



# The role of lung ultrasound in the diagnosis of interstitial lung disease

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*Contributions:* (I) Conception and design: R Melchio, A Falcetta, S Leccardi, L Fenoglio; (II) Administrative support: None; (III) Provision of study materials: F Papaleo, S Leccardi; (IV) Collection and assembly of data: A Falcetta, E Testa; (V) Data analysis: A Falcetta, R Melchio; (VI) Manuscript writing: All authors; (VII) Final Approval of Manuscript: All authors.

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**Abstract:** Current data have shown that lung ultrasound (LUS) is an emerging tool in the diagnosis of interstitial lung disease (ILD) by evaluating numbers of B-lines, pleural irregularities and nodules or consolidations. These features can distinguish between ILD and others different pulmonary conditions (i.e., patients with heart failure or end-stage renal disease accompanied by pulmonary congestion). Although there is not a standardized approach for diagnosis of ILD by LUS examination and most studies has been made on rheumatologic patients, we discuss utility of LUS in detecting ILD and its correlation to classical radiological finding, especially to high-resolution computed tomography (HRCT).

**Keywords:** Interstitial lung disease (ILD); lung ultrasound (LUS); B-lines; pleural abnormalities; high-resolution computed tomography (HRCT)

Received: 24 March 2018; Accepted: 16 April 2018; Published: 26 May 2018.

doi: 10.21037/shc.2018.04.10

View this article at: <http://dx.doi.org/10.21037/shc.2018.04.10>

## What is interstitial lung disease (ILD)?

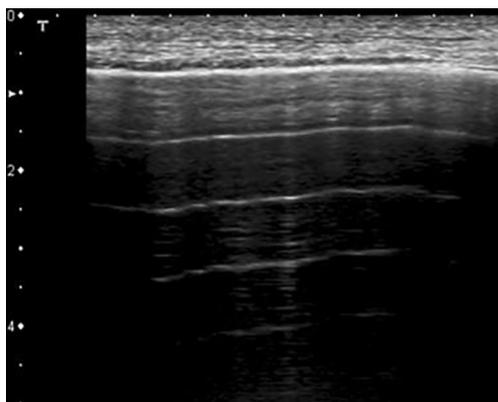
ILD is defined as thickening of the pulmonary interstitium (space between the capillary endothelium and the alveolar epithelium) leading to impaired gas exchange due to various causes. ILD may be idiopathic or caused by exposure to organic and inorganic substances (i.e., hypersensitivity pneumonitis and pneumoconiosis), medical conditions [i.e., connective tissue diseases (CTDs), multisystemic diseases and obstructive sleep apnea], drugs, infection and radiation therapy (1,2). The overall estimated prevalence of ILD is about 25–74/100,000 population and up to 80.9 per 100,000 in men and 67.2 per 100,000 in women (3). Diagnosis of ILD is usually made based on combination of clinical, functional, radiological and histological data. Chest X-ray (CXR) is often the first imaging test performed in ILD and British Thoracic Society recommend for high-resolution computed tomography (HRCT) if diagnosis is uncertain after CXR and clinical assessment. If diagnosis is still not clear, bronchoalveolar lavage, transbronchial lung biopsy or

surgical lung biopsy may be considered (1). Complications of ILD are irreversible pulmonary fibrosis, respiratory failure, acute exacerbation, pulmonary artery hypertension, malignancy and thromboembolic disease. Prognosis of ILD varies by type of ILD.

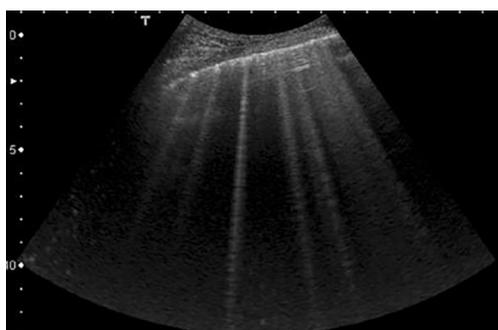
## LUS in thoracic conditions

Recently lung ultrasound (LUS) had become more and more important in evaluating a lot of thoracic conditions and pleural effusions (4–6). In addition it is useful as guidance in biopsies of chest wall masses. However, there are few data in the use of LUS to follow-up patients with an underlying pathologic lung conditions and as a screening tool to evaluate patients who a lung disease has been suspected (7).

In physiological conditions the lung is a strong acoustic reflector because there is a large acoustic impedance mismatch between the chest wall and the subpleural aerated tissue. In LUS the expressions of this biological

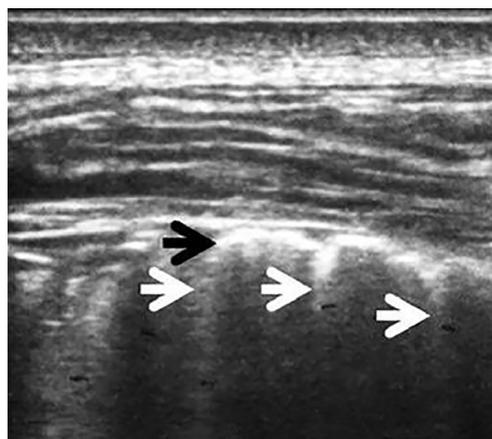


**Figure 1** Normal sonographic lung appearance.



**Figure 2** Sonographic interstitial syndrome. Multiple, separated B-lines.

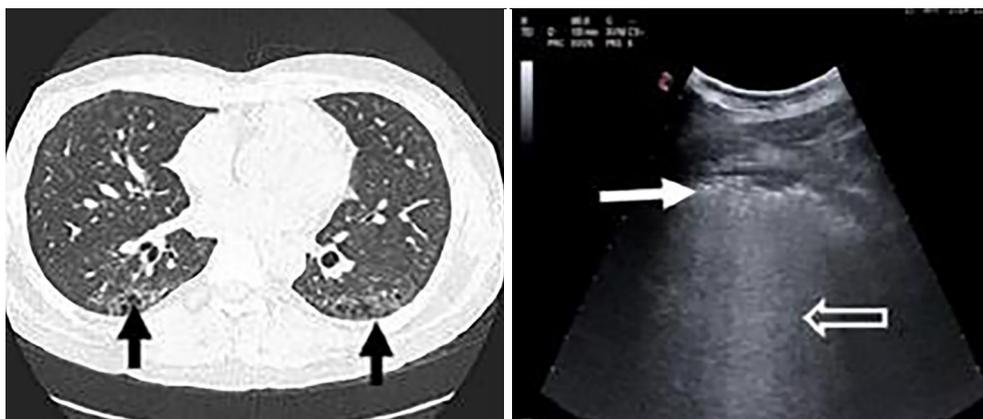
status entail the so called A-lines: the repetition of the pleural plane echo at different depths and the subpleural mirror reproductions of the parietal planes (*Figure 1*) (8). Occasionally, on US images of the thorax, healthy lung may produce a ring-down artifact called B-lines, (9). According to the International Consensus Conference on Pleural and Lung Ultrasound, B-lines are described as a discrete laser-like vertical hyperechoic lines arising from the pleural plane, extending to the bottom of the screen without fading and moving synchronously with the lung sliding (10). In literature B-lines have been described in pathological lung conditions, particularly when there is a diffuse parenchymal lung disease, for example lung edema, atelectasis or early pneumonia. In these conditions B-lines may reflect partial deaeration of the lung probably due to fluid accumulation (i.e., patients with heart failure or end-stage renal disease accompanied by pulmonary congestion) (*Figure 2*) (7,11-14) or deposition of collagen tissue (7,11). However there is not a clearly correlation between B-lines and a specific



**Figure 3** Black arrow indicates the pleura and white arrows show lung comets associated with thickened irregular pleural lines.

anatomical structure, rather B-lines are supposed to be correlated to the changes in the physical properties of the lung (15). Furthermore, B-lines can present as unifocal or oligofocal with variable arrangements (separate, dense or coalescent), pure or mixed with consolidations (16,17). Nowadays the presence of  $\geq 3$  B-lines between two ribs in a single scan is indicative for the presence of sonographic interstitial syndrome, a condition which may be focal, multifocal, homogeneously or non-homogeneously diffuse (10,16,18). Unfortunately both sonographic interstitial syndrome and B-lines have a low specificity: this not allow physicians to distinguish between primary pulmonary conditions and other different conditions. For example in evaluating only B-lines the physician cannot clear distinguish between a “water B-line” and a “connective B-line”, moreover it is not possible to estimate how much water is superimposed on a fibrotic lung. So for differentiate between pulmonary fibrotic conditions and lung fluid accumulation we can focus not only on B-lines, but also on the pleural line and on the lung parenchyma. For example when an inflammatory interstitial syndrome is suspected, LUS can show B-lines and pleural irregularities and nodules or consolidations of the parenchyma; this give evidence for a lung pathology (*Figure 3*). In fact B-lines are often observed in the areas adjacent to the pneumonic consolidations and are related to pulmonary inflammatory changes (19,20).

When diffuse granulomatous diseases of the lung and cryptogenic organizing pneumonia have been suspected, LUS may show subpleural micronodulations or recurring consolidations. Similarly idiopathic and secondary pulmonary fibrosis show pleural irregularities and mixed



**Figure 4** HRTC honey-combing (black arrows) and corresponding blurred and irregular pleural line (white arrow) and multiple B-lines (white empty arrow) on LUS finding on ILD.

configurations of dense and coalescent B-lines, together with scattered spared or mild-diseased areas on LUS (corresponding to subpleural tissue distortion that explain abnormalities showed on CT imaging) (Figure 4) (19,20). However there is no consensus on the specific diagnostic criteria in defining ILD by LUS (21) and to date most of studies calculated a total B-line score (TBLS): a complete count of B-lines on the entire thoracic surface, defining ILD as a TBLS >5 or >10 (see below) (22-25).

Importantly, Delle Sedie *et al.* showed there is not a single transducer to use: probes with frequencies ranging between 3 and 3.5 MHz and frequencies between 5 and 7.5 MHz can be equally used in detecting ILD (26).

Here we discuss use of LUS in ILD.

### LUS in ILD

Nowadays there are an increasing number of studies that showed the utility of LUS in ILD, most of them in rheumatological diseases, as we discuss in next paragraph. Here we explain use of LUS in non rheumatological ILD conditions.

Singh *et al.* (27), in a single center study, tried to differentiate between cardiogenic pulmonary edema (CPE) and noncardiogenic alveolar interstitial syndrome (NCAIS) using M-Mode US with a P21 phased array probe and a L30 linear vascular probe. Excluding subjects with an overlapping diagnosis of CPE and NCAIS, they enrolled 43 patients with previous demonstrated ILD and divided them into three groups: NCAIS group, CPE group and a control group. Afterwards they analyzed 308 lung

zones for pleural line morphologic features and 304 lung zones for subpleural morphologic features. On M-mode US they found a fragmented pleural line and a vertical subpleural pattern in most patients with NCAIS, while most patients with CPE have a continuous pleural line and a vertical subpleural pattern. The sensitivity and the specificity to distinguish between the two conditions was 67.8% and 89.2% respectively, with k value of agreement between interpreters  $\geq 94.6\%$ . Differently Santana *et al.* (28) showed the usefulness of LUS in the diagnosis of ILD identifying decreased diaphragmatic mobility and diaphragm thickening. Matching for age, gender, body mass index and smoking status, they enrolled 40 ILD patients and 16 healthy volunteers who underwent LUS examination and pulmonary functional test. Initially LUS were performed using a 2–5 MHz convex probe on M-mode: they insonated the anterior subcostal region (space between the midclavicular and anterior axillary lines) and measured and recorded the average value of three consecutive measurements of diaphragm mobility both during quiet breathing and deep breathing. Afterwards by B-Mode with a 6–13 MHz linear transducer positioned near the costophrenic angle (space between the right anterior and medial axillary lines) they measured diaphragm thickening and recorded the distance from the pleural line to the peritoneal line. Compared to controls, they found ILD patients had a reduced mobility in diaphragm mobility just during deep breathing ( $7.62 \pm 1.44$  vs.  $4.46 \pm 1.73$  cm;  $P < 0.01$ ) and a reduced diaphragm thickness correlate at total lung capacity ( $0.40 \pm 0.10$  vs.  $0.32 \pm 0.08$  cm;  $P < 0.01$ ).

Other studies tried to compare LUS as diagnostic tool

of ILD. For example, Vizioli *et al.* (29) compared LUS and CXR for diagnosis of ILD using HRCT as the gold standard in 104 patients with ILD have been suspected. Moreover, in confirmed ILD patients, they compared the accuracy of different echographic diagnostic criteria. Using linear (5–8 MHz) and convex (2–5 MHz) probe, they analyzed 12 chest areas per side for each patient: 6 per side to study the anterolateral lung fields (patient in supine decubitus position) and 6 per side to study the posterior lung fields (patient in the seated position). According to the recommendations of the International Consensus Conference on Lung Ultrasound (10), they recorded and evaluated for each area B-line distribution (focal or diffuse), the sonographic pattern (homogeneous or not) and the presence and characterization of pleural line abnormalities (irregularity, fragmentation, subpleural consolidations and swelling). Then they calculated TBLS ( $\geq 10$  or  $\geq 5$ ) and tried to make a simplified score considering LUS positive for ILD if  $\geq 5$  B-lines were present in  $\geq 3$  chest areas (not necessarily contiguous ones). Using HRCT as the gold standard, CXR vs LUS showed lower sensitivity (0.28–0.67 CXR *vs.* 0.81–1.00 LUS), but higher specificity (0.81–1.00 CXR *vs.* 0.53–0.89 LUS), suggesting that CXR and LUS may be complementary in diagnosis. Using LUS for diagnosis of ILD, the simplified score had the same sensitivity as TBLS (0.84–0.99), but higher in specificity (0.69–0.90 LUS *vs.* 0.54–0.79 for TBLS  $\geq 10$  and *vs.* 0.40–0.67 for TBLS  $\geq 5$ ).

In 2009 Volpicelli *et al.* and in 2012 Testa *et al.* show the usefulness of LUS in detecting viral pneumonia. In this cohort of patients LUS gives a particular pattern with spared areas strongly suggestive for viral pneumonia. In fact in viral pneumonia LUS findings had a good correlation with CT scans findings (30,31). Likewise, Asano *et al.* (32) found usefulness of LUS in diagnosis of interstitial pneumonia. According to the American Thoracic Society/European Respiratory Society Guidelines, 40 patients with interstitial pneumonia underwent CXR, CT, HRCT, LUS (using a 7.5 MHz linear probe), blood tests and clinical function tests to compare the US finding with others features of interstitial pneumonia. With the patients in seated position, the authors insonated both the right and left sides of posterior chest wall studying paravertebral, subscapular and posterior axillary lines sites of both the subscapular and lung base areas (12 locations overall). So they evaluated B-lines and pleural abnormalities (thickening and irregularities) finding a positive correlation with total numbers of B-lines and clinical, radiological and serological

activity of the interstitial disease. Moreover, as expected, there was a negative correlation between numbers of B-lines and forced vital capacity, diffusion capacity for carbon monoxide and SpO<sub>2</sub> level after the 6-minute walk test.

Other studies show a direct correlation between an increased number of B-lines, an irregular and/or blurred pleural line and the presence or absence of white lung by LUS and increased systolic pulmonary arterial pressure as expression of pulmonary hypertension. For example Zhu *et al.* found that a LUS score (a combination of B-lines, pleural irregularities and presence/absence of white lung)  $>16$  points predicts pulmonary hypertension (using a cut-off of systolic pulmonary arterial pressure  $>36$  mmHg) in ILD patients with a sensitivity of 85.2% and a specificity of 80.3% (33).

By contrast Zheng *et al.* reported that only a score of B-lines  $>4$  on LUS can predict elevated systolic pulmonary pressure ( $>30$  mmHg) with 89.5% sensitivity, 85.0% specificity and 87.2% accuracy (34).

### LUS in CTD-associated ILD

ILD is a frequent parenchymal manifestation of CTDs and to date HRCT is the gold standard to diagnose CTD-ILD, however patients cannot repeat HRCT very often because is associated with high radiation exposure. Since LUS is a non-invasive and nonionizing modality, rheumatologists and internists tried to use it to assess and follow-up CTD-ILD. The meta-analysis by Song *et al.* supported these data showing that the number of B-lines had a good correlation with the HRCT fibrosis pattern and good diagnostic accuracy in terms of sensitivity (91.5%) and specificity (81.3%) (35). Moreover an exhaustive overview has been proposed in 2016 by Gutierrez *et al.* who systematically evaluated the literature published on the topic between January 2000 and December 2015 (36).

### LUS in systemic sclerosis (SSc)

Nowadays most studies of LUS in rheumatological disease has been made in patients with SSc. Gargani *et al.* (22) showed LUS like a powerful tool in evaluating interstitial pulmonary fibrosis (IPF). In 33 consecutive SSc (both limited and diffuse type) patients, they compared LUS and chest HRCT showing a high correlation between HRCT and LUS finding (in terms of total number of B-lines) in quantification of IPF. Moreover, as expected, B-lines, were more frequent in the diffused form than in the limited form

of SSc. Similar results on SSc patients have been showed by Delle Sedie *et al.* (26) on SSc patients they found a good sensitivity (85%) and specificity (70%) of LUS findings compared to the chest HRCT findings. The pilot study of Barskova *et al.* (23) gave us important data on the role of LUS in the diagnosis of early SSc. The authors enrolled 58 consecutive patients with SSc: 32/58 patients (55%) had very early SSc. All patients underwent chest HRCT and LUS. The reported overall concordance between LUS and HRCT in assessment of IPF was 83%. Importantly, analyzing discordant cases, the authors find that all positive cases were reported by LUS, which gave a sensitivity and negative predictive value of 100% in detecting SSc and early SSc. In order to facilitate the correlation with chest HRCT finding and to establish IPF severity, Tardella *et al.* (25) created a semiquantitative score of B-lines on LUS and compared it with HRCT score. They enrolled 34 consecutive patients with different CTDs who underwent LUS (on the anterior, medial and posterior chest areas), HRCT and lung functional tests. By LUS, IPF involvement might be grade 0 = normal (<10 B-lines); grade 1 = mild (11 to 20 B-lines); grade 2 = moderate (21 to 50 B-lines); and grade 3 = marked (>50 B-lines). So they compared HRCT score with the LUS score and showed a significant linear correlation. Moreover they found a positive correlation between LUS B-lines and values of diffusing capacity of the lungs for carbon monoxide test. Both results correlated with severity of IPF. Unlike Tardella, but as previous studies, Gutierrez *et al.* (37) tried to use a simplified LUS assessment of ILD. They enrolled 36 patients with CTDs and evaluating B-lines on LUS and chest HRCT findings (used as gold standard). The authors performed LUS in evaluating anterior [2<sup>nd</sup> intercostal spaces (IS) along parasternal lines and 4<sup>th</sup> IS along midclavicular, axillary and midaxillary lines] and posterior (along the paravertebral, subscapular and posterior axillary lines) chest areas. Compared to HRCT, they found a good correlation between HRCT findings and the simplified LUS B-line assessment in the diagnosis of IPF. Likewise Tardella, Mohammadi *et al.* (38) tried to test a reduced LUS score (in evaluating B-lines) again in the diagnosis of IPF in SSc patients. In evaluating B-lines on LUS, differently to Tardella, they insonated anterior (4<sup>th</sup> IS along the midclavicular line), lateral (4<sup>th</sup> IS along the anterior axillary and midaxillary line) and posterior (8<sup>th</sup> IS along the anterior, subscapular, and posterior axillary lines) chest areas and compared US findings to chest HRCT findings (considered as the gold standard). Compared to HRCT, reduced LUS score showed a good sensitivity

(74%), specificity (88%) and positive (95%) and negative (52%) predictive values in establishing the severity of pulmonary involvement. Differently to previous studies described in this paragraph, Moazedi-Fuerst *et al.* (39), in order to evaluate the reliability of LUS in the diagnosis of SSc patients, using chest HRCT as the gold standard, evaluated not only B-lines but also pleural irregularities on chest US. In 25 SSc patients and in a similar number of healthy patients, they found both B-lines and pleural thickening on LUS in 44% vs 7% of SSc patients compared to healthy subjects. Two other studies correlate pleural irregularities and B-lines in CTDs patients. Hasan *et al.* (40), in 61 patients with different CTDs, showed that the severity of ILD had a positive correlation between B-lines on LUS and the findings on chest HRCT in terms of ground glass opacity, extensive fibrosis and honey combing. Likewise Sperandio *et al.* (20) enrolled 175 SSc patients who underwent LUS examination and chest HRCT. They found a good correlation between pleural and subpleural irregularities and nodules on LUS and the HRCT findings.

In 2016, Buda *et al.* (41) correlate both LUS findings and severity of ILD and LUS findings and HRCT. The authors enrolled 52 patients with demonstrated ILD and 50 healthy subjects and establish their own criteria of ILD on LUS in terms of pleural irregularities and B-lines. Compared to chest HRCT findings, they found a positive correlation between pleural irregularities (fragmented, blurred and/or thickened pleural line and presence/absence of white lung) and the progression of ILD. Importantly they also found that, at the start of disease, pleural irregularities were most often in the lower fields of the lungs and progressively there was a spreading in middle and upper fields of the lungs with the progression of ILD.

Recently Gigante *et al.* (42), in 39 SSc patients, correlate US, chest HRCT and pulmonary function tests (PFTs) findings. They found that number of B-lines had a positive correlation to HRCT score and a negative correlation to DLCO values.

### LUS in other rheumatic disorders

In 2013, Aghdashi *et al.* (43), evaluating B-lines in 31 consecutive patients with potential rheumatoid lung involvement, found a sensitivity of 74%, a specificity of 88% and a positive and negative predictive value of 95% and 52% respectively, in comparing LUS with chest HRCT. Cogliati *et al.* (24) enrolled 39 patients with rheumatoid arthritis (RA) in order to measure the accuracy of LUS,

compared to chest HRCT, in the diagnosis of ILD using both standard equipment and a pocket-size US device (PS-USD) (though the latter was mostly used as a screening tool). They assumed a positive examination when B-lines score was >10, so they insonated 28 anterior and 44 posterior chest areas and recorded B-lines. Using standard US, the authors found a sensitivity of 92% and a specificity of 56% compared to HRCT (with a positive correlation between B-line score and HRCT score). Using PS-USD *vs.* HRCT sensitivity was 89% and specificity was 50%.

Moazedi-Fuerst *et al.* (44), in a different study from the previous one, hypothesized the usefulness of LUS in detecting lung abnormalities in RA patients who did not present any clinical signs or symptoms of IPF. They enrolled 64 consecutive RA patients and 40 healthy volunteers who underwent both LUS (in order to evaluate pleural abnormalities and lung parenchyma) and chest HRCT. Compared to the latter, LUS showed B-lines and pleural nodules in 28% of RA patients, but also showed 7% of abnormalities in the healthy volunteers, not allowing to use it in an early stage of disease. In 2015 the same authors (45) compared LUS to chest HRCT as diagnostic tool of IPF. Moreover they tried to find a possible correlation between the underlying rheumatological disease and a specific US pattern. The study enrolled 45 patients with IPF [25 with RA, 14 with SSc and 6 with systemic lupus erythematosus (SLE)] and 40 healthy subjects. In performing LUS, they insonated 9 chest areas for each side (divided into anterior, lateral and posterior) and evaluated pleural and subpleural abnormalities and

B-lines which resulted more frequent in IPF patients than healthy patients, as expected. Moreover the authors found a significant different pattern of LUS abnormalities in different IPF disease. In fact in the group of IPF patients Moazedi-Fuerst *et al.* recorded subpleural nodes in 100% of the RA patients *vs.* 22% of the SSc patients (P=0.003) and *vs.* 50% of the SLE patients (P=0.049). Furthermore an irregular and thickened pleural line (>3 mm) was showed in 100% of SSc and SLE patients with IPF *vs.* 86% of IPF patients suffering from RA.

Likewise, Pinal-Fernandez *et al.* (46), in a study with 37 patients with a rheumatological disease (21 with antisynthetase syndrome, of which 2/21 without IPF and 16 with SSc, of which 6 without IPF) showed a positive correlation between LUS findings (again in terms of pleural irregularities and B-lines) and Warrick semiquantitative score at HRCT both in antisynthetase syndrome and SSc patients.

Lastly Vasco *et al.* (47) showed a positive correlation between B-lines at LUS examination and pulmonary fibrosis at chest HRCT in a small study with 13 Sjögren's syndrome patients. The authors showed LUS sensitivity and specificity of 100% and 89% respectively in detecting ILD.

Table 1 summarizes and compares CTD-ILD studies discussed in rheumatological diseases.

## Conclusions

Although there is not a standardized approach for the LUS examination in ILD, most studies included a small cohort

**Table 1** Demographic data, number of patients enrolled, type of diseases and sensitivity and specificity of LUS of patients with CTD-ILD [modified with permission from (36)]

Reference author; years	Type of study	Patients enrolled (female/male)	Age (SD)	Disease duration (years) (SD)	Type of disease	Sensitivity (%)	Specificity (%)
Gargani (22); 2009	Single-center	33 (30/3)	54±13	8±7	SSc	NA	NA
Delle Sedie (26); 2010	Single-center	25 (22/3)	53±10.5	NA	SSc	85%	70%
Gutierrez (37); 2011	Single-center	36 (32/4)	57±13	7.3±6.9	SSc, Sjogren, undifferentiated CTD, mixed CTD	NA	NA
Moazedi-Fuerst (39); 2012	Single-center	25 (23/2)	51±15	6.5 (1–20)	SSc	NA	NA

Table 1 (continued)

Table 1 (continued)

Reference author; years	Type of study	Patients enrolled (female/male)	Age (SD)	Disease duration (years) (SD)	Type of disease	Sensitivity (%)	Specificity (%)
Tardella (25); 2012	Single-center	34 (30/4)	57	7.3	SSc, SS, antisynthetase, DM, mixed CTD, undifferentiated CTD	NA	NA
Barskova (23); 2013	Pilot	58 (54/4)	51±14	1.9±3.2	SSc	100%	59%
Aghdashi (43); 2013	Single-center	31 (26/5)	48±10	5.6±1.9	SSc, RA, overlap, SS, DM	74%	88%
Mohammadi (38); 2014	Cross-sectional	70 (62/8)	50±10	7.3±6.9	SSc	74%	88%
Moazedi-Fuerst (44); 2014	Cross-sectional	64 (54/10)	59±12	9.4	RA	97%	97%
Cogliati (24); 2014	Single center	13 (8/5)	65±10	12.46±8.6	RA	Standard method (HRCT) 92%. Simplified method was 69%	Standard method 56% (HRCT). Simplified method was 88%
Hasan (40); 2014	Pilot	9 (NA)	49±12	NA	Sarcoidosis	NA	NA
Sperandeo (20); 2015	Single-center	175 (166/9)	46±15	7.5±6.2	dSSc [137]/ISSc [38]	Reticular pattern 80%. Reticular-nodular pattern (and honeycombing) 74%. Honeycombing 90%	Reticular pattern 99%. Reticular-nodular pattern (and honeycombing) 99%. Honeycombing 99%
Moazedi-Fuerst (45); 2015	Single-center	45 (15/30)	54 [28–74]	8 [1–35]	RA (n=25), SSc (n=14) or SLE (n=6)	NA	NA
Pinal-Fernandez (46); 2015	Single-center	37 (24/13)	51.5±14	NA	13 as having probable or definite dermatomyositis and 6 as polymyositis; the remaining 2 patients had pure antisynthetase-associated IPF, without myositis. Among the SSc patients, 8 were classified as limited SSc, 5 as diffuse SSc, and 3 as SSc without scleroderma	79%	100%
Buda (41); 2016	Single-center	30 (NA)	50±24	NA	Systemic connective tissue disease	Blurred pleura line 59%. White lung syndrome 95%	Blurred pleura line 82%. White lung syndrome 99%
Gigante (42); 2016	Cross-sectional	39 (33/6)	51±15	8.5±6.3	dSSc [24]/ISSc [15]	NA	NA
Vasco (47); 2017	Pilot	13 (13/0)	64±NA	NA	SSc	100%	89%

SD, standard deviation; NA, not applicable; SSc, systemic sclerosis; CTD, connective tissue disease; RA, rheumatoid arthritis; SS, Sjögren syndrome; SSc, systemic sclerosis; dSSc, diffuse systemic sclerosis; ISSc, limited systemic sclerosis; SLE, systemic lupus erythematosus; IPF, interstitial pulmonary fibrosis.

of patients and there is potential bias linked to changes in lung parenchyma over time, this review showed how US might have the necessary attributes to facilitate the best clinical practice in the detection of ILD. Applications of this imaging technology are still being developed and further opportunities with ongoing research strategies are likely to arise, especially to test its concurrent validity, reliability and responsiveness in multicenter studies.

## Acknowledgments

*Funding:* None.

## Footnote

*Provenance and Peer Review:* This article was commissioned by the Guest Editors (Luca Bertolaccini and Dania Nachira) for the series “Science behind Thoracic Surgery” published in *Shanghai Chest*. The article has undergone external peer review.

*Conflicts of Interest:* All authors have completed the ICMJE uniform disclosure form (available at <http://dx.doi.org/10.21037/shc.2018.04.10>). The series “Science behind Thoracic Surgery” was commissioned by the editorial office without any funding or sponsorship. The authors have no other conflicts of interest to declare.

*Ethical Statement:* The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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doi: 10.21037/shc.2018.04.10

**Cite this article as:** Falcetta A, Leccardi S, Testa E, Papaleo F, Fenoglio L, Melchio R. The role of lung ultrasound in the diagnosis of interstitial lung disease. *Shanghai Chest* 2018;2:41.