Monaldi Archives for Chest Disease

eISSN 2532-5264 https://www.monaldi-archives.org/

Monaldi Arch Chest Dis 2026 [Online ahead of print]

To cite this Article:
Singh R, Kumar N, Pradhan GS, et al. **Utility of lung ultrasound in assessing severity of interstitial lung diseases: correlation with high-resolution computed tomography and spirometry findings**. *Monaldi Arch Chest Dis* doi: 10.4081/monaldi.2026.3929

Submitted: 5-02-2026
Accepted: 29-07-2026

Utility of lung ultrasound in assessing severity of interstitial lung diseases: correlation with high-resolution computed tomography and spirometry findings

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Contributions: Ramandeep Singh, Naresh Kumar, Gaurav Shankher Pradhan: conceptualization. Ramandeep Singh, Gaurav Shankher Pradhan, Anju Garg, Anjali Prakash: data acquisition, investigation. Ramandeep Singh, Naresh Kumar, Anju Garg: formal analysis, interpretation. Ramandeep Singh, Sandeep Singh, Paramdeep Singh: methodology, software. Ramandeep Singh, Gaurav Shankher Pradhan: writing - original draft. Naresh Kumar, Gaurav Shankher Pradhan, Arvinder Wander: writing - review and editing. Gaurav Shankher Pradhan, Anju Garg, Anjali Prakash, Paramdeep Singh: supervision/administration. Ramandeep Singh, Naresh Kumar, Gaurav Shankher Pradhan: validation, visualization.

Conflict of interest: the authors declare that there is no conflict of interest.

Ethics approval and consent to participate: the institutional ethical review board granted a waiver for ethical clearance for this study as no ethical issues were found (F.1/IEC/MAMC/70/5/2019/569).

Informed consent: an informed and written consent was taken from all the patients involved in the study.

Patient consent for publication: an informed and written consent was taken from all the patients involved in the study for participation in study and for publication.

Availability of data and materials: the datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request. The dataset does not contain personally identifiable information and has been handled in accordance with patient confidentiality and applicable ethical requirements.

Declaration of generative artificial intelligence and artificial intelligence-assisted technologies in the writing process: the authors declare that no generative artificial intelligence or artificial intelligence-assisted technologies were used in the writing, preparation, or editing of this manuscript.

Abstract

Interstitial lung diseases (ILDs) constitute a diverse category of diffuse parenchymal lung disorders whose diagnosis and monitoring are challenging due to complex clinic-radiological profiles and the risks of serial high-resolution computed tomography (HRCT). Lung ultrasound (LUS) has potential to become an easily available, non-ionizing substitute, though its comparative performance against HRCT and spirometry in severity assessment has been inadequately studied. We conducted a cross-sectional study of 52 adult ILD outpatients enrolled over one year, excluding those with cardiac failure, pulmonary tuberculosis, neoplasia, pregnancy, or acute ILD exacerbation. Each patient underwent LUS using a linear probe to determine total B-line score, total positive chest areas with ≥5 B-lines, and pleural line abnormalities; HRCT was scored by the Warrick system, and spirometry measured forced vital capacity (FVC) and forced expiratory volume in 1 second (FEV1). There was a substantial correlation ($r=0.75$, $p<0.001$) between the Total B-line score (mean 39.3±15.3) and the Warrick score (11.94±5.09) and the Warrick score and total positive chest area score ($r=0.77$, $p<0.001$). Notable unfavorable associations were observed between LUS B-line score and FVC ($r=-0.75$, $p=0.00$) and FEV1 ($r=-0.73$, $p=0.00$). LUS demonstrated sensitivity of 97.9% and diagnostic accuracy of 94.2% compared with HRCT, though specificity was moderate (60%). These findings indicate that LUS closely mirrors HRCT and spirometry in assessing ILD severity. Given its high sensitivity, safety profile, and accessibility, LUS may serve as a valuable adjunct for routine evaluation and follow-up of ILD patients, particularly where repeated HRCT is impractical. Further large-scale, prospective studies are required to validate standardized LUS scoring and establish its role in guiding ILD management.

Key words: interstitial lung diseases, lung ultrasound, HRCT, spirometry.

Introduction

Interstitial lung diseases (ILDs) represent a heterogenous group of diffuse parenchymal lung diseases with complex pathophysiology and clinic-radiological profile, thereby challenging to diagnose. Early diagnosis and regular monitoring can improve the prognosis by reducing the patient`s morbidity and mortality.

Due to very low sensitivity of X-ray for ILD detection, high-resolution computed tomography (HRCT) chest is the current non-invasive gold standard technique for the diagnosis of ILDs, both for baseline evaluation and monitoring of disease activity [1]. Unfortunately, repeated HRCTs (which are usually required because of the chronic nature of the disease) cannot be done due to its cost, availability and the risk of radiation exposure. Thus, there is still a need for a more convenient and safer imaging technique for assessment of pulmonary features of ILDs.

Studies have highlighted the use of lung ultrasound (LUS) in detection of interstitial lung diseases using B line artefact. B line is basically a reverberation artefact that extends vertically down from the pleural line across the screen (*Supplementary Figure 1*). It is produced by thickening of the interlobular septa and appears hyperechoic and moves synchronously with lung sliding [2]. Though B lines are nonspecific finding as these can be seen in other causes of interlobular septal thickening such as pulmonary edema, however these can be utilised in proper clinical context.

Many studies have been conducted to elaborate the LUS findings in ILDs patients, however there are very few studies available which graded the severity of ILD based on the USG findings and did comparison with HRCT and spirometry findings. Hence, the present study was undertaken to find the correlation between the LUS and HRCT simplified scores to determine the role of LUS in assessing the severity of ILDs.

Materials and Methods

The study was performed in the Radiology Department in one of the tertiary care hospital of New Delhi over a period of one year. Fifty-two consecutive outpatients referred from Department of Pulmonary Medicine were the study subjects. Adult (age >18 years) patients of either gender who were diagnosed with ILD were enrolled in the study. Established international criteria using the clinical, radiological, serological and spirometry findings were used for the diagnosis of ILDs [3]. Exclusion criteria were

patients of congestive cardiac failure, primary pulmonary hypertension, pulmonary tuberculosis, pulmonary neoplasia; pregnant patients and acute exacerbation of ILDs.
The study was undertaken after due clearance from the Institutional Ethics Committee (F.1/IEC/MAMC/70/5/2019/569). A written consent was taken from all the patients. Demographic details of patient and relevant clinical history were taken.

Imaging technique

Lung ultrasound

LUS was performed by a radiologist with nearly a decade long experience in lung imaging. He was blinded to HRCT and spirometry findings. Once the patient fulfilled the inclusion and exclusion criteria, LUS was performed on an ACUSON S2000 ultrasound machine (Siemens Medical Solutions) using 9L4-linear array ultrasound transducer (4-9 MHz). Maximum depth of 8–10 cm was set and focus was placed at the level of pleural line, which is usually at 2-4cm depending on the thickness of the chest wall. Where the more depth was required as in obese patients, curvilinear probe was used; however the focus remains at the level of pleura. Anterior and lateral chest wall was scanned in supine position by moving the probe longitudinally along the mid-clavicular and mid-axillary lines respectively. Posterior chest wall was scanned in sitting position along the mid-scapular line. Five intercostal spaces (ICS) were examined on each side (*Supplementary Figure 2*).
The parameters assessed were: 1. Total B-lines score was calculated by summation of total number of B-lines in 10 predefined scanning sites, 2. ICSs with ≥5 B-lines were considered as Positive chest area and total number of such positive chest areas were calculated in each patient, 3. Pleural line thickening and irregularity
Based on the LUS B-line score, patients were categorized as normal: ≤ 5 B-lines, mild disease: 6-20 B-lines, moderate disease: 21-40 B-lines and severe disease: > 40 B-lines (*Supplementary Figures 3 and 4*).

HRCT technique

Chest HRCT was done on a 128 -slice MDCT scanner [Somatom Definition AS (Siemens Health Care _ Erlangen, Germany)] at full inspiration in the supine position at 120 kV. Axial images of the lung parenchyma were acquired followed by coronal and sagittal

reformations in the lung window. All HRCT chest were performed within one week of ultrasound.

All HRCT chest were analysed by a radiologist blinded to patients' LUS and spirometry findings. Parenchymal abnormalities on HRCT were reported and scored according to the Warrick score [4]. The parameters noted are tabulated in Table 1.

Similar to LUS B-line score, patient`s disease severity was categorized and expressed as a semi-quantitative data based on their respective HRCT Warrick score as: normal: 0 score; mild: </=7; moderate: 8-15 and severe: >15 score.

Spirometry

After doing LUS and HRCT chest, spirometry was completed within a week. Forced vital capacity (FVC), forced expiratory volume in first second (FEV_1) and ratio of FEV_1/FVC were measured while the patient made the maximum effort possible to prevent any anticipated diagnostic error.

Statistical analysis

Following the data collection, the information was converted into variables, coded and added to the Microsoft Excel spreadsheet. The SPSS-PC-31 version was used for analysis and statistical evaluation.

Results

The demographic characteristics of our study population (n=52), with average age of 48.48 years and an equal sex distribution, suggest a representative cohort for examining ILD (Table 2). The mean B-Line Score (39.3 ± 15.3) and Warrick Score (11.94 ± 5.093) provide baseline severity estimations according to HRCT and USG, respectively. The reported FEV1/FVC ratio (0.84 ± 0.07) is within the normal range, indicating that the cohort, on average, did not present with significant obstructive ventilatory defects.

The total positive chest areas score was 7.3 ±3.07. Total B-lines score ranged from 0-64 while the HCRT score ranged from 0-23; and range of the total positive chest areas score was 0-10.

The scatter plot (*Supplementary Figure 5*). clearly shows that the Warrick Score and the B-Lines Score have a favourable association. This suggests that as patient's Warrick Score increases, their B-Lines Score generally behaves similarly (R = 0.75, p = <0.001), indicating a potential correlation between the two measures. While the overall trend is evident, there is also individual variability in the data points, implying that other factors may influence the B-Lines Score beyond just the Warrick Score.

There was a clear positive correlation between the Warrick Score and the Positive Chest Areas Score. As the Warrick Score (HRCT severity) increases, the Positive Chest Areas Score (USG severity) also tends to increase (R = 0.77, p <.001). This suggests that USG findings largely reflect the severity of ILD as assessed by HRCT. The association between severity of ILD based on HRCT and USG is tabulated in Table 3.

Both FVC and FEV1 showed negative correlation with Total Number of B-Lines score (r = - 0.75, p = 0.00 for FVC and r = - 0.73, p = 0.00 for FEV1).

The Ultrasound (USG) is a highly effective diagnostic tool, showing substantial agreement with the gold-standard HRCT, as evidenced by a Cohen's Kappa coefficient of 0.64. The primary strength of USG lies in its excellent sensitivity (97.87%) and high Positive Predictive Value (95.83%), making it exceptionally reliable for detecting the disease and confirming positive cases. While its overall accuracy is high at 94.23%, its principal limitation is a moderate specificity (60.00%), which may lead to a higher rate of false positives. These findings strongly support the use of USG as a robust, non-invasive first-line screening modality; it can confidently rule out the disease, though positive findings may warrant confirmation with HRCT to achieve a definitive diagnosis.

Discussion

The purpose of this study was to examine the LUS role in assessing the severity of pulmonary involvement in Interstitial lung diseases in comparison with the HRCT and spirometry results. Two LUS scores (Total B-lines score and total positive chest areas score) were compared with HRCT Warrick`s score and various spirometric parameters. We discovered that the LUS scores and HRCT Warrick score had a significant positive association for severity of pulmonary involvement and this correlation was statistically

significant (r = 0.75, p = < 0.001 for Total B lines score) and (r = 0.77, p = < 0.001 for Total Positive Chest Areas score). We demonstrated irregular/thickened pleura as the second most common LUS finding after the B lines, which was predominantly seen in UIP patients (n=11). Only single case of NSIP showed thickened pleura. To best of our knowledge this distinction between the UIP and NSIP has never been demonstrated before on LUS.

In present study, FVC and FEV1 demonstrated a substantial inverse relationship with LUS scores (r = - 0.75, p = 0.00 for FVC and r = - 0.73, p = 0.00 for FEV1). Our results are in concurrence with previous studies conducted by Cakir et al [5] & Tardella et al [6] who also reported a significant negative correlation between most PFT parameters and LUS scores. It was seen that most patients had a FEV1/FVC ratio more than 80% and showed reduction in FVC, suggesting a restrictive pattern of lung disease. Further, most patients had a moderately reduced forced vital capacity (FVC) suggesting a significant pulmonary involvement. Interstitial lung diseases lead to reduction in lung capacity and gas transfer across alveolo-capillary barriers, thus leading to changes in PFTs, which are predictive of disease prognosis.

Due to its great versatility, LUS may have a substantial clinical influence for ILD evaluation. It has a short learning and interpretation curves, is readily available, and is reasonably priced [7]. Additionally, the method is non-ionizing and could help in lowering the x-ray exposure risk by reducing the frequency of HRCT scans for the lung evaluation [8]. However, HRCT chest is currently the investigation of choice for evaluating ILD because other imaging techniques are not at par with HRCT in providing all the information. However, LUS may prove to be a helpful modality for directing the optimal utilization of HRCT, even if it is unlikely to ever completely replace the important information provided by chest HRCT.

Over the past decades, several studies have been published demonstrating the role of LUS in detecting lung involvement in ILDs and showed strong correlation with HRCT findings [4,9-12]. Research has demonstrated that LUS is quite sensitive for identifying ILD at early stages, and it appears to be a trustworthy screening method to direct further workup with HRCT [6]. This is of utmost importance especially in case of CTD-ILD as these patients are usually young females who require sequential imaging, thus use of LUS in these patients helps to reduce the radiation exposure.

LUS B line score also has a good statistically significant correlation with PFTs, supporting the complementary use of ultrasound for measuring severity of ILDs [13-14]. This is particularly important in patients in whom there is severe degree of lung parenchyma involvement, as these patients are not able to perform the spirometry comfortably. In such patients, LUS score along with HRCT finding and other clinical parameters can help to monitor the disease without performing spirometry. Although there is currently a dearth of published data in this context, LUS may also offer close follow-up to evaluate ILD changes during the course of treatment.

Apart from the inherent limitations of the ultrasound, there are few limitations in use of LUS in evaluation of ILD. The primary drawback of the B-lines is their lack of specificity. B-lines represent thickening of the pulmonary interstitium either by fluid (e.g., cardiogenic pulmonary oedema) or fibrosis (as in interstitial lung diseases). However, as the diuretic medication only clears the cardiogenic B-lines, the differential diagnosis is usually obvious from the patient's history and/or dynamic serial evaluation [15]. Also, the presence of irregular pleura favours the diagnosis of ILD rather than cardiogenic pulmonary edema, which shows thin smooth pleura. B-lines, however, cannot distinguish alveolitis from fibrosis, a limitation which is there with HRCT as well. Ultrasound can't provide a global assessment and may not be useful, if the disease is focal, for which HRCT is far more superior. However, as lungs are diffusely involved in interstitial lung diseases, LUS can be used with reasonable accuracy.

Our study can have good clinical impact in management of ILDs. LUS is an accurate imaging technique both for diagnosis and assessing the severity of lung involvement in interstitial lung diseases. It has potential implication in early detection of ILD in certain group of patients like CTDs. It can also prove useful in follow up of ILD patients and for assessing eventual response to therapy, though large scale prospective studies are still awaited in this aspect.

Our study's cross-sectional design and one-time evaluation of pulmonary involvement in ILD are its limitations. A longitudinal study evaluating the temporal evolution of the LUS and HRCT findings would be more clinically relevant. Also, non-inclusion of parameters like diffusion study, 6-minute walk test and dyspnea scores limits the comparison of this study with the available literature where these parameters have been studied.

Conclusions

Lung ultrasound correlates strongly with HRCT Warrick scoring and spirometric parameters in assessing disease severity in interstitial lung diseases. LUS B-line–based indices reliably reflect both structural lung involvement and functional impairment, with high sensitivity and diagnostic accuracy. Owing to its non-ionizing nature, availability, and suitability for repeated assessment, lung ultrasound serves as a valuable adjunct to HRCT for routine severity evaluation and follow-up of ILD patients. Prospective longitudinal studies are warranted to standardize LUS scoring and further define its role in clinical management.

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Online supplementary material

Supplementary Figure 1. Grey scale ultrasound image of lung showing the ‘A’ lines and ‘B’ lines.

Supplementary Figure 2. Intercostal sites for lung ultrasound. 5 sites were examined on each side.

Supplementary Figure 3. Interstitial lung disease patient with mild disease. 45 year old female who was known case of scleroderma.

Supplementary Figure 4. Interstitial lung disease patient with moderate disease. 54 year old male presented with dry cough and dysnea for 4 years.

Supplementary Figure 5. Scatter plot showing the relationship between Warrick Score and B-Lines Score.

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Table 1. The Warrick scoring system.

Parenchymal Alterations	**Severity score**
Ground glass opacities	1
Irregular pleural margins	2
Septal/subpleural lines	3
Honeycombing	4
Subpleural cysts	5
Number of lung segments	
1-3	1
4-9	2
>9	3

Table 2. Demographic data of the study group.

Variables	***Study group (%) (n = 52)***
Mean age (years)	48.48 ± 16.6
Gender Male Female	 26 26
Smoking Status Yes No	 13 39
Pattern of ILD UIP NSIP Micronodular/others	 29 19 04
Type of ILD Idiopathic Connective tissue disorder related Sarcoidosis Silicosis Chronic hypersensitivity pneumonitis Idiopathic pulmonary hemosiderosis	 26 20 3 1 1 1

Table 3. Association between severity of ILD based on HRCT and USG.

Severity based on USG	**Severity based on HRCT**				**p-value**
	Normal	**Mild**	**Moderate**	**Severe**	
Normal	3	1	0	0	**<0.01**
Mild	2	4	2	0	
Moderate	0	3	15	7	
Severe	0	0	7	8	