Transthoracic ultrasound for the pulmonologist
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Purpose of review
Transthoracic ultrasound has received increased interest from chest physicians in recent years. Modern ultrasound devices are user friendly, inexpensive, lightweight, and portable, which makes them suited for outpatient settings as well as for bedside investigation of the severely ill. Ultrasound is set to become a practical and essential tool for the pulmonologist in the near future.

Recent findings
An ever-increasing number of articles are aimed at describing and refining how ultrasound can be utilised by chest physicians in daily practice. Only basic ultrasound skills are required to assess pleural effusions and perform ultrasound-guided thoracocentesis. Sonographic assistance with insertion of chest drains as well as identification or biopsy of thoracic masses are more complex, and advanced skills are required for the investigation of pneumothorax and thromboembolic disease.

Summary
The current literature documents the progress in the application of ultrasound for the practicing chest physician. In this article the authors describe the most recent developments and follow up with some simple but essential advice for the novice venturing into chest ultrasound.

Keywords
empyema, pleural disease, pleural effusion, pleural tumors, ultrasound

Introduction
This article appears only 2 years after a comprehensive review of the principles of ultrasound (US) in the diagnosis and management of chest disease was published in this very journal [1]. A growing proportion of articles in this field is written by physicians and addressed at an audience beyond research or tertiary facilities. This heralds the emergence of US as an essential tool for the practicing pulmonologist. The first part of the current article will provide the seasoned sonographer with an update on the latest available information. On a different note, the second section is aimed at the pulmonary physician less experienced with US. From a more personal perspective, we will share some hands-on advice that we have found useful for our clinical practice with chest US.

Literature review
Sonography is not a new technology. Once a radiologic domain, it was adopted by specialist physicians long ago. It does not come as a surprise that the latest developments in chest US are rather based on its application to chest disorders than on technologic progress. Some excellent current reviews have become available in the print literature [1–3]. Evans and Gleeson [4] put ultrasonography for pleural disease in perspective with other commonly used radiologic techniques. The review by Koh et al. [5], which is accessible free of cost via the Worldwide Web, conveys dynamic information beyond anatomy using animated material and is recommended as a complete guide to sonographic chest morphology.

Pleural effusion
The value of ultrasonography for detection and quantification of pleural effusions is uncontested. In small effusions, US is more sensitive than decubitus expiratory films [6]. Sonographically, a pleural effusion manifests as an anechoic, homogeneous space between parietal and visceral pleura. Transudates are echo-free, unseptated, and free flowing. Exudates can exhibit specific patterns of echogenicity and fibrinous septations of various quality and density, which can serve as diagnostic clues. Echogenic swirling patterns have recently been linked to a malignant nature of an effusion [7]. In parapneumonic effusion and empyema, US has been well established in pediatric patients [8–11] and is gaining ground in adults. Chen et al. [12] demonstrated that patients with sonographically septated effusions needed longer chest tube drainage, longer hospital care, and were more likely to require fibrinolytic therapy or surgery compared with those with unseptated effusions. Tu et al. [13] recently
confirmed some of these findings in medical intensive care unit (ICU) patients. US ideally integrates with swift decision making in parapneumonic effusion and empyema. At the bedside, extent and quality of the effusion can be determined, a guided aspirate can be obtained, and, if necessary, a thoracostomy tube can be positioned during the same session [14].

**Pneumothorax, seropneumothorax**

Pneumothorax detection requires more skill than the investigation of pleural fluid. Pneumothorax can be diagnosed with the absence of respiratory movement of the lung surface beneath the chest wall (gliding sign) [15]. Herth et al. [16] have recently shown that a pneumothorax following transbronchial biopsy can be reliably excluded with US (sensitivity, 100%; specificity, 83%). This is likely to reduce costs for chest radiographs, increase patient comfort, and offers an excellent opportunity to acquire practice pneumothorax detection. In a commendable effort to extend the indications of US, Lin et al. [17] have recently defined a panel of sonographic features for the differentiation of pyopneumothorax from peripheral lung abscess.

**Thoracentesis and drainage**

US is particularly well suited for guiding pleural interventions. It increases the success rate and reduces complications of thoracentesis [18–20], and routine use of US assistance in small effusions and in those with abnormal presentations on chest radiograph must be advised. Ultrasoundography in the clinician’s hands also allows bedside procedures, and the safety and usefulness of US-guided thoracentesis in the critically ill has repeatedly been proved recently [13*,21].

**Tumors and biopsy procedures**

Lesions originating from the pleura, the chest wall, and the anterior mediastinum can be visualised with US. Peripheral lung lesions with pleural contact are also detectable, and US is a proved modality for determining whether and how far a peripheral lung tumor has advanced to or penetrated the pleura and the chest wall [22,23]. Apart from staging of lung cancer, US is a formidable tool to assist with biopsy procedures. Although US-guided needle biopsy requires a certain expertise, the technique is relatively easy to learn and can replace computed tomographic guidance at a much lower cost [24,25]. In a recent study with 91 patients in our own center, US-guided cutting biopsy was 85% sensitive for neoplastic disease and 100% sensitive for mesothelioma [25,26]. Cutting biopsies might not always be necessary for thoracic lesions. In our experience, the yield of fine-needle aspiration cytology in epithelial lung malignancies is comparable with cutting biopsies, whereas the latter performs better in sarcomas, mesotheliomas, and benign lesions [27].

**Other indications**

Current pioneering work is targeted at improving the diagnostic approach to the severely ill. Lichtenstein *et al.* [28,29] report that lung pathology associated with severe pulmonary illness such as acute respiratory distress syndrome or lung consolidation can be reliably assessed non-invasively and at the bedside with chest US. Pleural effusion and lung consolidation associated with pulmonary embolus are also amenable to US investigation [30], which can also detect other sequelae of thromboembolic disease such as venous thrombosis or right ventricular overload with hepatic congestion. Currently, however, US for these entities is still reserved for experienced physicians with a keen interest in US. A growing number of case reports highlights the broad spectrum of disease accessible to US [31,32].

**How to start with thoracic ultrasound**

An expert review of all practical aspects of chest sonography is beyond the scope of this article. From a personal perspective, however, we would like to give the novice chest ultrasonographers some practical advice for the initial struggle with gel, sound, and vision. Anyone venturing into chest ultrasonography should start with the evaluation of pleural disease. Determination of a site for a puncture or tube placement comes next, and with growing experience anyone used to performing blind pleural biopsies can proceed to needle aspiration or biopsy of solid lesions.

**General appraisal of chest ultrasound**

The normal lung does not easily lend itself to sonographic examination. The air-filled space beyond the visceral pleura completely reflects US and gives rise to artefacts that might be confused with structural detail by the less experienced. Lesions shielded from the probe by only a tiny portion of air cannot be seen at all, and even air-containing lesions with pleural contact such as lung abscess or seropneumothorax can be difficult to appreciate. As soon as fluid or solid tissue extends to the pleura, however, an acoustic window opens to a variety of lesions of pleural, pulmonary, mediastinal, and chest wall provenance (Fig. 1).

**Equipment**

Bedside examination is one of the advantages of US, and although there are arguments for advanced technical features such as color screens, Doppler probes for line placement, or advanced digital recording devices, we strongly recommend to go for a basic model that is lightweight, robust, reasonably priced, and transportable. A curvilinear probe at 2 to 5 MHz and a linear probe at 7.5 to 10 MHz are more than sufficient for chest ultrasonography. At no time of the day should there be hesitation to take the machine to the bedside where it is needed. Most occasional ultrasonographers, including us, struggle to memorise the purpose of more than three controls even on a modest keyboard. We advise consulting a radiologist to have the
most basic model-specific functions explained one-on-one. Freezing the image not only generates a still image on the display, but also puts the sonar probe in idling mode. This increases its life span.

**Diagnostic scanning**

It is common sense that one should avoid trying the most challenging case first. We advise performing sonography routinely on every patient referred for pleural fluid aspiration, no matter how large the effusion and how obvious the puncture site might seem. This strategy allows familiarisation with sonographic anatomy and leads to rapid accumulation of experience.

Patient positioning is an underappreciated yet important aspect. There is no standard position suitable for every indication. Patient mobility and the presumed location of the targeted lesion must be considered. Our preferred position is with the patient sitting sideways on a stretcher and both arms resting on a bedside table, which allows shifting the scapula when necessary. Lateral decubitus, supine, or sitting positions are also used. Repositioning a patient or even small postural changes can make a big difference for the sonographic visibility.

For scanning, use enough gel to provide a sound interface between probe and skin. One of the most frequent
beginner’s mistakes is not to maintain skin contact with the hand holding the probe for scanning. Hands clean of gel are not the objective. As an analogy, one should hold the probe like a pen for writing on paper and not like chalk for writing on a blackboard. Experienced sonographers keep their eyes on the screen while their hand moves the probe across the area of interest and provides the positional information. The probe is moved slowly, preferably along intercostal spaces, which are oblique and not horizontal. The best approach is to identify the area of interest on a radiograph first, and then depart from known anatomic structures to the target area. Liver and spleen have characteristic sonar patterns and indicate the position of the diaphragm. Once identified, the lesion can be assessed for mobility with normal or forced respiration. A typical finding in a patient with a free-flowing effusion of a moderate size is demonstrated in Figure 2.

**Thoracentesis and drainage**

Selection of an entry site for a needle or a chest drain is an easy task in large effusions. In small effusions, however, it is important to monitor the selected site during inspiration and expiration, and it might even be necessary to instruct the patient to hold his breath for the puncture. It has happened with beginners that the liver or spleen was mistaken as fluid collections. It is our policy to identify the upper abdominal organs before a puncture to ensure

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**Figure 2. Peripheral lung lesion with and without pleural contact**

(a–c) A peripheral lung lesion is shown schematically on the left without (top) and with (bottom) pleural contact. The corresponding sonar images recorded with a sector scanner are shown on the right. Only the lesion with pleural contact is visible on ultrasound. Note that the acoustic window is too narrow to demonstrate the whole circumference of the lesion, but it allows determining its full depth.

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**Figure 3. A schematic view of a cutting biopsy of a peripheral lung lesion**

(a) The device is positioned within the lesion, keeping a safe distance from the intercostal neurovascular structures below the ribs. (b) The inner stylet is deployed with the cutting bit pointing away from the neurovascular bundle. (c) The biopsy specimen is harvested by sliding the cutting bit over the inner stylet (not by withdrawing the inner stylet back into the cutting bit). The absence of air between the lung lesion and the chest wall provides both an acoustic window and a pathway for the sampling device through nonaerated tissue, which reduces the risk of pneumothorax. The peripheral nature of the lung lesions makes significant bleeding unlikely.
that the targeted structure is indeed above the diaphragm. We discourage marking a puncture site at a remote facility and then transporting the patient elsewhere for thoracentesis. Both the fluid collection and the skin mark might shift considerably with a small change in body position.

**Aspiration and biopsy of solid lesions**

If a lesion provides a sufficiently large acoustic window throughout the breathing cycle, a puncture can be performed under local anesthesia with little risk of pneumothorax or major bleeding (Figs. 3 and 4). Although dedicated probes are available, we prefer the free-hand technique for its simplicity. The entry site is marked, and the safe range, direction, and depth of the puncture are memorised before the biopsy. The patient must not move between marking and biopsy, because the skin mark can shift away from the targeted deeper structure. Under local anesthesia, we routinely use fine-needle aspiration with a 22-gauge injection-type or spinal needle and a cutting biopsy when the lesion is suitable. A word of caution before using cutting biopsy devices: These are extremely sharp and it is of utmost importance to spare the mammary and intercostal arteries when using them.

Sonographic exclusion of pneumothorax after aspiration or biopsy of a solid lesion is a simple task. If the aspirated lesion is still visible on US in unchanged shape and size, no free air is present between the sampled process and the visceral pleura, and a clinically relevant pneumothorax is unlikely.

**Conclusion**

The usefulness of US for chest physicians is firmly established. It is an easy-to-learn, low-cost, and elegant method that extends the physicians’ diagnostic and interventional potential at the bedside in peripheral lung, pleural, and chest wall disease. In our institution, ultrasonography is routinely used for thoracentesis in the ICU and for chest tube placement. It has replaced computed tomographic guidance for aspiration and sampling of all lesions involving the pleura and also lung masses abutting the pleura. Our experience with ultrasonography is that it adds a new dimension to our anatomic and functional understanding of disease, integrates with our interventional practice, is an excellent training instrument, improves ICU care, and frequently obviates transport of the critically ill. Future research and developments should include formal training programs for chest physicians to ensure a basic standard for chest US and aim at refining the application of chest
sonography to problems frequently encountered in the lung physicians' practice.

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References
From a radiologic point of view, this article puts transthoracic US into perspective with other radiologic techniques commonly used in chest disease.