its depth; 4) differentiating a pleural effusion from pleural thickening; 5) identifying a consolidated lung; and 6) guided thoracocentesis and ICD placement (60).

Requirements for basic accreditation include a formal training course, supervised practice, and the acquisition of specific competencies. At least one year of practical experience of thoracic US and a further 300 examinations (after obtaining level 1) are required for level 2 accreditation. Level 3 accreditation is reserved for experts in the field

CONCLUSION

Given the growing body of evidence on the usefulness of transthoracic US as a diagnostic modality and its ability to guide diagnostic and therapeutic interventions, all training programs in respiratory medicine should include training in basic transthoracic US competency (level 1). Not only does US aid in the qualitative and quantitative description of pleural effusions but it also aids in visualizing lung tumors, pulmonary consolidations, and other parenchymal pulmonary processes, provided they abut the pleura. US provides a real-time guide to pleural procedures such as thoracentesis and drainage of effusions, fine-needle aspirations, and CNB of lesions arising from the chest wall, pleura, peripheral lung, and mediastinum, with a high yield in the hands of a pulmonologist. It can provide ancillary information that may direct the need for and mode of pleural tissue sampling, particularly if US findings suggest pleural malignancy. US has become an essential tool in emergency and intensive care units as an application at the point of care for prompt and accurate diagnosis of pneumothoraces, pulmonary emboli, and pulmonary edema.

Peer-review: Externally peer-reviewed.

Author contributions: Concept - M.J.V., B.W.A., C.F.K.; Design - M.J.V., B.W.A., C.F.K.; Supervision - M.J.V., B.W.A., C.F.K.; Resource - M.J.V., B.W.A., C.F.K.; Materials - M.J.V., B.W.A., C.F.K.; Data Collection and/or Processing - M.J.V., B.W.A., C.F.K.; Analysis and/or Interpretation - M.J.V., B.W.A., C.F.K.; Literature Search - M.J.V., B.W.A., C.F.K.; Writing - M.J.V., B.W.A., C.F.K.; Critical Reviews - M.J.V., B.W.A., C.F.K.; Other - M.J.V., B.W.A., C.F.K.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study has received no financial support.

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