

# Introduction to transthoracic ultrasound for the pulmonologist

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## Key words:

- Transthoracic ultrasound,
- Pleural effusion,
- Thoracentesis,
- Guided biopsy,
- Education

**SUMMARY.** Transthoracic ultrasound (TUS) has a significant contribution to make in the everyday clinical practice of pulmonology, thanks to its proven efficacy in the diagnosis of chest diseases and the guidance of related interventions. TUS is a portable technique which can be performed at the point of care. It can also be repeated in the same patient as many times as necessary because of the absence of ionizing radiation and the low cost of the procedure. It is considered to be the most sensitive method for identifying pleural effusion, but it can also effectively rule out pneumothorax, and detect a variety of peripheral pulmonary abnormalities, albeit with less sensitivity than other imaging methods. TUS is indispensable in guiding invasive procedures such as thoracentesis, increasing the success rate and reducing the complications. Acquisition of the basic skills in the use of TUS is strongly recommended by several chest specialty boards worldwide, but experience in Greece remains fairly limited compared that in many other countries. *Pneumon 2013, 26(3):229-234.*

## INTRODUCTION

Diagnostic imaging of the chest commonly includes chest X-ray and high resolution computed tomography (HRCT) of the chest. Recently, thoracic ultrasound (TUS) has been used with increasing frequency by pulmonologists either instead of or as a supplement to these methods, because of its proven efficacy in the diagnosis of chest diseases and in guiding related interventions. It is a low-cost test with no radiation exposure, and it provides real time images. Pleural effusions, pleural tumours and pneumothorax are easily detectable on TUS, which can be followed, as needed, by diagnostic thoracentesis and tube drainage under real time guidance. The portability and ease of use of modern US devices render TUS an essential tool for the pulmonologist.

## TECHNICAL-PHYSICAL PROPERTIES OF ULTRASOUND

US imaging is based on the transmission of a brief ultrasonic wave from

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a transducer, which penetrates the tissue and is reflected at the surfaces separating tissues of different composition. The degree of reflection depends on the acoustic impedance, which is mainly related to the density of the specific tissue. Among the inherent limitations of US imaging of thoracic pathology are the presence of the ribs that produce an acoustic shadow, preventing the display of any structure located below them, and the presence of air in the normal lung parenchyma that generates artifacts due to the strong reflection of US waves.<sup>1</sup>

## ULTRASOUND DEVICES

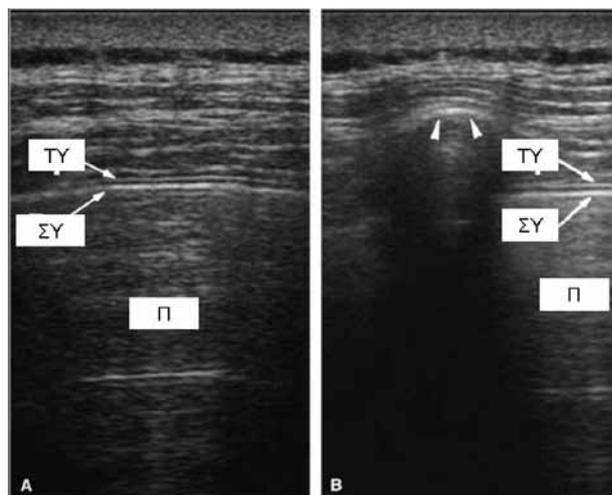
Pleural US may be practically performed by any of the devices suitable for cardiac or abdominal examination. A convex transducer with a frequency range of 2 to 5 MHz is preferable. At this frequency the optimum correlation between analysis and tissue penetration is achieved. Higher frequencies, such as those used in imaging vascular structures (i.e., 7.5-10 MHz), offer better resolution but less depth of penetration, precluding the examination of deeper structures. These frequencies can be used, however, for further evaluation of any abnormality of the chest wall detected by lower frequencies.<sup>2</sup>

## NORMAL APPEARANCE

Imaging of the aerated lung and the pleura is achieved through the intercostal spaces. The ribs are recognized by loss of signal (acoustic shadow). The normal chest wall is illustrated as a series of echogenic layers corresponding to the layers of muscle and connective tissue that comprise the chest wall and the two pleural layers. (Figure 1) Separate recognition of the two pleural layers is possible by using a high-resolution linear transducer. The normal motion of lung during the respiratory movements produces a characteristic image at the point of contact of the two pleural surfaces known as lung sliding. Normal lung below that point cannot be examined due to the presence of air which fully reflects the sound wave.<sup>1,2</sup>

## COMMON USES OF TRANSTHORACIC ULTRASOUND

By far the most common indication of TUS is for the investigation of a pleural effusion (Figure 2). Less commonly, US may be used to exclude pneumothorax and to investigate pleural thickening and tumours or peripheral



**FIGURE 1.** Ultrasound appearance of the normal pleura with high frequency linear transducer. TY = parietal, ΣY = visceral pleura, Π = lung. Arrows show rib with the corresponding acoustic shadow.



**FIGURE 2.** Ultrasound appearance of a large pleural effusion. Red arrows = pleural fluid, yellow arrows = flattened diaphragm, indication of a highly symptomatic pleural effusion.

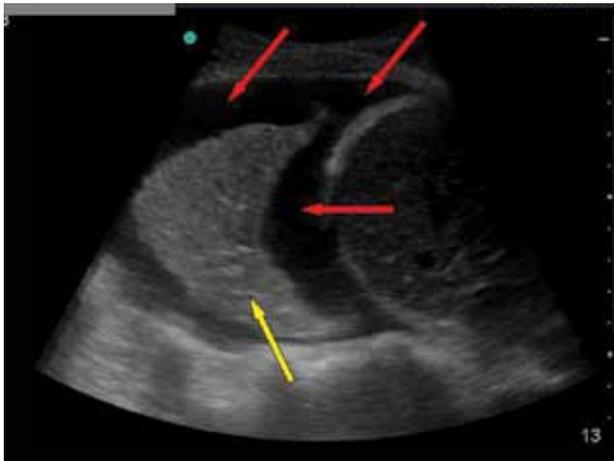
lung lesions.<sup>3,4</sup>

## PLEURAL EFFUSION

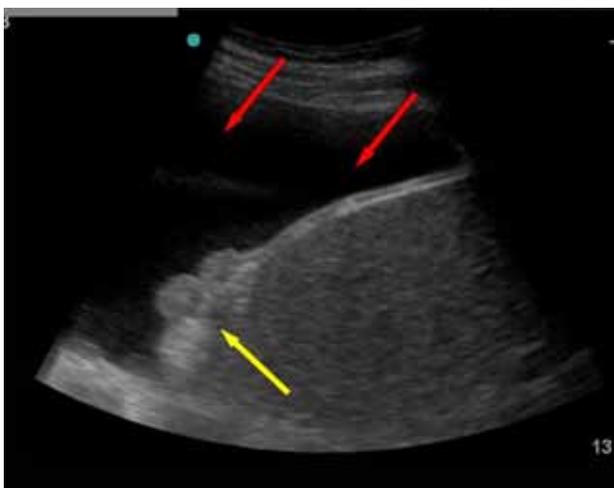
TUS is undoubtedly superior to other techniques in the detection of pleural effusions of minimum volume (5mL), such as physical examination which can detect collections over 300mL of fluid, or chest X-ray which detects collections of greater than 150mL, the minimum

amount required to blunt the costophrenal angles.<sup>1,5</sup> TUS, in addition, successfully identifies the position of the fluid and can immediately and definitively distinguish pleural effusion from paralysis of the diaphragm, pleural thickening, atelectasis (Figure 3) or masses originating from the pleura (Figure 4).<sup>6</sup> TUS is also clearly superior to HRCT in detecting septation of the effusion (Figure 5).<sup>7</sup>

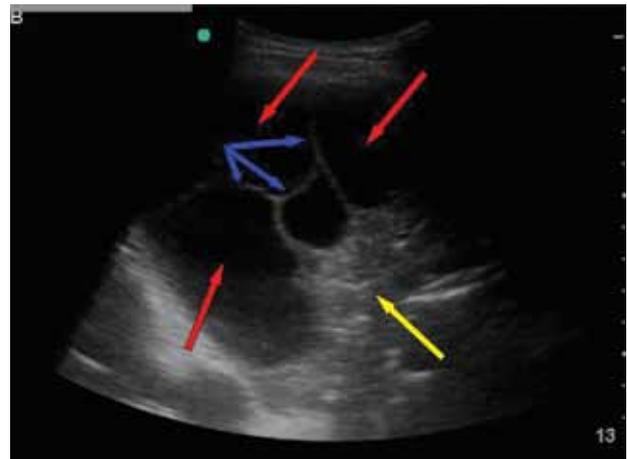
The US imaging features of pleural effusions have been characterized according to their nature. Based on



**FIGURE 3.** Ultrasound appearance of atelectasis of the right lower lobe of the lung with a small pleural effusion. Red arrows = pleural fluid, yellow arrow = atelectasis of the right lower lobe with minimal air, indicating central occlusion of the bronchus.



**FIGURE 4.** Ultrasound appearance of a large pleural effusion with a multilobular lesion on the diaphragmatic pleura. Red arrows = pleural fluid, yellow arrow = multilobular mass in the diaphragmatic pleura, diagnostic of malignant pleural effusion.



**FIGURE 5.** Ultrasound appearance of parapneumonic polycystic pleural effusion, pneumonia. Red arrows = pleural effusion, yellow arrow = pulmonary consolidation, blue arrows = diaphragm.

sonographic characteristics, an effusion can be characterized as anechoic, homogeneously echogenic and complex or septated echogenic. Exudative effusions may be homogeneously echogenic or septated echogenic, in contrast to transudate effusions that are almost always anechoic. The anechoic imaging of a fluid could, however, be related to either an exudate or a transudate. Empyema and haemothorax are intensely echogenic, while septation in parapneumonic effusion has been associated with prolonged tube drainage and the need to use fibrinolytics<sup>8,1</sup>. Based on US findings, a malignant can be distinguished from a benign pleural effusion; features consistent with malignant effusion are the presence of pleural thickening (>1cm), circumferential pleural thickening and the presence of pleural nodular lesions (Figure 4), and also consistent pathological findings in the diaphragm or the liver<sup>9</sup>.

### PLEURAL THICKENING, PLEURAL MASSES AND CHEST WALL INFILTRATION

The use of US has proved to be reliable in detecting solid lesions and thickening of the pleura. It is superior to traditional imaging methods not only in distinguishing between pleural effusion and thickening, but also in identifying infiltration of the parietal pleura or the chest wall<sup>10,11</sup>.

## PNEUMOTHORAX IMAGING

The use of TUS has been sufficiently documented for the immediate diagnosis or exclusion of pneumothorax, especially in critically ill patients in whom imaging with chest X-ray or HRCT scan may be difficult. The presence of lung sliding and the transmission pulse sign, along with the typical B-lines, can safely exclude pneumothorax.<sup>12-14</sup> It should be noted, however, that confirmation of pneumothorax can be challenging, especially in patients with partial pneumothorax or emphysema, demanding significantly greater familiarization and skills than are needed for recognizing a pleural effusion. Furthermore, US is mainly a qualitative method for the exclusion of pneumothorax, and chest X-ray is essential for quantifying the size of a pneumothorax.<sup>10</sup>

## INVASIVE PLEURAL PROCEDURES: THORACENTESIS, CHEST TUBE DRAINAGE

TUS is the method of choice for selecting an appropriate site for diagnostic thoracentesis and chest tube insertion, far more sensitive than physical examination or chest X-ray, and it also able to provide real time guidance for the procedure. TUS guidance for thoracentesis has been shown to increase the rate of successful punctures, especially when clinical guidance has failed, as may happen in case of septations or small pleural effusions<sup>8</sup>. Using TUS guidance, the puncture of inappropriate sites, such as liver or spleen, is avoided and the rate of unnecessary punctures (e.g., for negligible or subdiaphragmatic effusions) is minimized.<sup>15,16</sup> The incidence of adverse events, particularly iatrogenic pneumothorax, is significantly reduced when US guidance is utilized, although it should be noted that the rate of iatrogenic pneumothorax only decreases when the thoracentesis is performed immediately after the diagnostic US; the practice of sending the patient over to the radiology department for skin marking of the appropriate spot is unreliable.<sup>8</sup>

US guidance is also helpful for the optimum site selection for chest tube insertion, with a reported success rate of close to 100%. The risk of malpositioning is decreased, and the rate of complications due to rupture of adjacent structures such as lung, diaphragm, etc., is reduced<sup>6</sup>, but since US cannot recognize intercostal arteries, the established rules of good practice should be followed in order to avoid iatrogenic haemothorax.

## INVASIVE PROCEDURES: IMAGE-GUIDED BIOPSY

Closed pleural biopsy has low sensitivity rates and has therefore almost been abandoned, but as the sensitivity of pleural fluid cytology does not exceed 60%, and is even lower for mesothelioma, a high percentage of patients will have to proceed to some form of pleural biopsy. Image-guided pleural biopsy has success rates comparable with those of thoracoscopic biopsy, and can be obtained with US guidance, either by real-time imaging or visualization of the lesion and subsequent biopsy. The reported sensitivity reaches 85% in cases of malignancy, and even 100% accuracy in cases of mesothelioma, while the rate of iatrogenic pneumothorax requiring treatment is no higher than 2%. The prospect of sampling tissue from a pleural lesion with a method performed by a trained pulmonologist, without transfer of the patient to another department or exposure to radiation, and with success rates comparable with those of CT guidance, or thoracoscopic biopsy makes this method an attractive alternative.<sup>17-19</sup>

## THORACOSCOPY GUIDANCE

Medical thoracoscopy is a technique that is increasingly being performed to establish diagnosis in the case of exudative pleural effusion, and with concomitant draining and pleurodesis for malignant pleural effusions. This technique often involves establishing a pre-procedure pneumothorax, to avoid injury to the underlying lung parenchyma. This process causes additional delay, and complete collapse may not be achieved because of the presence of septations. TUS identifies the optimum position of the entry site for trocar placement, especially in cases of multiple adhesions or small pleural effusions.<sup>20</sup>

## TRANSTHORACIC ULTRASOUND IN THE INTENSIVE CARE UNIT

TUS is gaining ground in the intensive care unit (ICU) setting. The limitations of radiography in patients in the decubitus position, and in distinguishing between parenchymal infiltrates and pleural effusions, are well known, and identification of pneumothorax may also be challenging in these patients. TUS correctly recognizes pneumothorax, with a sensitivity that reaches 95%, compared with 28-60% for bedside radiography.<sup>21</sup> It can also definitively differentiate between pulmonary infiltrates

and pleural effusion. With its proven efficacy in guiding bedside diagnostic thoracentesis and the insertion of chest tubes, it has become particularly useful for IC patients for whom transportation would be difficult or hazardous.

## RARE USES OF TRANSTHORACIC ULTRASOUND

The literature is being constantly updated with new uses for TUS, including its supplementary role in the diagnosis of pulmonary embolism and the recognition of infarction and in diagnosing ALI/ARDS or cardiogenic pulmonary oedema ("wet lung").<sup>22-24</sup> In general, the relevant studies have been conducted in specialized centres by chest physicians with extensive experience in TUC and are beyond the scope of this article.

## EDUCATION

The increased diagnostic yield of TUS, coupled with the portability and ease of use of modern US devices, have led several medical boards, such as the American Board of Internal Medicine, the American College of Emergency Physicians and the American College of Surgeons to incorporate recommendations for their members to acquire skills and knowledge in this area.<sup>25</sup> In safety and efficacy, the use of US by trained pulmonologists appears to be comparable to that of radiologists, as far as diagnostic thoracentesis is concerned<sup>26</sup>. The Royal College of Radiologists (RCR) has published guidelines regarding the training of non-radiologists in TUS.<sup>27</sup> Daily training programmes have been shown to contribute favourably to the acquisition of basic skills.<sup>28</sup>

## TRANSTHORACIC ULTRASOUND IN GREECE

While the British Thoracic Society has already incorporated TUS in its recent guidelines, strongly suggesting the use of US before thoracentesis and chest tube insertion, the Greek experience in TUS is still fairly limited by international standards.<sup>29</sup> Until recently patients were referred to the radiology department following clinically guided thoracentesis, where they were scanned and then returned for repeat thoracentesis. This 'X marks the spot' technique is not only time consuming and inconvenient, but it is also, as noted above, much less safe. For the past few years the Hellenic Thoracic Society has organized daily seminars for the training of pulmonologists in TUS, with the participation of acknowledged instructors from the

UK, and modelled on those conducted in the UK. These seminars provide the participants with the basic skills, mainly for recognizing pleural effusions and performing safely procedures such as thoracentesis and chest tube insertion. The further development of TUS in Greece, however, along with the standardization and establishment of US training as an integral part of pulmonology will need to include the participation of radiologists. Until this can be ensured, further training in TUS, beyond the scope of the present seminars, can only be obtained in specialist centres abroad.

## CONCLUSION

In conclusion, TUS can contribute significantly to the diagnostic approach to chest disease. It is a simple technique, requiring a relatively simple learning process, characterized by no radiation exposure and low cost. It is considered the most sensitive method for identifying pleural effusions and pleural thickening, and can also enable the recognition of certain pulmonary abnormalities (e.g., peripheral infiltrations, atelectasis, infarction) provided they are adjacent to the visceral pleura. Conducting diagnostic chest puncture under US guidance has increased success rates and lowered complication rates. Although recent reports show that although pleural effusion was the sole indication for performing TUS in 75% of cases, it was crucial in the diagnosis and defined further diagnostic procedures in 65% of other cases.<sup>30</sup> Referral of patients to be scanned in the radiology department raises the cost of hospitalization cost and may be more hazardous for the patients.<sup>31</sup>

For these reasons, the development of standardized basic TUS training programmes for pulmonologists, is essential, in order to incorporate the application of TUS in the diagnostic approach to issues frequently encountered in the everyday clinical practice of pulmonology.

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