European Respiratory Society Statement on Thoracic Ultrasound

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Abstract

Thoracic ultrasound is increasingly considered to be an essential tool for the pulmonologist. It is used in diverse clinical scenarios, including as an adjunct to clinical decision making for diagnosis, a real-time guide to procedures, and a predictor or measurement of treatment response. The aim of this European Respiratory Society task force was to produce a statement on thoracic ultrasound for pulmonologists using thoracic ultrasound within the field of respiratory medicine. The multidisciplinary panel performed a review of the literature, addressing major areas of thoracic ultrasound practice and application. The selected major areas include equipment and technique, assessment of the chest wall, parietal pleura, pleural effusion, pneumothorax, interstitial syndrome, lung consolidation, diaphragm assessment, intervention guidance, training, and the patient perspective. Despite the growing evidence supporting the use of thoracic ultrasound, the published literature still contains a paucity of data in some important fields. Key research questions for each of the major areas were identified, which serve to facilitate future multi-centre collaborations and research to further consolidate an evidence-based use of thoracic ultrasound, for the benefit of the many patients being exposed to clinicians using thoracic ultrasound.

Introduction

Thoracic ultrasound (TUS) is increasingly considered an essential tool for the pulmonologist [1-3]. Although this technique was for many years considered "of no use" in the lung, many decades of research have demonstrated high clinical utility in a number of areas of pulmonary disease. While the technique of TUS originated with radiologists, it is increasingly being used by pulmonologists "at the bedside", and in this context is used with several potential aims. These include as an adjunct to clinical decision making for diagnosis, as a real-time guide to procedures, and as a predictor or measurement of treatment response [1, 2, 4-6].

This European Respiratory Society (ERS) statement has been written in light of the growing evidence behind the use of TUS across a broad range of respiratory disease areas, as a summary of the evidence to clinicians who wish to understand the current rationale and state of the art of this technique. An evidence-based approach has been used throughout, addressing major areas of TUS practice and application. These include chapters on required equipment and technique, assessment of the chest wall, parietal pleura, pleural effusion, pneumothorax, the utility of ultrasound (US) in diffuse lung parenchymal diseases, diaphragm assessment, intervention guidance, and finally suitable training in TUS.

We have highlighted areas of potential future research, as suggested by the current state of the evidence, at the end of each topic, and hope that this will lead to further definitive studies which will further improve our diagnostic and treatment armamentarium and benefit our patients.

Methods

The task force was comprised of clinicians with internationally recognised expertise in TUS. In order to reflect the multidisciplinary use of TUS, the expert group included pulmonologists and relevant experts from other specialties (e.g. radiology, emergency medicine, intensive care, thoracic surgery, paediatrics). This group was supplemented with young ERS members with TUS experience, and representatives of the European Lung Foundation (ELF). An ERS methodologist provided feedback on research strategy, evidence and statement synthesis, and oversight of the task force process.

The task force was initiated in December 2018 and comprised one face-to-face meeting, regular telephone conferences and e-mail correspondence. Initially, the task force established the overall scope and aim of the statement. It was agreed to limit the statement to the general use of TUS in the context of the clinical use by a pulmonologist. The members then agreed on a list of core topics which was to be addressed in the final statement.

A group of task force members with a designated topic leader was assigned to each topic and was responsible for development of a search strategy, evidence synthesis, and writing of an initial topic section for the statement. MEDLINE and Scopus databases were used for the literature searches, with inclusion of additional studies identified by individual task force members. An ELF representative was assigned to the write a section on the topic “patient perspectives”. The search terms for each topic are provided in the Appendix. The topic leader identified and used relevant studies and knowledge of current clinical practice to make an initial topic draft which the topic group then reviewed until a proposed final topic section had been completed. In addition to evidence synthesis, each group was given the task of identifying major gaps in the current evidence and provide key areas for future TUS research. The findings from the literature regarding the “patient perspectives” topic were shared with patients who had experience of TUS to identify additional perspectives.

Using the proposed topic sections, the task force chairmen comprised a first draft of the statement manuscript. Task force members then provided comments and suggestions in the making of the final manuscript based on the draft. The final version of the manuscript was reviewed and approved by all task force members. The statement provides an overview of the evidence and current clinical practice for general TUS performed by pulmonologists but does not provide recommendations for clinical practice.

According to ERS policies task force members disclosed potential conflict of interests at the beginning of the task force process and prior to the publication of the statement manuscript.

Results

1. Equipment and technique

Overview of the evidence and current practice

When compared to other forms of clinical US with an established clinical tradition or more narrow clinical indication, international consensus publications regarding the equipment and technique used for TUS are scarce [1, 3, 7]. The first international consensus paper on point-of-care lung US provides some essential basic definitions and terminology [1]. However, when compared to recommendations on point-of-care cardiac US, a general recommendation regarding equipment and technique is not provided [8]. This reflects current clinical practice, in which choice of TUS scanning protocol, equipment and technique varies between specialties and countries. Numerous different protocols, techniques and use of different equipment have been assessed and validated in prospective diagnostic accuracy studies [6, 9-29]. Studies directly assessing or comparing different TUS equipment or techniques are fairly limited. These studies have however demonstrated that factors such as choice of US machine (e.g. high-end, hand-held), protocol, transducer and patient positioning have a potential clinical impact [30-39]. Even though studies have addressed important factors, it is not possible to derive a universal and evidence-based TUS approach for any given clinical scenario. Apart from the examination itself, the COVID-19 pandemic has increased awareness of US operators in ensuring necessary safety precautions, specifically regarding cleansing of equipment and appropriate infection control [40].

Table 1. Recommendations for future research: Equipment and technique

Area of future research	Question
Protocol	Which specific TUS protocol is optimal for a given clinical setting or problem?
US equipment and software	What is the optimal choice of US equipment and software in a given clinical setting or problem?
Inter- and intra-observer variance	What are the inter- and intra-observer variance for the specific protocols and equipment in various clinical settings?

Conclusions

Many different approaches and techniques have been described and validated. Comparative studies directly comparing different TUS approaches are limited. Given the many clinical settings and indications, a “one size fits all” TUS approach is not feasible or meaningful. There remains a need to reach consensus on a general TUS principles and to determine the optimal approach for more specific clinical problems or settings.

2. Chest wall and parietal pleura

Chest wall soft tissues

On TUS, the intercostal muscle and fascia are visualised as echogenic layers under the subcutaneous tissue (fig. 1). TUS can be used to identify and characterise superficial chest wall lesions, although generally cross-sectional imaging modalities, such as computed tomography (CT) and magnetic resonance imaging (MRI) are more accurate [41].

Visceral and parietal pleura

Below the intercostal muscle, the visceral and parietal pleura are visualised as an echogenic ‘pleural line’ visible between and deep to the ribs (fig 1.). In healthy individuals, the pleural line slides parallel to the chest wall during respiration generating a sparkling appearance (‘lung sliding’) and may move in synchrony with cardiac pulsation (‘lung pulse’). Lung sliding can be confirmed using M-mode, which gives a characteristic ‘seashore’ sign [1].

Hypoechoic parietal pleural thickening may mimic a pleural effusion on US and use of colour Doppler may help to differentiate these conditions, with fluid showing disordered colour flow unlike static, solid pleural thickening. Benign pleural tumours such as fibromas and lipoma are relatively rare, are usually round or ovoid in shape, hypoechoic and homogeneous and do not infiltrate surrounding structures (fig. 1) [42]. Asbestos-related pleural plaques have a distinctive TUS appearance and are hypoechoic, elliptical, and smoothly limited foci; if calcified, they produce prominent acoustic shadows [42].

Malignant pleural nodularity is a more common finding and can be seen as irregular, well-circumscribed, often heterogeneous lumps arising from the parietal pleura and distorting the normal contour of the visceral pleura. They may be associated with a pleural effusion or chest wall/rib invasion [43].

TUS has been evaluated in the identification of the presence and degree of chest wall invasion of intrathoracic malignancies, and in one study was shown to have a higher sensitivity than CT [44]. The absence of pleural motion next to a peripheral lung lesion may identify parietal pleural invasion thus refining radiological staging. In one study, the use of qualitative and quantitative colour

Doppler sonography was more sensitive and specific than CT for predicting chest wall invasion by lung tumours [45].

Ribs

The ribs are seen as superficial, curvilinear structures, which completely reflect the US wave, resulting in posterior acoustic shadowing (rib shadows) (fig. 1). If an US probe is placed along the long axis of a rib, the cortex of the bone is visible as a static, bright, echogenic line. When a cortical fracture is present, this line is disrupted by a step or gap and reverberation echoes occur at the point of the fracture (known as ‘the lighthouse phenomenon’) (fig. 1). Fractures may be associated with a visible haematoma, a reactive pleural effusion or subpleural parenchymal changes from lung contusion. A recent systematic review suggests that TUS is more sensitive than chest radiography (CXR) in diagnosing rib fractures; however it can be painful and time-consuming, may be technically challenging in obese patients and the first ribs and retroscapular areas are incompletely visible. TUS may have a useful role in assessing focal areas of rib pain [46].

Metastatic disease to the ribs causes destruction of the bone cortex, resulting in an irregular cortical appearance and loss of the usual rib shadows. In this instance, the infiltrated bone structure may be more visible and appear hypoechoic and heterogenous [47].

Intercostal muscles

The intercostal muscles can be directly visualised between the ribs. Even though the role of TUS assessment of intercostal muscle function is yet to be established, studies have reported several possible clinical implications. In a study by Wallbridge et al. muscle thickness and echogenicity was found to correlate with spirometry assessment of severity in patients with chronic obstructive pulmonary disease (COPD)[48]. Intercostal muscle assessment has also been reported as a possible tool for assessing respiratory workload in mechanically ventilated patients and for predicting failure of spontaneous breathing trials after supported ventilation [49-51].

Intercostal vessels

Distal to the apex of the rib posteriorly, the intercostal vessels run in the subcostal groove, but their course may be tortuous particularly in the elderly. Colour flow Doppler, using a linear probe allows good visualisation of the vessels and in theory may reduce vascular injury during pleural intervention [52]. However, the technique is operator and experience dependent and its reliability and accuracy has been questioned.

Table 2. Recommendations for future research: Chest wall and parietal pleura

Area of future research	Question
Trauma patients	What is the role for TUS in the diagnosis of rib fractures?
Malignancy	What is the accuracy of TUS for pleural and chest wall invasion by peripheral lung cancers?
Invasive procedures	Does TUS of intercostal vessels actually reduce frequency of vessel injury?

Conclusions

TUS is a useful clinical tool for assessing the chest wall and parietal pleura. Further studies are required to ascertain its clinical utility and impact in specific clinical scenarios.

3. Pleural effusion

TUS has been used to assess suspected pleural effusion for at least 40 years [53-55]. Recently, a desire for better identification, classification and quantification of pleural fluid, coupled with rapid improvements in technology, has driven the widespread adoption of TUS amongst many pulmonologists. Indeed, being able to locate fluid with US to guide intervention is now seen as a core skill for trainees [56].

Benefits of TUS over other modalities

Basic, grey-scale TUS can identify much smaller volumes of fluid in comparison to other modalities, particularly CXR [57, 58]. It can do so reliably (meta-analysis data suggests a sensitivity of 93% and specificity of 96%) [59] in real-time at the bedside, with very high spatial resolution. The addition of colour Doppler may enhance assessment and improve differentiation of fluid from pleural thickening [60, 61].

Point-of-care versus diagnostic imaging

TUS is most commonly used as a point-of-care test to guide intervention for pleural effusions and there is strong evidence to suggest this improves safety and can guide management decisions [62-64]. With sufficient experience, more formal diagnostic imaging is possible. While the ultrasonographic appearance of the fluid in itself cannot be considered diagnostic of the underlying disease, other typical TUS findings may help support a diagnosis (e.g. irregular nodularity on the diaphragm in malignant pleural effusion) (fig. 2) [65].

Visualising fluid and estimating volume

Pleural effusions are most completely imaged with low frequency US transducers which allow for better understanding of fluid location and depth relative to deeper organs. Such frequencies are usually associated with curvilinear (typically 2-6 MHz) or sector (typically 1-3 MHz) probes. [66] Care must be taken with image processing settings, particularly gain, as these may adversely influence interpretation of fluid characteristics if incorrect [67]. The following four categories, described by Yang et al. are commonly referred to when describing effusion appearance: anechoic, complex non-septated, complex septated, and homogeneous echogenic (fig. 2)[68].

Freely mobile fluid will often be most easy to scan with the probe placed on the posterior or lateral chest, with the patient sat upright to allow the effusion to pool inferiorly. In some circumstances, particularly in those who are recumbent on the intensive care unit, finding a suitable window may be more challenging.

Basic estimations of fluid volume may be useful when trying to quantify treatment effects of non-invasive therapy (such as diuretics for cardiac impairment) or when deciding whether to drain an effusion in a ventilated patient. Several simple equations have been devised to try and estimate fluid volume based on US appearances. Hassan et al. tested the accuracy of five of these in 46 patients, and determined the most accurate to involve the total height of the effusion (H) in cm and the distance from bottom of the lung to apex of the diaphragm (C) in cm:

$$(H+C)\text{ cm} \times 70\text{ ml/cm} = \text{effusion volume ml}$$

This calculation was found to have an 83% accuracy when predicting fluid volume [69].

Transudative disease versus exudative disease

Although not specific, presentation with bilateral effusions or associated ascites are strongly associated with transudates [70, 71]. Effusions due to transudative processes tend to have lower concentrations of complex molecules, particularly proteins. On TUS, this often makes the fluid appear anechoic (fig. 2). This is not specific, however, with one series finding 14% of transudates to be echogenic [72]. By contrast, effusions which are exudates will almost always demonstrate echogenicity, complexity, or both [72-74]. There is also a strong correlation between 'swirling' and exudative processes, although again this is not a specific sign (fig. 2)[75-77].

Features of malignant disease

There are no effusion features specific to malignant effusions although many will show exudate characteristics and swirling is also frequently noted [74, 75]. Anechoic appearances have been described in around 10% of cases [65]. Chronicity or more active malignancy may lead to the formation of fibrous septations and/or loculation [74]. The presence of an effusion in conjunction with pleural or diaphragmatic nodularity is almost always indicative of malignancy, although such signs may be subtle (fig. 2) [65].

Features of pleural infection

Septation and/or loculation are suggestive of pleural infection requiring drainage in the appropriate clinical context (fig. 2) [63], and may indicate a greater likelihood of failing fibrinolytic therapy [78]. One small series described the "suspended microbubble" sign and found it to be highly sensitive and specific for frank empyema [79]. In tuberculous effusions, complex septated appearances have a positive predictive value of 84% at 12 months for residual pleural thickening [80]. For 'simple' parapneumonic effusions, no fluid signs are known to be associated with eventual need for treatment [81] but in a small paediatric series, a greater degree of echogenicity was associated with positive fluid culture, the need for more procedures, and longer duration of treatment [82].

Imaging atelectatic lung within fluid

The presence of even a relatively small effusion may cause compressive atelectasis, and this allows the non-aerated lung to be assessed by US [83]. Atelectatic segments have been described as resembling a 'J' or a 'hockey stick' (fig. 2), and within them it may be possible to appreciate malignant lesions. There is also evidence to suggest that M-mode measurements taken from atelectatic lung may be predictive of non-expandable lung [84].

Table 3. Recommendations for future research: Pleural effusion

Area of future research	Question
Non-expandable lung	Are there any TUS techniques which might help to predict the development of non-expandable lung?
Improved diagnostics	Can the use of newer technology or contrast material improve the diagnostic utility of TUS in characterizing effusions?
Point-of-care	Can point-of-care TUS for the detection of pleural effusions become standard practice for non-pulmonologists or radiologists?

Conclusions

The immediate and accurate identification of fluid prior to intervention remains the primary purpose of most TUS. Ongoing developments in technology, leading to even greater portability and higher resolution, will likely improve our ability to identify and characterise effusions, especially at an early stage, as may the use of fluid contrast agents, which remains relatively rare.

4. Pneumothorax

Overview of the evidence and current practice

Pneumothorax has traditionally been identified on erect CXR. However, there has been increasing interest in the use of TUS in the identification of pneumothorax, particularly in the context of trauma and critical care [12]. The difficulty with TUS in pneumothorax is due to the high impedance of the tissue/air interface causing most of the US waves to be reflected. Therefore, both air in the lung and air in the pleural space create a bright line at the pleural surface. However, there are three specific features of TUS described in pneumothorax: a lack of "lung sliding", the absence of "B-lines", and identification of a "lung point" [85-87].

Lung sliding is a "sparkling" of the pleural line as the lung moves with respiration [88]. If lung sliding is identified, then pneumothorax can be excluded in that area. Conversely, the absence of lung sliding is not specific for pneumothorax. Lung sliding can also be assessed using M-mode [89]. Lung sliding distal to the pleural line creates a granular pattern distal to the pleural line, referred to as the "seashore sign". The absence of lung sliding creates lines known as the "bar-code" or "stratosphere" sign (fig.

3). Importantly, loss of lung sliding can be caused by hyperinflation or bullous emphysema in COPD [90] and pleural adhesions.

“B-lines” (otherwise known as ”comet-tails”) are vertical artefacts projecting distally from the pleural line due to imperfections at the lung surface (fig. 3) [91]. The presence of B-lines excludes pneumothorax, but their absence does not confirm it.

The “Lung point” is an ultrasonographic sign which attempts to locate the junction between the pneumothorax and area with no air between the visceral and parietal pleural, i.e. where the visceral and parietal pleural part company [92]. With a stationary probe, the lung point refers to a pattern of repeated transitions between no lung sliding or B-lines (pneumothorax) into a demonstrable area of sliding (lung). It has been suggested that identification of the lung point is 100% specific for pneumothorax [92], and, by marking the lung point at multiple locations on the chest wall, this can be used to determine pneumothorax size [93]. However, a lung point is only seen in partial pneumothoraces and will be dependent on patient position.

TUS for pneumothorax can be challenging in small loculated pneumothoraces, and impossible in the context of significant subcutaneous emphysema where air in the subcutaneous tissue reflects all US waves (fig. 1).

Studies have been published on the utility of TUS in pneumothorax diagnosis for over 20 years. The majority of these have been prospective case series comparing imaging modalities in diagnosing pneumothorax in the context of trauma, iatrogenic (post-image guided biopsy) or in critical care, but no randomised controlled trials have assessed clinical effect or outcome. Currently, four meta-analyses have been published pooling data comparing the accuracy of TUS for pneumothorax compared to CXR [94-97]. Pooled sensitivity for TUS was 78–90% and pooled specificity was >98%. CXR performed poorly with a pooled sensitivity of 39–52%, but a similar specificity. However, these results must be taken in context; the vast majority of studies included mainly trauma patients lying in a supine position in the emergency department (ED), which will naturally reduce the sensitivity of the CXR comparator.

There was significant heterogeneity among all four meta-analyses, with one metanalysis suggesting it was due to operator performance [94], but a number of other factors could contribute. Importantly, pneumothoraces in trauma patients missed on supine CXR could have been occult. The diagnosis of occult pneumothorax has not been shown to impact clinical outcome and may indeed lead to over treatment (e.g. pleural drainage may not be required).

The identification of pneumothorax post-lung biopsy was specifically assessed in three studies: Chung et al. performed high resolution CT (HRCT) scans on 97 patients after fluoroscopic-guided lung biopsy, identifying pneumothorax in 36% [98]. The authors conclude a sensitivity of 80% for TUS but did not discriminate the size of pneumothorax; thus, these studies are likely to be identifying a number of small, clinically insignificant pneumothoraces on CT (in keeping with the higher than usual pneumothorax rate). Reissig et al studied 53 patients post transbronchial biopsy during bronchoscopy, with TUS identifying pneumothorax in all four (7.5%) cases [99]. Sartori et al also concluded that the sensitivity for TUS was 100% by examining 285 patients post-TUS-guided lung biopsy [100]. In this series only eight (2.8%) patients had pneumothorax, all of whom were identified by TUS; although CT was only performed when there was a discrepancy between TUS and CXR.

Another application of TUS could be in determining when pneumothoraces have resolved after chest tube drainage. One study suggested that TUS was superior to CXR [101], but was limited by being a single centre study with small patients numbers (n=44).

Table 4. Recommendations for future research: Pneumothorax

Area of future research	Question
Trauma patients	Can early TUS detection of pneumothorax positively impact the patient's outcome?
Post-lung biopsy	Can TUS be used to identify iatrogenic pneumothorax requiring drainage?
Pneumothorax – resolution	Is TUS more sensitive than CXR in showing resolution of pneumothorax after successful drainage? (i.e. can we reduce the need for CXR?)
Pneumothorax – predicting recurrence	Can a lack of lung sliding on TUS at early follow-up predict long term recurrence?

Conclusions

The utility of TUS in diagnosing pneumothorax has been reported in many prospective case series mostly in the context of trauma, iatrogenic (post-image guided biopsy) or in critical care. Four meta-analyses suggest TUS has a better sensitivity for pneumothorax compared to CXR but there are no randomised controlled trials assessing clinical effect or outcome, and the performance may be operator dependent. The development of well-designed clinical trials will help to guide practice in the future.

5. Interstitial syndrome

Overview of the evidence and current practice

The interstitial syndrome (IS) describes a composite TUS finding that represents an increased density of the lung interstitium secondary to a diffuse underlying disease or condition [102, 103]. The space and tissues around the alveolar sacs compose the lung interstitium and includes the alveolar epithelium, pulmonary capillary endothelium, basement membrane, perivascular- and perilymphatic tissues. If one or more of these tissues are affected in both lungs, IS may be present.

Presence and quantification of B-lines constitute the cornerstone finding when aiming to identify and confirm IS [104]. B-lines arise due to continuous reflection of the US beam between increased lung density areas and non-aerated areas near the pleural line [105, 106], and are defined as vertical reverberation artefacts originating from the pleural line in synchrony with lung sliding, extending uninterrupted to the edge of the screen without fading (fig. 3) [107]. Several TUS scanning approaches involving a different number of scanning zones to detect IS have been recommended [5, 16, 17, 27, 108-112], but the majority are expansions of Volpicielli et al. defining IS when ≥3 B-lines in >2 anterior or lateral lung interstitial spaces are present in each hemithorax [107]. In many settings cardiogenic and non-cardiogenic pulmonary oedema are the most common causative IS conditions, but other conditions such as acute respiratory distress syndrome (ARDS) also causes IS to be present [113]. In these conditions, IS arises due to hydrostasis or capillary leak with protein accumulation in the interstitium leading to interstitial and alveolar oedema [114]. A meta-analysis of 1,827 patients found TUS to be more sensitive to detect IS in dyspnoeic patients with acute HF (AHF) than CXR (88% vs. 73%), but with comparable specificities (90%) [115]. In a prospective multicentre study including 1,005 patients attending ED with acute dyspnea, Pivetta et al. found that adding TUS to a standard diagnostic regime was superior to detect IS as part of AHF [116]. Two randomised clinical trials (RCT) support these findings: Laursen et al. compared usual clinical assessment and diagnostics with an approach using point-of-care US of the lung, heart and deep veins alongside usual clinical assessment and diagnostics. A significantly higher proportion received a correct diagnosis (88.0% vs. 63.7%) and treatment (78.0% vs. 56.7%) in the US group compared to the usual clinical assessment and diagnostics group [5]. Pivetta et al. demonstrated an approach using TUS had a higher diagnostic accuracy than an approach using CXR and NT-proBNP (AUC 0.95 vs. 0.87, $p < 0.01$) for the diagnosis of AHF [117]. In the context of an intensive care setting, Bataille et al. however found that the presence of IS was poor in discriminating between cardiogenic pulmonary oedema and pneumonia, unless supplementary echocardiography was performed [118]. Whether the results of the two RCT's can be generalized to other settings with more highly selected patients and whether TUS in the case of presence of IS should be routinely combined with echocardiography or focused cardiac ultrasound require further investigation.

In addition to IS, pleural oedema and the development of pleural fibrosis may occur in ARDS giving rise to pleural irregularity and decreased lung sliding [23, 119]. However, extrapolation of data regarding diagnostic accuracy of IS detected in AHF may not necessarily be applied to IS in ARDS [120]. This also applies to patients undergoing dialysis, although a clear association between interstitial oedema identified by IS and fluid overload has been shown [121, 122]. Hence, besides its relevance as a diagnostic add-on modality in these 'wet B-line' conditions, TUS shows operational applicability to monitor IS dynamics and guide treatment [123-126].

In interstitial lung diseases (ILD), IS arises from ongoing inflammation or formation of fibrosis following collagen accumulation in the interstitium resulting in distorted lung architecture with compromised alveolar aeration [106]. ILD represents a heterogeneous disease category involving idiopathic and connective tissue disease (CTD) related subtypes [110, 127]. The applicability of TUS to detect IS based on the number of B-lines has primarily been assessed within CTD-ILDs secondary to scleroderma, rheumatoid arthritis, Sjogren's- and antisynthethase syndrome [108, 109, 128, 129]. In several of these studies, an increased number of B-lines correlated with disease severity better than HRCT [110, 128]. Furthermore, the presence of pleural irregularity and increased distance between B-lines were associated with increasing fibrosis and reduced lung physiological parameters such as total lung capacity (TLC) and diffusion capacity of the lung for carbon monoxide (DLCO) (fig. 3)[110]. Similar findings are observed in idiopathic ILDs [11]. A recent review proposed that TUS identified IS can be used to determine the distribution of an usual interstitial pneumonia pattern when comparing to a HRCT [130]. Though some studies have observed high diagnostic accuracies of TUS-related IS in ILDs compared to HRCT [109], it is questionable whether these are representative due to small study cohorts, misclassification of disease, and disease behaviour [131, 132].

Table 5. Recommendations for future research: Interstitial syndrome

Area of future research	Question
ILD patients - identification	Can early TUS detection of IS in ILD suspected patients reduce latency in ILD diagnosis?
IS monitoring and impact	Can TUS be used to monitor treatment and/or disease development? Studies assessing clinical impact of TUS identified IS are warranted.
IS detection validity	In patients with IS, does the number of B-lines per LIS relate to underlying cause of disease and disease severity?
IS causality prediction	Can the combination of IS with visceral pleural pathology be used to distinguish between underlying pulmonary or extrapulmonary conditions?

Conclusions

The presence of IS is a dynamic surrogate marker of a disease or condition affecting the lung interstitium. As the genesis of IS does not clearly permit the differentiation between 'wet' and 'connective' B-lines, the role of TUS is as an integrated clinical add-on modality together with supplemental diagnostic work-up in order to determine an underlying diagnosis, It may also be used to monitor disease behaviour and treatment response. However, available knowledge on TUS' validity to identify IS in selected disease categories is lacking. This warrants further prospective large-scale studies to determine diagnostic cut-off points for TUS-detected IS before clarifying its clinical use in controlled trials.

6. Lung consolidation

Overview of the evidence and current practice

The sonographic pattern of lung consolidation has been defined as a subpleural echo-poor region or one with tissue-like echotexture [1]. Animal and human studies have demonstrated that consolidation as it appears at TUS is the result of an increase in density of lung tissue, eventually resulting in complete de-aeration [24, 133]. This is the sole condition in which the lung can be visualized as a solid organ. Since many conditions (e.g. pneumonia, malignancy, pulmonary embolism, atelectasis, contusion, aspiration) may result in complete de-aeration of the lung tissue, lung consolidation is in itself a non-specific finding. Lung consolidation should be differentiated from the presence of B-lines in which the density of the lung tissue is increased but the lung parenchyma remains at least partially aerated and therefore does not allow visualisation of the lung parenchyma.

In order to visualise lung consolidation by the use of TUS, the de-aerated lung area needs to be in contact with the chest wall (with or without interposition of fluid) in a “lung zone” which can be assessed transthoracically. Nonetheless, the diagnostic accuracy of TUS for lung consolidation has been shown to be higher than CXR when CT is used as the reference standard [134]. Studies with more robust designs limiting potential biases are however still warranted [135].

Studies assessing different aspects of using TUS for diagnosing pneumonia, especially community acquired pneumonia, have been published since the 1980’s, with a steady increase with the more widespread availability of point-of-care US [26, 136-144]. In a meta-analysis by Orso et al. with a combined sample size of 5,108 patients, the pooled diagnostic accuracy of TUS for diagnosing pneumonia in the ED was: sensitivity 92% (95% confidence interval (CI) 87-96%), specificity 94% (95%CI 87-97%) (fig. 4) [145]. The use of TUS integrated with clinical assessment and other diagnostic modalities including CXR seems to increase the overall diagnostic accuracy, but little is known of the clinical impact of TUS for diagnosing pneumonia [5, 146, 147]. Based on a study by Jones at al it seems that TUS can safely replace the CXR as the initial imaging modality of pneumonia in children and thus reduce radiation exposure [148]. The study did however report frequent use of CXR in the TUS group. Despite studies favouring the use of TUS over CXR for diagnosing pneumonia in adults, the optimal combination of TUS and CXR from a diagnostic and safety perspective has not been established. Several confounding factors in the intensive care setting make TUS diagnosis of pneumonia more complex, reducing the diagnostic accuracy; in this setting, a constellation of TUS additional signs and preliminary microbiological findings conversely yields a high diagnostic accuracy [144].

Despite the fact that using TUS for the diagnosis of pulmonary embolism (PE) was described more than 50 years ago, research in the area has primarily evolved within the last two decades, with several descriptive and diagnostic accuracy studies [15, 29, 149-163]. In a meta-analysis of TUS' diagnostic accuracy for PE, Squizzato et al. reported a bivariate weighted mean sensitivity and specificity of 87.0% (95%CI 79.5-92.0%) and 81.8% (95%CI 71.0-89.3%), respectively [164]. Based on these findings, TUS seems superior to other forms of mono-organ US for diagnosing PE [165, 166]. Several studies have advocated a whole-body-ultrasonography approach combining assessment of the lungs, heart and deep veins in patients with suspected PE or respiratory symptoms. This multi-organ approach is superior to what has been described using a mono-organ approach, but randomized trials assessing potential clinical impact and safety aspects are yet to be published [5, 22, 27, 29, 162, 167].

Several studies describing the use of TUS for assessing various other specific causes of lung consolidation (e.g. atelectasis, tumors, contusion) have been published. The findings and utility of TUS for assessing these conditions may be highly clinically relevant (e.g. assessment of invasive growth) but most of the studies are of a descriptive nature or with relatively small sample sizes (fig. 4) [19, 44, 168-179].

While most of the previous research has aimed to assess the use of TUS as a diagnostic tool, increasing attention is being directed at TUS' abilities as a monitoring tool [180]. The basic principles on how TUS can be used in real-time to monitor a gradual change from normal pattern to interstitial syndrome, lung consolidation, and subsequent reversal of these findings have been well described using a whole lung lavage model [24]. Several TUS monitoring studies have reported promising and clinically relevant results, especially in the intensive care setting of Acute Respiratory Distress Syndrome (ARDS), ventilator-associated pneumonia, and weaning from mechanical ventilation. However, there is still a lack of robust data on TUS oriented management in improving clinical outcomes [6, 112, 124, 138, 181-187].

Table 6. Recommendations for future research: Lung consolidation

Area of future research	Question
Inter- and intra-observer agreement	What is the inter- and intra-observer agreement for diagnosing conditions causing lung consolidation in a population of unselected patients with various different lung diseases?
Clinical impact	Can the apparent good diagnostic accuracy of TUS also lead to improvement in clinically relevant outcomes?
Implementation	If TUS is to be implemented in clinical practice, how should it then be ideally used alongside other diagnostic modalities?
Monitoring	Can the use of TUS for monitoring consolidation lead to improvement in clinically relevant outcomes?

Conclusions

Based on currently published studies, TUS has a role as a bedside tool for assessing patients with possible or known lung consolidation, and potentially as a monitoring tool. Future research should focus on TUS' effect on clinically relevant outcomes and how TUS is ideally used alongside other diagnostic modalities.

7. Diaphragm

Overview of the evidence and current practice

Diaphragm mobility and thickness have been correlated with respiratory muscle strength and lung function in healthy subjects [188, 189]. In 27 patients with hemidiaphragm paralysis, diaphragm mobility during quiet breathing, thickness at functional residual capacity (FRC) and TLC, and diaphragmatic thickening fraction (TF = diaphragmatic thickness variation during respiration) were decreased on the side of the hemidiaphragm paralysis when compared to the non-paralysed hemidiaphragm [190]. TUS was more sensitive than fluoroscopy to detect hemidiaphragm movement abnormalities, with 4/30 technical failures for fluoroscopy and no failures for TUS [191]. Even though the diaphragm has traditionally been assessed using conventional B- or M-mode, a few studies have indicated that more advanced techniques (e.g. Area-method, speckle tracking) might prove more accurate and feasible [192-194].

TUS assessment of the diaphragm in the intensive care unit

Spontaneous breathing trials (SBT) are used to predict weaning outcomes in patients on mechanical ventilation (MV); however, 13-26% of those extubated after successful SBT need rescue non-invasive ventilation or are re-intubated within 48-72 hours [195, 196]. Ventilation-induced diaphragm dysfunction is often observed in patients who are difficult to wean off MV, and can be assessed by TUS by measuring diaphragm thickness at end expiration, or more dynamic evaluation of TF or diaphragm excursion (DE) at the zone of apposition of the pleural and peritoneal membranes. Data on TUS parameters and weaning is varied; in a systematic review including 19 studies and 1,071 patients on invasive MV for at least 24 hours, the area under the operating curve for TF was 0.87, with a pooled diagnostic odd's ratio (DOR) 21 (95% CI 11-40), and pooled sensitivity for DE was 75%, DOR 10 (95% CI 4-24)[197]. Another meta-analysis (13 studies and 742 patients) reported pooled sensitivity of 90%, specificity 80%, and DOR 32.5 (95% CI 18.6 - 56.8) for TF, and 80%, 70%, 10.6 (95% CI 4.2 - 27.1) respectively for DE [198]. Low TF was a good predictor of weaning outcome with consistency across studies, and higher DOR suggests that TF has better diagnostic accuracy than DE. Both TF and DE are reproducible [192, 197, 199-203]. In a large multicentre RCT by Vivier et al, diaphragmatic dysfunction identified by TUS was however not associated with an increased risk of extubation failure [204]. Hence, further studies are needed to establish the exact role of TUS assessment of the diaphragm in mechanically ventilated patients.

Pleural effusion

The mechanism of breathlessness in pleural effusion is not fully understood. Pleural effusion adversely affects the diaphragm's ability to generate negative pressure, and this is postulated to be a cause of breathlessness. In 14 MV patients on pressure support ventilation with a pleural effusion, respiratory rate decreased, tidal volume increased, and diaphragm displacement and thickening increased after pleural fluid aspiration, with correlation between volume of effusion drained and increase in tidal diaphragm thickening [205]. When TUS was performed before and after thoracoscopy (14/19 MPE), larger effusion volumes were associated with impaired diaphragm movement compared to effusions with normal diaphragm movement [206]. After pleural aspiration, patients with paradoxical movement of the hemidiaphragm (*n*=21) had a small but significant improvement in forced expiratory volume in 1 second (FEV_1), forced vital capacity (FVC), PaO_2, A-a oxygen gradient, and dyspnoea, whereas those without paradoxical movement of the diaphragm (*n*=41) did not [207]. In a larger study (n=145) of patients with symptomatic pleural effusions, Muruganandan et al. showed TUS demonstrating abnormal hemi-diaphragm shape and movement prior to thoracentesis were independently associated with relief of breathlessness post-drainage [208]. These results suggest diaphragm flattening or abnormal movement are strong indications for aspiration to restore normal diaphragm position and shape, and TUS can aid in this assessment.

Other

Diaphragm mobility has been shown to be decreased in COPD patients compared to healthy subjects. DE correlates with lung function [209, 210], and TF in acute exacerbations of COPD complicated by respiratory acidosis correlated with non-invasive ventilation (NIV) failure, longer intensive care unit stay, prolonged MV, need for tracheotomy and mortality [211, 212]. TF predicted nocturnal hypoxaemia in COPD with mild or no daytime hypoxaemia [213].

A review of respiratory muscle imaging modalities in neuromuscular disorders (NMD) identified 9 studies (*n*=292 patients) that used US [214]. Diaphragm thickness was significantly lower in patients with NMD than in healthy controls [215, 216], and in amyotrophic lateral sclerosis was positively correlated with vital capacity, and negatively correlated with $PaCO_2$, with good interobserver reliability [217].

Table 7. Recommendations for future research: Diaphragm

Area of future research	Question
Novel imaging in diaphragm function assessment	Does Speckle tracking measurement correlate with transdiaphragmatic pressure?
”Area” method of DP function assessment	Is an assessment of the entire hemidiaphragm dome movement using the Area method better than a single point measurement using M-mode?
Ventilation	Can TUS be used to assess patient-ventilator asynchrony?
Risk of extubation failure	Does TUS have a role for predicting risk of extubation failure?

Conclusions

TUS assessment of the diaphragm has been assessed in various clinical settings. Studies are however mostly small observational studies, the findings of which are not yet well validated, and it is as yet unclear whether TUS findings can be translated to clinically meaningful outcomes. In addition, most studies are either done in healthy volunteers or in small highly selected populations. More data from larger studies is necessary.

8. US guided procedures

Overview of the evidence and current practice

The increased use of TUS has transformed the scope of procedures the interventional pulmonologist is able to offer. Studies have consistently demonstrated that TUS is safer than clinical examination in direct comparison [218], and reduces risk and cost of iatrogenic complications [219-221]. The current position of most international guidelines is that all pleural procedures (for fluid) should be performed under TUS guidance [3]. Clinical research has highlighted the diagnostic and therapeutic value of pleural interventions in improving key outcomes [222, 223], further challenging the physician to extend their procedural boundaries with the aid of TUS, to meet an increasing patient demand and improve accessibility.

As well as pre-procedure TUS guiding optimal pleural puncture site, real-time US imaging can facilitate thoracentesis of small effusions, where most experts suggest at least 1cm depth is required to be safe [42]. In the setting of loculated effusions, the introducer needle of the aspiration catheter can be guided towards the largest collection of fluid, whilst being used to traverse and break up septations along its course [224]. Post-procedure US can rule out pneumothorax with up to 100% NPV [85]. The use of colour Doppler can screen for the intercostal artery at the site of intervention pre-procedure as well as confirm absence of post-procedure haemorrhage [225, 226].

TUS provides similar procedural benefits in chest tube insertion. TUS is not currently recommended to guide drainage of pneumothorax. Currently used techniques for chest tube insertion are ‘Seldinger’ (or guide-wire), blunt dissection and the trocar method. Most of the data suggests that 12-French (F) drain is an appropriate size for the majority of pleural drainage indications, providing a balance of safety, effectiveness and patient comfort [227, 228]. A retrospective analysis of the largest prospective RCT of pleural infection to date (MIST-1; n=405)

[229], showed that there was no significant difference in frequency of death or surgery in patients managed with small bore (<15F) chest tubes [228]. In addition, their suitability for intrapleural fibrinolysis makes them an appropriate treatment choice [230]. The optimal size of chest tube for pleurodesis is still an area of controversy with some studies suggesting small bore (<14F) drains may be less effective [231, 232]. Based on these studies the pulmonologist will be able to handle the majority of indications for chest tube insertions by the use of TUS guided insertion of small bore chest tubes.

Indwelling pleural catheters (IPCs) have had a huge impact on the management of recurrent malignant pleural effusions [233], with ongoing studies looking to delineate their place in benign effusions. While TUS plays an established role in guiding initial insertion, it may potentially guide the selection of patients who may be more suitable for IPCs rather than drainage and pleurodesis. The identification of non-expandable lung (NEL) has been traditionally achieved through drainage of pleural fluid followed by a CXR demonstrating pneumothorax *ex vacuo* or using pleural manometry [234]. Recently published data suggests that speckle tracking imaging analysis and M-mode can identify entrapped lung prior to effusion drainage, allowing upfront choice of definitive management option [84].

Local anaesthetic thoracoscopy (LAT) has now become the gold standard investigation of an undiagnosed unilateral pleural effusion and/or suspected malignancy [235], with an increasing number of centres having routine access [236]. TUS is a vital accessory to LAT, allowing the operator to assess volume of fluid, presence/absence of lung sliding, degree of septation as well as characterising the nature of pleural and diaphragmatic thickening and nodularity. The operator is then able to target entry point for maximal success or conversion to an alternative intervention in the same visit, e.g. if effusion volume deemed to be inadequate. In this circumstance, TUS can facilitate artificial pneumothorax-induction in suitable patients, using real-time introduction of a Boutin needle or blunt dissection [237, 238]. Another option in this setting, and increasingly conducted by physicians in recent years, is TUS-guided closed pleural biopsy (fig. 4). This technique is particularly advantageous in the elderly or frail patient, as a less invasive alternative to LAT. In the hands of an experienced operator, TUS-guided pleural biopsy outcomes are comparable to those conducted by specialised colleagues in radiology [4]. To date, there is no robust evidence to determine whether newer core-cutting needles are superior to traditional reverse bevel (e.g. Abrams) needles.

TUS-guided lung biopsy conducted by pulmonologists is not only safe and feasible with comparable yields [239, 240], but may also be advantageous over radiologist-led CT guided biopsy due to shorter procedure times, quicker access, and limited risk of complications [241-243] (fig. 4). The supplementary use of more advanced ultrasound modalities such as contrast-enhanced US and elastography could have a role for selecting patients with a high risk of malignancy for subsequent biopsy and to guide the choice of biopsy site thereby increasing the diagnostic yield of the biopsy procedure [244-248].

Pulmonologists performing focused US of structures related to the chest (e.g. neck) and subsequent US guided biopsy has been described and potentially provides a rapid, less invasive method for obtaining a diagnosis and staging patients with suspected thoracic malignancy [249-252]. A potential role has also been described in other diseases with extrapulmonary involvement (e.g. sarcoidosis, tuberculosis) [253-255].

Table 8. Recommendations for future research: US guided procedures

Area of future research	Question
Contrast-enhanced US-guided biopsy	Can contrast-enhanced US improve diagnostic yield from TUS-guided biopsy through differentiating benign and malignant pleural disease?
Tissue elastography-guided biopsy	Can TUS elastography reliably allow non-invasive differentiation between benign (soft) and malignant (hard) tissue (pleura/lung) to guide TUS biopsy?
US-guided intervention based on US-guided assessment of breathlessness	Therapeutic pleural aspiration based on US guided assessment of breathlessness to differentiate from non-pleural effusion related breathlessness

Conclusions

TUS is portable, cost-effective and adds diagnostic and therapeutic value in guiding pleural interventions. As an increasing number of practitioners continue to extend the scope and complexity of procedures they undertake, it is important to recognise limitations, both of operator and environment, and remain safe and evidence-based at all times.

9. Training

Overview of the evidence and current practice

TUS has no direct complications or risks, but important decisions are made based on TUS and competent operators are essential to achieve a high diagnostic accuracy [256-258]. Structured and evidence-based training and assessment of new operators are necessary to ensure competence [2, 259]. A systematic review in training methods and assessment in TUS was published in 2018 with 16 included articles [259]. Since then, 12 articles were published and eligible for inclusion in this statement.

Procedural competence in TUS is often taught at the bed-side, during rounds by an experienced colleague, or at courses with a fixed time frame [3, 260-263]. Unfortunately, the clinical setting can be an un-systematic and stressful environment where learning is dependent on the simultaneous availability of suitable patients and skilled supervisors. Several TUS courses exist, but the fixed time frame makes it impossible to guarantee all trainees reach competence in scanning a range of different pathologies. Additionally, implementation and integration of the technical procedure is just as important as learning the procedure itself, meaning that feedback and clinical discussions with other US operators are important.

Simulation or phantom-based training provides a stress-free and standardized learning environment where individual trainees can continue practicing their technical skills and hand-eye coordination until they have acquired necessary competencies [264, 265]. Trainees' hands-on training time is maximized and the need for expert supervision is reduced which can make simulation-based training more effective and economically advantageous [266].

Hands-on training, whether on simulators or by scanning simulated patients or healthy volunteers, must be based on solid theoretical knowledge to improve the efficacy of training and must be followed by supervised refinement of skills in the clinic until independent competency is acquired. A fixed timeframe or an arbitrary number of performed/supervised procedures do not equal obtained competence; all trainees learn at different learning paces [267].

The European Federation of Societies for Ultrasound in Medicine and Biology (EFSUMB), and Royal College of Radiologists have made recommendations about what topics to include in a theoretical curriculum (table 9) [262, 263]. Several studies assess new operators' theoretical knowledge by using theoretical tests covering the same topics, or nearly the same topics [260, 268-270]. Many different learning methods have been used; e.g. classroom-based lectures, group sessions, web-based sessions, or individual homework with books or papers [270-273]. All studies showed increased knowledge regardless of the learning method used, but only one study presented validity evidence for the theoretical test that was used [274].

Table 9. Comparing the recommendations on theoretical knowledge needed for completion of level 1 practitioner in TUS by different organisations.

The Royal College of Radiologists UK	**EFSUMB**
Physics and technology, US technique and administration	*Physics, US techniques and administration*
Sectional and ultrasonic anatomy	*Anatomy*
Right and left hemidiaphragms	Right and left hemidiaphragms
Heart	Heart
Liver and spleen	Liver and spleen
Rib and intercostal space	Rib and intercostal space
	Superior and anterior mediastinum
	Chest wall
	Supraclavicular region
Pathology in relation to US	*Pathology in relation to US*
Pleural effusion	Pleural effusion
Pleural thickening	Pleural thickening
Consolidated lung	Consolidated lung
Paralysed hemidiaphragm	Paralysed hemidiaphragm
Pericardial effusion	Pericardial effusion
	Pneumothorax
	Chest wall abnormalities

Practical hands-on training was included in a majority of studies [260, 261, 269, 271-273, 275-279]. Several hands-on training modalities are represented and probably useful, including animal models, virtual reality simulators, phantoms, and humans (healthy volunteers or patients with pulmonary disease/symptoms). However, the study designs and methods were heterogeneous, outcomes measures without evidence of validity were used, and results were difficult to compare. Two studies have presented simulator models with validity evidence for practical assessment [280, 281], several tools for assessment in a clinical setting were identified [282-284], and a guide for a minimum training standard with both theoretical and practical training by experienced TUS operators is proposed [285].

Gaps in knowledge and/or evidence in training and assessing TUS

Just as physicians are expected to treat and practise according to best medical evidence, educators should use the best available evidence to guide their education in the best possible direction [286]. Geographical, financial, and administrative aspects can affect the possibilities to educate on the highest possible level. No studies have assessed the effect of different hands-on training modalities, the educational intervention on an institutional level, or used patient outcomes as a primary endpoint. These studies are needed to propose recommendations on a European level.

Table 10. Recommendations for future research: Training

Area of future research	Question
Comparison of clinical assessment tools	What advantages and disadvantages do the current assessment tools have and which is more effective in an educational setting?
Patient related outcome of an educational intervention	Can an educational intervention increase patient outcome?
Effect of an educational intervention on clinical decision making	Can an educational intervention in TUS improve the integration of TUS with the clinical decision-making process?
Patient communication	How can patient communication during TUS be trained during a TUS course and subsequently assessed?

Conclusion

A TUS curriculum should be well planned and evidence-based similar to the requirement for clinical practice. The ERS have launched such a training program in 2020. Heterogeneous case load, scarcity of expert supervision, and different learning paces are major challenges to education in a clinical setting. Suitable, objective assessments with solid evidence of validity are necessary to ensure competence at each step before independent practice moving towards competency-based training and Entrusted Professional Activities.

10. Patient perspectives

Overview of the evidence

The literature search could not identify any quantitative or qualitative studies specifically addressing this topic. Four articles were included for review addressing patient discomfort and satisfaction with US in emergency department settings and included but were not limited to TUS [287-290]. Key themes identified were high patient satisfaction, low levels of discomfort with bedside US, and patient-provider interactions.

Patient satisfaction

Bedside US in the emergency department was found to increase patient satisfaction in two studies [287, 288]. Heating the US gel did not significantly increase patient satisfaction, overall satisfaction with the emergency department visit, or patient perceptions of physician professionalism [290]. Patient feedback indicated that bedside scanning is also welcome outside the emergency setting, particularly if the patient is having trouble breathing as it avoids the additional strain of visiting multiple hospital departments. Patients may take comfort from understanding the lower risks of ultrasound when compared to other imaging techniques, such as CT. Exposure to radiation is of concern to patients, particularly if multiple scans are required over time.

Discomfort

The majority of patients do not experience discomfort during point-of-care US of the heart, lungs and deep veins [289]. An increased level of discomfort was most often due to an underlying condition (e.g. rib fracture) or the result of an intervention (e.g. resuscitation) causing localised pain. Most patients, including those who experience some discomfort, would be willing to accept US assessment in future. Professionals should inform patients with an underlying condition that they may experience discomfort before performing US.

Patient-provider interactions

Bedside US may improve communication between patients and professionals by offering the chance to explain examination results and provide a clearer understanding of the patient's diagnosis [287, 288]. Professionals' communication skills play a crucial role in patient experience of imaging. Professionals should be mindful of the language they use and avoid jargon when discussing the procedure and results.

Table 11. Recommendations for future research: Patient perspectives

Area of future research	Question
Patient experiences	What are the patient experiences of TUS in a variety of settings (e.g. emergency department, intensive care unit, outpatient clinic)
Patient preferences	What are the patient experiences and preferences of TUS alongside other diagnostic and imaging tools (e.g. sequencing, overall burden of diagnostic testing)
Patients with lung conditions	What are the experiences and preferences of TUS for patients with existing lung conditions?
Patient information	What are patients' information needs before, during and after TUS?
Communication techniques	What are the most effective communication techniques between professionals and patients undergoing TUS?

Conclusions

TUS is acceptable to most patients in emergency department settings. Further qualitative studies are needed to fully understand patient experiences and preferences of TUS.

Overall conclusions

Continued clinical use and research has established TUS as a key-tool and skill for the modern pulmonologist. The increased availability of US equipment has helped facilitate the implementation and use of TUS across Europe and world-wide. Since US examinations historically have been provided by other specialties, many of the national and international respiratory societies have no tradition or recommendations for the use of TUS. The clinical use of TUS by pulmonologists is therefore in many ways far ahead of the guidelines and recommendations. A potential advantage of TUS is the relatively short pathway from research to clinical implementation, with the major disadvantage however being a general lack of consensus, and research results being implemented without sufficient scientific evidence to support such implementation. In order to achieve a further “professionalisation” of pulmonologists performing TUS, societal guidelines and recommendations from national and international respiratory societies are called for. The aim of this task force statement was to provide a state-of-the art summary guide for the pulmonologist of the current use of TUS and to identify key future research areas. This first official ERS statement on TUS is an important step to further advance professionalisation of TUS at an international level, which will in turn benefit the many patients being assessed by physicians in this way on a daily basis.

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