

Assessment of interstitial lung disease severity using lung ultrasound and its correlation with high-resolution computed tomography findings and functional status: a cross-sectional study

Montaser G. Ahmed^a, Mohamed M. Metwally^a, Dina W. Fahim^a, Mohamed Osman^b, Mostafa A. Sayed^c, Nermen M. Abuelkassem^a

^aDepartment of Chest Diseases and Tuberculosis, Faculty of Medicine, Assiut University, Assiut, Egypt, ^bDepartment of Cardiovascular Medicine, Faculty of Medicine, Assiut University, Assiut, Egypt, ^cDepartment of Diagnostic and Interventional Radiology, Faculty of Medicine, Assiut University, Assiut, Egypt

Correspondence to Dina W. Fahim, MBCh, Department of Chest, Faculty of Medicine, Assiut University Hospital, Assiut 71511. Egypt
Tel: +21 287 799 134;
e-mail: tinawageh0@gmail.com

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Background

Owing to its ability to accurately characterize parenchymal involvement, high-resolution computed tomography (HRCT) is the cornerstone imaging modality for the evaluation of interstitial lung diseases (ILD). Although highly informative, its use is limited by radiation exposure and the challenges of repeated imaging. Recently, lung ultrasound (LUS) has gained importance as a bedside tool for assessing interstitial involvement using B-lines. We aimed to evaluate the correlation between LUS B-line scores and HRCT visual severity score in patients with ILD, and to investigate their associations with pulmonary function, exercise capacity, and health-related quality of life (HRQoL).

Patients and methods

Fifty adult patients diagnosed with ILD were enrolled in a prospective cross-sectional study. Participants underwent clinical assessment, HRCT visual scoring, LUS using a quantitative B-line score, spirometry, arterial blood gas analysis, echocardiography, 6-min walk test, and HRQoL assessment using the Saint George's Respiratory Questionnaire. Correlations between imaging scores, physiological parameters, exercise capacity, and HRQoL were analyzed.

Results

The study included 50 patients (mean age: 50.3 ± 15 years; 72% female). Connective tissue disease-associated ILD was the most common subtype (36%), followed by idiopathic pulmonary fibrosis (26%), nonspecific interstitial pneumonia (22%), and hypersensitivity pneumonitis (12%). Total LUS B-line scores demonstrated a pronounced positive correlation with HRCT visual severity scores ($r=0.631$, $P<0.001$). Higher HRCT scores were also significantly associated with worse Saint George's Respiratory Questionnaire scores, consistent with reduced HRQoL.

Conclusions

LUS B-line score demonstrated a strong association with HRCT severity and may serve as a complementary tool in the assessment of disease severity in patients with ILD.

Keywords:

B-lines, health-related quality of life, high-resolution computed tomography, interstitial lung disease, lung ultrasound, pulmonary function tests

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Background

Interstitial lung diseases (ILDs) include a diverse group of disorders characterized by diffuse involvement of the lung parenchyma that predominantly involves the lung interstitium but frequently extends to the airspaces, peripheral airways, and pulmonary vasculature. These disorders show variable degrees of inflammation and fibrosis, finally resulting in disruption of the alveolar-capillary membrane, reduced lung compliance, impaired gas exchange, and progressive respiratory failure. Gradual onset dyspnea, dry cough, and reduced exercise capacity are the most common symptoms affecting those patients, which interfere with daily activities and health-related quality of life (HRQoL) [1].

International multidisciplinary statements by the American Thoracic Society (ATS) and European Respiratory Society (ERS) have established standardized definitions, diagnostic criteria, and updated classifications, most recently in 2025, which distinguish idiopathic interstitial pneumonias, autoimmune-associated ILDs, environmental and occupational ILDs, drug-induced ILDs, and

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hypersensitivity pneumonitis [2]. Nonetheless, diagnostic delay remains common, and many patients are exposed to unnecessary investigations or inappropriate treatments due to nonspecific symptoms, limited awareness in primary care, and restricted access to specialized multidisciplinary ILD services [3].

High-resolution computed tomography (HRCT) remains the cornerstone for diagnosing and staging ILD, providing detailed visualization of parenchymal abnormalities such as ground-glass opacities, reticulation, traction bronchiectasis, and honeycombing. HRCT pattern recognition is central for distinguishing usual interstitial pneumonia (UIP), nonspecific interstitial pneumonia (NSIP), hypersensitivity pneumonitis, and other ILD subtypes. However, HRCT involves ionizing radiation, is relatively costly, and may not be readily available or feasible for repeated monitoring in many low-income and middle-income settings, where access to advanced imaging and pulmonary function testing is limited [3].

Lung ultrasound (LUS) is increasingly used as a convenient, radiation-free bedside method for assessing interstitial changes. The presence and distribution of B-lines reflect thickened interlobular septa and alveolar edema, and are considered a sonographic marker of pulmonary interstitial involvement. LUS total B-line scores have shown good correlation with CT visual scores. Nevertheless, there is still limited evidence integrating LUS findings with HRCT visual scores, spirometric indices, and HRQoL measures across a broad spectrum of ILD subtypes [4].

Beyond imaging, ILD severity assessment is inherently multidimensional, including radiologic extent of fibrosis, physiological impairment, symptoms, exercise capacity, and patient-reported outcomes. Declines in forced vital capacity (FVC) and diffusing capacity for carbon monoxide are considered significant predictors of prognosis. While to monitor clinical status, the widely used tools are dyspnea scales such as the modified Medical Research Council (mMRC) and functional tests like the 6-min walk test (6MWT) [3]. Validated HRQoL measures, including the Saint George's Respiratory Questionnaire (SGRQ), provide critical insights into the subjective burden of disease, which may not be fully captured by imaging or spirometry alone [5].

In resource-limited environments, such as many centers in Egypt, there is a pressing need for simplified, reproducible tools that integrate readily available measures to stratify ILD severity and guide follow-up [3]. LUS is particularly appealing in this context because it is

portable, inexpensive, repeatable, and can be performed at the bedside without radiation exposure [6].

Therefore, this study aimed to assess LUS as a noninvasive, bedside complementary tool to HRCT for ILD severity assessment and also to evaluate the relationship between HRCT visual severity scoring and spirometric parameters in patients with ILD, and to determine their relationship with HRQoL.

Patients and methods

Study population

In this prospective observational cross-sectional study, 50 patients diagnosed with ILD, who presented to the outpatient clinic of the Chest Department between October 2024 and October 2025 were evaluated.

Study protocol

The study was approved by the Institutional Review Board (IRB) of the Faculty of Medicine (Approval Number: 04-2023-200439). Based on international criteria, clinical features, radiological findings, serological results, and spirometry, a multidisciplinary team confirms the diagnosis of ILD [2]. We included patients with the following criteria, age more than or equal to 18 years of both sexes, availability of a chest HRCT scan performed within 3 months of the clinical assessment or the capability to undergo the scan at the time of assessment, availability of spirometry for the patient, who should be capable of performing the test and repeating it according to the ATS and ERS standards [7], ability to complete the Arabic version of the SGRQ, with or without assistance, for low-literacy patients [5], and clinical stability, with no acute ILD exacerbation at the time of assessment or within the preceding 4 weeks. We excluded the patients with one or more of the following: dominant non-ILD respiratory disease, inability to perform acceptable spirometry maneuvers, hemodynamic instability [8], advanced cardiac disease (e.g. decompensated New York Heart Association Class IV heart failure, myocardial infarction within the last 2 months and/or patients with reduced left ventricular ejection fraction less than 40%, and patients with a history of previous lung resections and pregnancy. Written informed consent was obtained before undergoing procedures from all enrolled patients.

A standardized clinical evaluation was performed for all patients, incorporating a detailed medical history (demographics, smoking status, and occupational/environmental exposure) and a comprehensive physical examination. We used the mMRC dyspnea scale to evaluate the burden of the dyspnea and the SGRQ to assess HRQoL. Furthermore, all patients performed

a 6MWT to objectively measure functional exercise distance [9].

High-resolution computed tomography assessment

At the Radiology Department, using GE Bright Speed Elite 16-slice and Toshiba Alexion 16-slice scanners, HRCT scans were performed for all participants. Following a standardized ILD protocol, volumetric scans were sequentially acquired using thin-section cuts (1-mm thickness) with the patient in the supine position at full inspiration during a single breath-hold [10].

Parenchymal abnormalities were evaluated by an expert radiologist blinded to all clinical history, laboratory results, spirometric parameters, and LUS findings. For disease quantification, we used a semiquantitative visual scoring system based on anatomical segmentation of the lungs into 18 bronchopulmonary segments, 10 segments in the right lung (apical, posterior, anterior, medial, lateral, superior, medial basal, anterior basal, lateral basal, posterior basal) and eight in the left lung (apicoposterior, anterior, superior lingular, inferior lingular, superior, anteromedial basal, lateral basal, posterior basal). Precise localization was achieved by correlating vascular anatomy and the bronchial tree with known segmental boundaries [11]. Each segment was assessed for the ILD abnormality and scored from 1 to 4 based on the most severe abnormality present:

1=ground-glass opacities (hazy opacity with preserved underlying vessels).

2=reticulations and fibrotic changes (thickening of interlobular/intralobular septa).

3=traction bronchiectasis (bronchial dilatation due to surrounding fibrosis).

4=honeycombing and subpleural cysts (clustered air-filled cysts with dense walls). If multiple abnormalities were present in a single segment, only the highest score was assigned [12]. A total HRCT score was obtained from the cumulative scores of all 18 segments, resulting in a maximum potential score of 72.

Lung ultrasound assessment

The included patients underwent transthoracic ultrasound in the ultrasound unit of the Chest Department. LUS was performed by a pulmonologist blinded to all clinical history, laboratory results, spirometric parameters, and HRCT visual scores. Sonographic examinations were conducted using a SONOACE R3, MEDISON portable ultrasound scanner. A 10-zone scanning protocol was adopted, comprising five zones per hemithorax (anterior upper

and lower zones, lateral upper and lower zones, and a posterior zone) [13]. Each zone was examined in longitudinal and transverse orientations to maximize the visualization of the pleural line and subpleural structures.

B-lines were identified as perpendicular, laser-like hyperechoic artifacts starting from the pleural line, reaching to the bottom of the screen without attenuation, and moving in synchrony with respiratory excursions [14]. Two complementary scoring systems were used for quantification:

1. Total B-lines score (TBLS): the total of all individual B-lines documented across the 10 explored zones [15].
2. Positive chest areas score: a simplified score where each zone containing more than or equal to 3 B-lines was defined as one point, resulting in a total score ranging from 0 to 10 [16] (Fig. 1).

Spirometry

For all included patients and in the Pulmonary Function Unit of the Chest Department, spirometry using a Cosmed SrL, Quark PFTs ergo (Italy) was done. We measured and recorded the following parameters: FVC, forced expiratory volume in 1 s (FEV1), and the FEV1/FVC ratio, expressed as absolute values and as a percentage of predicted values. All maneuvers were performed and interpreted in strict accordance with ATS and ERS standards for acceptability and reproducibility [7].

Arterial blood gas analysis

Arterial blood gas (ABG) investigation was conducted to evaluate the baseline gas exchange status using a Rapid Lab 850 (CHIRON/Diagnostics) analyzer. Arterial samples were drawn from patients at rest while breathing ambient air. The recorded values included pH, partial pressure of oxygen, partial pressure of carbon dioxide, and arterial oxygen saturation [17].

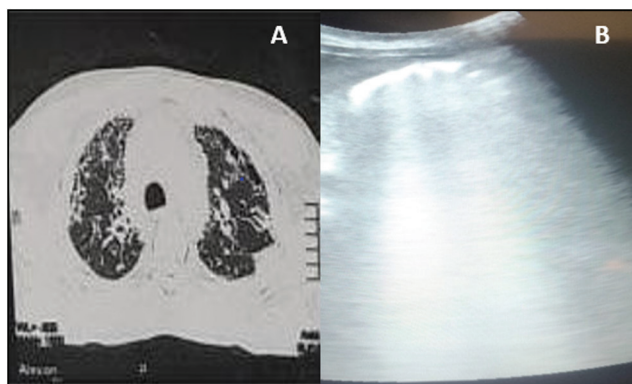
Quality of life and functional assessment:

1. SGRQ: the Arabic version of SGRQ was administered to assess the quality of life. Scores range from 0 to 100, with higher scores indicating more severe impairment in HRQoL. Patients received standardized instructions and could complete the questionnaire independently or with assistance for clarification if literacy was limited [5].
2. 6MWT: the 6MWT was executed in accordance with ATS guidelines. Patients were instructed to

walk as far as possible for 6 min. The total distance walked was recorded [9].

Echocardiography: all enrolled patients underwent 2D transthoracic echocardiography, using a VIVID S5 (GE Medical Systems, Horten, Norway).

Figure 1



A representative imaging findings in a patient with interstitial pulmonary fibrosis (IPF). (a) HRCT showing bilateral thickening of interlobular septa with areas of traction bronchiectasis seen mainly at the right upper lung lobe and subpleural area of cystic dilatation (honeycomb) seen at the left upper lung lobe. (b) LUS demonstrating B-lines corresponding to subpleural interstitial thickening seen on HRCT. HRCT, high-resolution computed tomography; LUS, lung ultrasound.

Statistical analysis

Sample size calculation

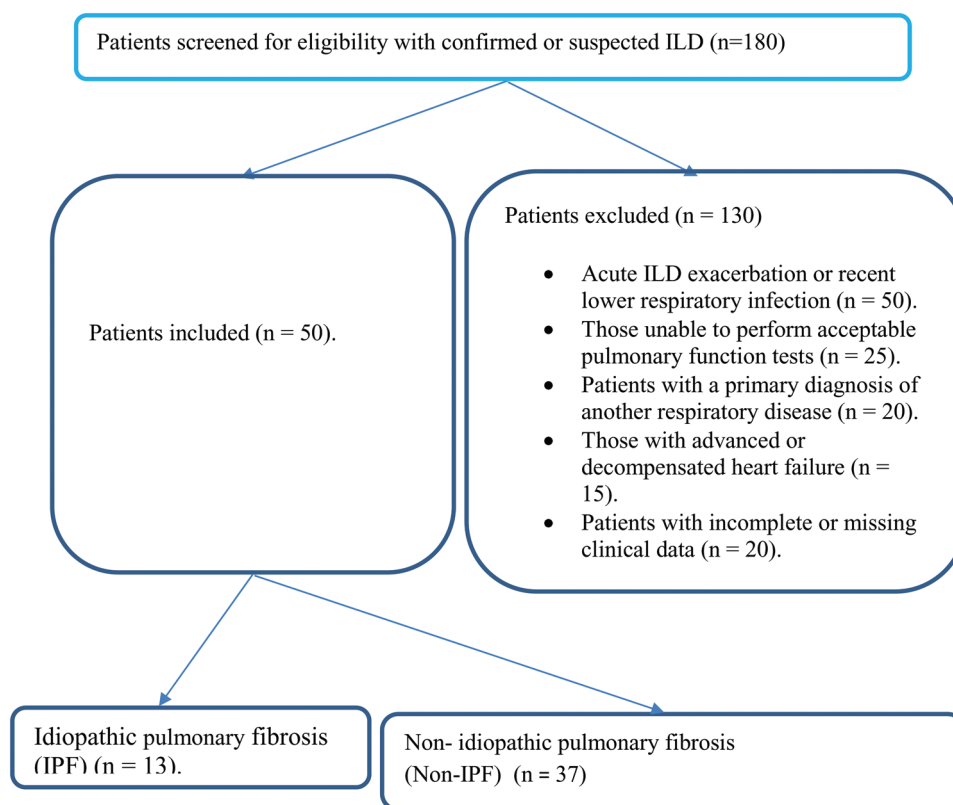
Based on a previous study showing a significant correlation between LUS B-line scores and HRCT scores in patients with ILD, and using a conservative expected correlation coefficient of 0.40, the minimum required sample size was estimated to be 47 patients [16]. The calculation was performed using G*Power software, version 3.1, with a two-tailed α error of 0.05, a power of 80% ($\beta=0.20$), and an expected correlation coefficient of 0.40. Therefore, 50 patients were included in the present study.

The resulting data from this study were calculated using SPSS (Statistical Package for the Social Sciences; SPSS Inc., Chicago, Illinois, USA), version 22. Data were presented using mean $\pm$ SD or median and range for nonnormally distributed variables, and as counts and percentages for categorical variables. Student's t test for normally distributed data and Mann-Whitney U test for nonnormally distributed data were done for comparison of quantitative variables. For comparing categorical data, χ^2 test was performed. A P value less than 0.05 was considered statistically significant.

Results

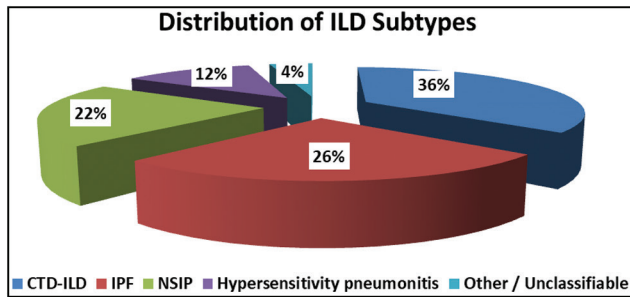
In our study, after fulfilling the inclusion criteria, we enrolled 50 patients with ILD, as shown in Fig. 2.

Figure 2



Flow diagram of patient selection and final study population ($n=50$). Of 180 patients assessed for eligibility, 130 were excluded for predefined reasons. A total of 50 ILD patients were included. ILD, interstitial lung diseases.

Figure 3



Relative distribution of interstitial lung disease (ILD) subtypes among the included patients ($n=50$). Pie chart showing the distribution of ILD subtypes among the studied patients. Connective tissue disease-associated interstitial lung disease (CTD-ILD) represented the most common subtype (36%), idiopathic pulmonary fibrosis (IPF) (26%), and nonspecific interstitial pneumonia (NSIP) (22%). Hypersensitivity pneumonitis accounted for 12% of cases, while other or unclassifiable ILD represented 4% of the study population.

A total of 13 (26.0%) patients were diagnosed with idiopathic pulmonary fibrosis (IPF), while 37 (74.0%) patients had non-IPF ILD. Within the non-IPF group, connective tissue disease-associated interstitial lung diseases (CTD-ILD) was the most common subtype (36.0%), followed by nonspecific interstitial pneumonia (NSIP, 22.0%) and hypersensitivity pneumonitis (12.0%), as shown in Fig. 3.

Table 1 describes the baseline demographic and clinical features of the participants. There was no significant difference between the two groups regarding age, as the mean age was comparable between patients with IPF and those with non-IPF ILD (47.85 ± 15.88 vs. 51.16 ± 15.36 years, $P=0.510$). The distribution of male patients was similar across both groups (38.5 vs. 24.3%, $P=0.474$). However, BMI in the non-IPF group was significantly higher than the IPF group (28.1 ± 4.2 vs. 23.4 ± 3.1 kg/m², $P=0.023$). Severe dyspnea (mMRC grade 3) was more common in patients with IPF than in those with non-IPF ILD (61.5 vs. 21.6%, $P=0.048$). Furthermore, patients with IPF experienced a longer duration of dyspnea compared with the non-IPF group, and this difference was significant [median 3 years (range 1–5) versus 2 years (range 6 months–5 years), $P=0.032$]. Regarding the total HRCT score in the two groups, no statistically significant differences were detected (21.1 ± 8.5 vs. 20.0 ± 8.5 , $P=0.535$) or the total B-line score on LUS (29.3 ± 7.8 vs. 30.0 ± 12.4 , $P=0.868$) as shown in Table 1.

Functional evaluation of the included patients is displayed in Table 2, which compares functional status between the studied groups. It shows that the IPF group had a shorter mean of 6MWT distance than the non-IPF group, with statistically significant differences noticed (mean 6MWT was 290.92 ± 44.95

Table 1 Baseline demographic, clinical, and imaging characteristics of the study population stratified by idiopathic pulmonary fibrosis status ($n=50$)

Parameters	Idiopathic pulmonary fibrosis ($N=13$)	Non-idiopathic pulmonary fibrosis ($N=37$)	<i>P</i> value
Age (years)	47.85 ± 15.88	51.16 ± 15.36	0.510
Male gender, <i>n</i> (%)	5 (38.5)	9 (24.3)	0.474
BMI (kg/m ²)	23.4 ± 3.1	28.1 ± 4.2	0.023*
Dyspnea (mMRC grade 3), <i>n</i> (%)	8 (61.5)	8 (21.6)	0.048*
Dyspnea duration (years), median (range)	3 (1–5)	2 (0.5–5)	0.032*
Total HRCT score	21.1 ± 8.5	20.0 ± 8.5	0.535
Total B-line score (LUS)	29.3 ± 7.8	30.0 ± 12.4	0.868
Total number of positive chest area score	4.62 ± 1.39	4.54 ± 2.26	0.911 [†]

Data are presented as mean $\pm$ SD for continuous variables and number (percentage) for categorical variables. *t* test for continuous variables and the chi-square test for categorical variables, were used for comparison between both groups. A *P* value less than 0.05 was considered statistically significant.

HRCT, high-resolution computed tomography; LUS, lung ultrasound; mMRC, modified Medical Research Council dyspnea scale.

*Statistically significant.

vs. 335.14 ± 61.35 m, $P=0.022$). Also, resting oxygen saturation (SpO_2) was lower among IPF patients ($94.85 \pm 0.55\%$) compared with non-IPF patients ($95.86 \pm 1.23\%$; $P=0.006$). No significant differences were observed between the two groups regarding other functional parameters. SGRQ scores were greater in the IPF group (60.54 ± 14.32) compared with the non-IPF group (55.78 ± 16.50); however, this difference did not touch statistical significance ($P=0.176$), as shown in Table 2.

ABG analysis showed comparable acid–base status between the studied groups. pH ($P=0.241$), $PaCO_2$ ($P=0.412$), or bicarbonate levels ($P=0.791$) showed insignificant differences between both groups. However, weighty differences were detected in oxygenation parameters. IPF patients showed significantly lower PaO_2 values (71.54 ± 2.93 mmHg) compared with non-IPF patients (74.68 ± 4.08 mmHg; $P=0.013$). Similarly, SaO_2 was significantly reduced in the IPF group ($94.77 \pm 0.60\%$) relative to the non-IPF group ($95.76 \pm 1.21\%$; $P=0.007$) as shown in Table 3.

Table 4 presents spirometric findings among studied patients; FEV1, FVC, and FEV1/FVC were compared between IPF ($n=13$) and non-IPF ($n=37$) patients. Our study showed that IPF patients had significantly lower FEV1% predicted compared with non-IPF patients (65.36 ± 7.69 vs. $73.91 \pm 10.98\%$, $P=0.013$). Although FVC % predicted was also lower in the IPF group ($65.97 \pm 5.10\%$) compared with the non-IPF

Table 2 Functional status and exercise capacity of the studied population according to idiopathic pulmonary fibrosis status (N=50)

Functional status	Idiopathic pulmonary fibrosis (N=13)					Non-idiopathic pulmonary fibrosis (N=37)					P value
	Minimum	Maximum	Median	Mean	SD	Minimum	Maximum	Median	Mean	SD	
St George's Respiratory Questionnaire	30	78	65	60.54	14.32	22	92	50	55.78	16.50	0.176 ^M
6-min walk test distance	228	379	294	290.92	44.95	204	523	323	335.14	61.35	0.022 ^M
Resting oxygen saturation SpO ₂	94	96	95	94.85	0.55	94	98	96	95.86	1.23	0.006 ^M
Nadir SpO ₂	88	95	92	92.15	2.15	88	97	93	92.89	2.29	0.316 ^M
Degree of oxygen desaturation	0	7	2	2.69	2.43	0	7	3	3.05	2.09	0.576 ^M

Continuous variables are presented as minimum, maximum, median, mean, and SD. Mann–Whitney *U* test was done to intergroup comparison.

Table 3 Arterial blood gas analysis findings in the studied patients (N=50)

Arterial blood gas analysis	Idiopathic pulmonary fibrosis (N=13)					Non-idiopathic pulmonary fibrosis (N=37)					P value
	Minimum	Maximum	Median	Mean	SD	Minimum	Maximum	Median	Mean	SD	
pH	7.41	7.44	7.43	7.43	0.01	7.36	7.44	7.42	7.42	0.02	0.241 ^M
Partial pressure of carbon dioxide (mmHg)	34.00	39.00	37.00	36.77	1.54	35.00	42.00	37.00	37.30	1.31	0.412 ^M
Partial pressure of oxygen (mmHg)	68.00	78.00	70.00	71.54	2.93	68.00	85.00	75.00	74.68	4.08	0.013 ^M
Oxygen saturation %	94.00	96.00	95.00	94.77	0.60	94.00	98.00	96.00	95.76	1.21	0.007 ^M
Bicarbonate (mEq/l)	22.00	26.00	24.00	24.08	1.12	22.00	26.00	24.00	24.01	0.86	0.791 ^M

Numerical data are displayed as mean $\pm$ SD and median (range). The Mann–Whitney *U* test was used for comparing continuous data.

Table 4 Spirometric parameters of the study population according to idiopathic pulmonary fibrosis status (N=13 vs. 37)

Spirometric parameters	Idiopathic pulmonary fibrosis (N=13)					Non-idiopathic pulmonary fibrosis (N=37)					P value
	Minimum	Maximum	Median	Mean	SD	Minimum	Maximum	Median	Mean	SD	
FEV1 pred (%)	52.2	78.2	64.9	65.36	7.69	54.2	94.6	75.6	73.91	10.98	0.013 ^t
FVC pred (%)	58.8	74.9	66.1	65.97	5.10	55.8	94.3	67.5	71.86	11.37	0.079 ^t
FEV1/FVC (%)	77.7	95.7	84.4	85.69	5.56	72.6	95.2	84.6	84.53	5.28	0.504 ^t

Numerical data are presented as mean $\pm$ SD and median (range).

FEV1 pred (%), forced expiratory volume in 1 s (% predicted); FVC pred (%), forced vital capacity (% predicted). Significance defined by *P* value less than 0.05. Student's *t* test was used for comparing continuous data.

group ($71.86 \pm 11.37\%$), this difference did not touch statistical significance ($P=0.079$), as shown in Table 4.

In this study, we found a mean total HRCT score of 20.34 ± 8.47 (range: 9–44) and a mean TBLS of 29.84 ± 11.38 (range: 1–54). The mean total number of positive chest area score was 4.56 ± 2.06 (range: 0–9).

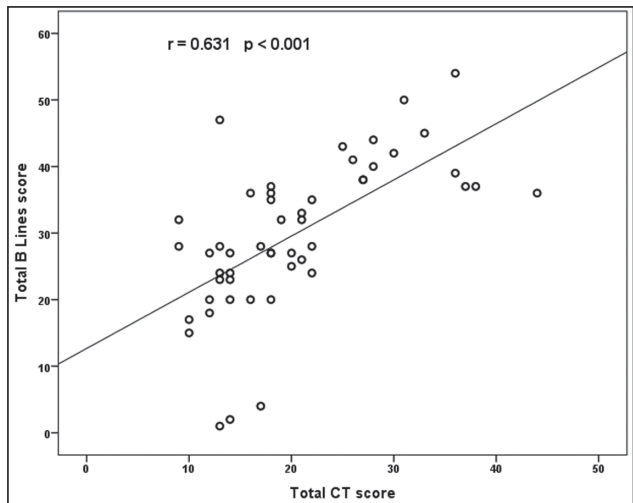
The analysis of the relationship between modalities showed a significant positive correlation between the total HRCT visual score and TBLS ($r=0.631$, $P<0.001$), as shown in Fig. 4.

The correlation analysis between TBLS and spirometric as well as functional parameters showed no statistically significant correlations. TBLS showed a weak negative correlation with FEV1 % predicted and FVC % predicted, indicating a nonsignificant trend toward lower pulmonary function with increasing B-line burden. Regarding symptoms and functional assessment, TBLS demonstrated weak

positive correlations with dyspnea severity (mMRC score) and HRQoL evaluated by SGRQ, though neither reached statistical significance. A weak negative correlation was observed between TBLS and 6MWT distance, but without statistical significance, as shown in Table 5.

For evaluating the relationship between the total CT score and spirometric parameters and severity assessment, we performed correlation analysis. No significant correlations were observed between total CT score and FEV1 % predicted, FVC % predicted, or FEV1/FVC ratio. Total CT score showed a weak positive correlation with dyspnea severity assessed by the mMRC scale, although this did not reach statistical significance. Also, a weak negative correlation was detected between the total CT score and 6MWT; however, this association was not statistically significant. This study identified a statistically significant moderate positive correlation between total CT score and SGRQ score ($r=0.305$, $P=0.031$) as shown in Fig. 5.

Figure 4



Relationship between lung ultrasound B-line score and HRCT severity score in the study populations ($n=50$). Scatter plot demonstrating the relationship between the total lung ultrasound B-line score and the total CT score in patients with ILD. Each point represents an individual patient. A statistically significant positive correlation was recorded between lung ultrasound findings and total CT score ($r=0.631$, $P<0.001$), signifying that higher B-line scores are associated with greater radiological disease extent on HRCT. The solid line represents the linear regression trend line. HRCT, high-resolution computed tomography; ILD, interstitial lung diseases.

Table 5 Correlation between total lung ultrasound B-lines score and clinical, functional, and quality-of-life parameters among the studied patients (N=50)

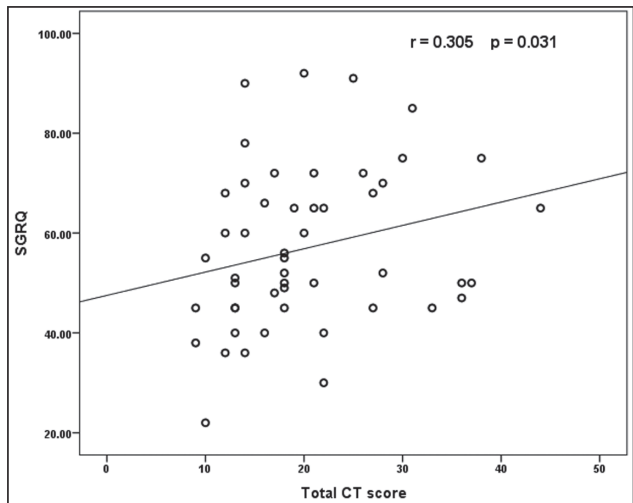
	Total B-lines score
Forced expiratory volume in 1 s predicted	
<i>r</i>	-0.264
<i>P</i>	0.064
Forced vital capacity predicted	
<i>r</i>	-0.122
<i>P</i>	0.400
Ratio of forced expiratory volume in 1 s to forced vital capacity (FEV1/FVC ratio)	
<i>r</i>	0.072
<i>P</i>	0.621
Dyspnea mMRC	
<i>r</i>	0.210
<i>P</i>	0.144
St George's Respiratory Questionnaire	
<i>r</i>	0.182
<i>P</i>	0.206
6-min walk test distance	
<i>r</i>	-0.203
<i>P</i>	0.157

Pearson correlation analysis was used for normally distributed variables. Insignificant correlations were documented between the total B-lines score and pulmonary function parameters, dyspnea severity, exercise capacity, or health-related quality of life. *r*, correlation coefficient.

Discussion

The main goals of this study were to evaluate the association between HRCT visual severity scores, LUS

Figure 5



Correlation between HRCT severity score and St George's Respiratory Questionnaire (SGRQ) among the studied patients ($n=50$). Scatter plot showing the relationship between the total CT score and the St George's Respiratory Questionnaire (SGRQ) total score in patients with ILD. Each point represents an individual patient. It was noticed that higher radiological disease severity is associated with worse SGRQ scores with significant positive correlation ($r=0.305$, $P=0.031$). HRCT, high-resolution computed tomography; ILD, interstitial lung diseases.

B-lines scores, spirometric parameters, and HRQoL in patients with ILD, and to evaluate the potential role of LUS as a complementary tool to HRCT in severity assessment. Our results demonstrated a significant positive correlation between the total HRCT visual score and the LUS B-line score ($r=0.631$, $P<0.001$). These results emphasize the role of LUS as an applied, noninvasive, radiation-free bedside method for assessing ILD severity.

Our observed correlation of $r=0.631$ is highly consistent with the findings of Man *et al.* [16], which reported a correlation of $r=0.64$ using a similar 10-zone protocol. This reinforces the reproducibility of B-line quantification as a semiquantitative marker of interstitial involvement, mirroring the findings of Tardella *et al.* [18], who also established strong links between sonographic B-lines and the distribution of reticular patterns on HRCT.

A critical clinical finding of our study is the pronounced dissociation between symptomatic burden and radiological extent in patients with IPF. Despite having comparable HRCT and LUS severity scores to the non-IPF group, IPF patients exhibited significantly worse clinical impairment, characterized by more advanced dyspnea (61.5% mMRC grade 3 vs. 21.6%, $P=0.048$), shorter walking distances ($P=0.022$), and significantly lower resting oxygen saturation ($P=0.006$). This suggests that visual scoring

of macrostructural fibrosis on imaging does not fully capture the microstructural alveolar destruction and ventilation–perfusion mismatch unique to the IPF pathophysiology.

Nevertheless, SGRQ scores showed insignificant difference between the studied groups, demonstrating equivalent quality-of-life impairment despite IPF's objective functional deficits. This objective–subjective dissociation, where IPF exhibits worse exercise capacity and gas exchange but comparable SGRQ, parallels Yorke *et al.* [19], who found high SGRQ scores across multiple ILD subtypes. This confirms that disease burden severely impacts quality of life regardless of ILD cause. Both groups' mean SGRQ exceeded 50, indicating severe impairment, consistent with prior ILD studies.

ABG analysis showed worse resting hypoxemia in IPF patients with a significant difference, while pH, PaCO₂, and HCO₃ remained comparable between IPF and non-IPF groups. This selective hypoxemia without hypercapnia confirms IPF's characteristic ventilation–perfusion mismatch from diffuse alveolar destruction, consistent with Saleem *et al.* [20], establishing resting PaO₂ less than 75 mmHg as a mortality predictor in fibrotic ILD. Normal PaCO₂ across both groups reflects preserved ventilatory drive typical of early restrictive physiology, preventing CO₂ retention until terminal stages as documented by Nishiyama *et al.* [21]. The ABG–functional dissociation, characterized by IPF's worse resting hypoxemia despite comparable 6MWT desaturation patterns ($P=0.316$) highlights physiological heterogeneity beyond exercise testing alone. This underscores ABG analysis as essential for detecting subclinical gas exchange impairment in early IPF, complementing dynamic functional assessment [22].

In this study, non-IPF patients demonstrated higher mean FEV1% predicted, confirming IPF's greater spirometric impairment. These findings match those of Martinez *et al.* [23] and Erçen Diken *et al.* [24], who documented more severe baseline lung function impairment in IPF versus other ILDs. The trend toward lower FVC% predicted in IPF further supports restrictive physiology. FEV1/FVC ratio was normal (>70%) in all 50 patients, confirming pure restrictive physiology across all ILD subtypes and ruling out obstructive disease.

HRCT demonstrated a weighty correlation only with SGRQ ($r=0.305$, $P=0.031$), showing radiological extent affects quality of life. This matches with Watadani *et al.* [25], who established significant visual HRCT

score correlations with patient-reported outcomes across the ILD spectrum. In this study, no statistically significant correlation was identified between the total HRCT score and pulmonary function test parameters. This discrepancy from the findings of Hussein *et al.* [26], who reported a significant correlation between HRCT findings and pulmonary function indices, may be attributed to differences in sample size, disease heterogeneity, or scoring methodology. Absence of HRCT–spirometry associations confirms the necessity of comprehensive multidimensional assessment protocols.

Chest ultrasonography is a readily accessible bedside imaging tool that is considered as an initial diagnostic approach in outpatient chest clinics, offering satisfactory diagnostic accuracy and easing rapid patient evaluation, predominantly for peripheral and subpleural lung abnormalities such as those encountered in ILD [27]. In our study, the mean total B-line scores in IPF patients was 29.38 ± 7.89 (range: 20–42). All patients had more than or equal to 11 B-lines, confirming abnormal interstitial findings [15]. This high sensitivity aligns with Sperandeo *et al.* [28], who established LUS as a highly sensitive bedside screening tool for ILD (93% sensitivity vs. HRCT), establishing LUS as an effective bedside tool for IPF screening, and Vermant *et al.* [29] reporting LUS AUROC more than 0.9 for early RA-ILD screening.

However, LUS demonstrates clear limitations for definitive ILD diagnosis and subtyping. The lack of significant differences in total B-line scores between IPF and non-IPF patients and total number of positive chest areas score, showed insignificant differences between both groups ($P=0.868$ and 0.911 , respectively). This subtype-independent severity assessment distinguishes LUS from HRCT pattern recognition. Sperandeo *et al.* [28] established that while LUS reliably detects interstitial involvement, it cannot distinguish between UIP, NSIP, or other ILD patterns.

HRCT is suggested to be the main imaging modality for ILD diagnosis and classification according to ATS/ERS guidelines. HRCT achieves 90–95% specificity for IPF diagnosis through characteristic UIP pattern recognition, including subpleural basal predominant reticulation, honeycombing, and traction bronchiectasis, features impossible to discern with LUS B-lines alone. The prognostic value of quantitative HRCT scoring is superior to LUS, as honeycombing correlates with survival [30], while total B-line burden provides only gross interstitial quantification. Previous studies support this complementary relationship

between LUS and HRCT. Moazedi-Fuerst *et al.* [31] demonstrated that B-lines explained ~40% of CT variance in systemic sclerosis-ILD, confirming LUS utility for monitoring after HRCT diagnosis.

The optimal clinical approach integrates both modalities strategically: HRCT provides definitive diagnosis and pattern-based subtyping during initial evaluation, and LUS represents a promising radiation-free modality for pulmonary assessment. Longitudinal studies are required to determine the role of serial LUS in monitoring ILD progression.

Our findings confirm that ILD severity is inherently multidimensional and cannot be adequately assessed by structural imaging alone. Although radiologic extent may seem comparable, patients with IPF exhibit disproportionately worse symptom burden and gas exchange impairment. These subtype-specific differences highlight the need for integrated structural, functional, and symptomatic assessment models and support the development of a practical ILD severity framework applicable across diverse healthcare settings.

Conclusion

This study demonstrates a robust positive correlation ($r=0.631$) between the total HRCT visual score and total LUS B-line score, validating LUS as a reliable, noninvasive, and radiation-free bedside complementary tool that enhances the clinical monitoring of ILD. Furthermore, the study highlights a significant symptom-radiology dissociation in IPF patients, who suffer from more severe functional impairment and hypoxemia despite having radiological scores comparable to other ILD subtypes.

Limitations

The relatively small sample size ($n=50$) with few patients in some subgroups reduced statistical power and limited subgroup analyses. As a single-center study from a tertiary referral hospital, it may involve selection bias and reduced generalizability to community populations. In addition, the lack of diffusing capacity for carbon monoxide measurements restricts full physiological characterization of ILD severity.

Recommendations

A combined multidimensional severity assessment approach for ILD patients, including clinical dyspnea scoring (mMRC), spirometry, quality of life evaluation (SGRQ), and imaging (HRCT and LUS) is recommended to provide a comprehensive understanding of disease impact and guide individualized management. LUS should be incorporated as a complementary tool to HRCT for

severity assessment due to its safety, accessibility, and cost-effectiveness advantages.

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Conflicts of interest

There are no conflicts of interest.

Abbreviations

6MWT, 6-min walk test; FEV1, forced expiratory volume in 1 s; FVC, forced vital capacity; HRCT, high-resolution computed tomography; HRQoL, health-related quality of life; IPF, idiopathic pulmonary fibrosis; LUS, lung ultrasound; mMRC, modified Medical Research Council; SGRQ, Saint George's Respiratory Questionnaire; TBLS, total B-line score.

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