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Role of diaphragmatic ultrasound in the assessment of disease severity in stable interstitial lung disease patients

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Abstract

Assessment of disease severity in interstitial lung disease (ILD) is usually performed using lung function tests, exercise testing, and chest imaging. Each modality has its own benefits and drawbacks. Ultrasound (USG) examination of the diaphragm is a non-invasive imaging modality that has been found to be effective in evaluating diseases like chronic obstructive pulmonary disease and asthma. However, its role in the assessment of stable ILD has been scarcely evaluated. We conducted a cross-sectional study to evaluate the role of diaphragmatic USG in the assessment of disease severity in 55 stable ILD patients. After clinical evaluation, all patients underwent spirometry [forced expiratory volume in 1 second (FEV1) and forced vital capacity (FVC)], high-resolution computed tomography (HRCT) of the thorax and 6-minute walk test as per standard criteria. The Warrick score was calculated using HRCT to quantify the radiological extent of disease. Thereafter, USG was performed, and diaphragmatic excursion (DE) and thickness were measured during both quiet and deep breathing (DB). Dyspnea grade, spirometry values, 6-minute walk distance (6MWD), and the Warrick score were correlated with USG variables to assess for any possible association. The mean age of the patients was 57.6±12.8 years (M:F=1:1). Idiopathic pulmonary fibrosis (n=15) was the most common ILD. The median FVC%, FEV1%, 6MWD, and Warrick score of the patients were 60 (48-74), 68 (53-90), 360 (245-400) m, and 18 (14-22), respectively. Out of 5 USG variables studied, thickening fraction, DE & diaphragmatic thickness (DB) showed statistically significant correlation ($p<0.05$) with dyspnea grade, FVC, 6MWD, and Warrick score in decreasing order of strength. On logistic regression analysis, FVC was the only factor that independently predicted thickening fraction (adjusted odds ratio: -1.08; 95% confidence interval 1.03-1.13; p=0.003). Diaphragmatic mobility and thickness showed a strong correlation with dyspnea, lung functions, exercise capacity, and radiological extent of disease in ILD patients. USG of the diaphragm can play an effective role in the assessment of disease severity in ILD.

Key words: diaphragm, ILD, diaphragmatic excursion, thickening fraction, idiopathic pulmonary fibrosis.

Introduction

Interstitial lung disease (ILD) is a group of subacute to chronic lung diseases characterised by interstitial fibrosis. Chronic dyspnoea and dry cough are the predominant symptoms that also serve as clinical markers of disease severity [1]. High resolution computed tomography (HRCT) of thorax is the non-invasive modality of choice that has a high sensitivity for early detection of asymptomatic ILD. Besides diagnosis, it also aid in monitoring of disease activity, taking treatment decisions and diagnosing acute exacerbations [2]. Despite the growing advantages of HRCT in the management of ILD, high cost, lack of easy availability, associated radiation exposure precludes its routine use, particularly in resource limited settings [3,4].

Lung functions parameter particularly the spirometry variable, forced vital capacity (FVC) provide useful information regarding the diagnosis, severity and progression of ILD [4]. These are non-invasive tests that are devoid of radiation exposure and can be repeated as per physician's judgement. However, their accuracy is primarily dependent on patient cooperation which is often lacking especially in later stages of ILD. Exercise capacity testing in the form of 6-minute walk test (6MWT) is a recent addition in the diagnostic armamentarium which also yields prognostic information about the disease [5]. However, lack of its standardization in ILD and a need for long corridor to conduct the test hinder its routine use.

Diaphragm is an important muscle that accounts for approximately 60% of the tidal volume during quiet breathing [6]. Ultrasound (USG) based assessment of the diaphragmatic function (thickness and mobility) has shown promising results in the evaluation in different lung diseases, such as bronchial asthma [7], COPD [8] and diaphragmatic paralysis [9]. It has also been found to be useful in predicting successful weaning from mechanical ventilation [10]. To a large extent, it overcomes the limitations of HRCT and lung function tests in terms of no radiation exposure, ease to perform and cost effectiveness.

Previous studies have suggested diaphragmatic dysfunction in patients with ILD [11,12]. Mechanical disadvantage due to restriction/fibrosis, chronic hypoxia, persistent inflammation, corticosteroid usage and exercise deconditioning are the key factors that contribute to diaphragmatic dysfunction in these patients [13,14]. In line with the evidence, there is also some emerging evidence on the role of ultrasonographic diaphragmatic assessment in predicting the disease severity in ILD patients [15]. Diaphragmatic thickness (DT) and diaphragm excursion (DE) measured during different phases of respiratory cycle using B-mode and M-mode ultrasound techniques appear to be accurate predictors of lung volume loss in ILD patients. However, the data on correlation of diaphragmatic ultrasound with dyspnea grade, lung functions, HRCT score and exercise capacity is scarce with few studies published from India [16] and outside [15]. Thus, the present study was conducted to evaluate the role of diaphragmatic ultrasound in assessing severity of stable ILD by correlating it with Modified Medical Research Council (mMRC) dyspnea score, lung functions, 6MWT and radiological extent of disease.

Materials and Methods

Study design and participants

This cross-sectional study was conducted in the Department of Pulmonary Medicine in collaboration with Department of Radio-diagnosis at Government Medical College and Hospital (GMCH), Chandigarh between Non 2022 to June 2024. Diagnosed stable cases of Interstitial Lung Disease, attending the Pulmonary Outpatient department (OPD) were consecutively enrolled. All patients were diagnosed with ILD according to the recent guidelines based on the clinico-radiological presentation with or without histopathological confirmation [1,17,18]. Patients with history of acute clinical worsening in the preceding 6 weeks, ILD patients with other respiratory comorbidities like COPD, lung cancer, asthma, kyphoscoliosis, ILD patients with severe renal, heart and liver dysfunction, muscular disorders, pregnant patients and patients who are unable to perform spirometry were excluded from the study. A sample size of 50 patients was calculated based on the previous evidence on the correlation between DE and FVC (r= 0.56-0.76) [12,15] as well as between thickening fraction (TF) and FVC (r=0.33-0.68) [15,16] ensuring 80% power and 95% level of significance. Informed written consent was taken from all patients and the study was approved by the institutional ethics committee (No. GMCH/IEC/789R/2022/217 dated 09.12.2022)

Methodology

A detailed history and clinical examination were performed on all the patients. Complete demographical and clinical parameters including age, gender, smoking history, environmental/occupational exposure and drug exposure, duration and severity of breathlessness (mMRC grade), clubbing and extra pulmonary features were recorded.

HRCT Thorax was done in patients who had scan images >3 months old and where the disease was suspected to have progressed. CT was done in supine position using 64 slice MDCT Philips ingenuity machine from apex to the base of lung with slice thickness of 1mm, 120 KvP and axial section was taken in lung window. Pulmonary involvement due to ILD was quantified by the HRCT using Warrick Score [19]. Warrick score is composed of two parts: disease severity score (based on 5 types of elementary lesions) and disease extension score (based on number of segments involved). The total score is derived by adding the 2 scores. The total score ranges from 0 to 30.

Subsequently all patients underwent spirometry, six-minute Walk test and ultrasound study of diaphragm.

Spirometry and exercise capacity

Spirometry was done on spirometer (make RMS Helios 401 machine) as per the latest American Thoracic Society Guidelines [20]. Functional vital capacity (FVC), Forced expiratory volume in 1st second (FEV_1) & FEV_1/FVC ratio were calculated.

The exercise capacity was assessed using Six-minute Walk test (6MWT). The test was performed on 30 meters walk scale according to standard criteria [21]. Total distance covered in 6 minutes, number of halts and heart rate, peripheral oxygen saturation (before and after the test) were measured.

Transthoracic ultrasonography

Transthoracic ultrasonography (TUS) was performed by a single trained radiologist who had >25 years of experience in the field. The results of lung function assessment and exercise capacity were not known to him. The examination was conducted on a portable system make Mindray, Model M5 with subjects in a semi-recumbent position. For diaphragmatic mobility evaluation, a convex transducer (2–5 MHz) was placed over the right anterior subcostal region between the midclavicular and anterior axillary lines. The transducer was directed medially, cephalad and dorsally, so that the US beam reached perpendicularly to the posterior third of the right diaphragm. After obtaining the best view on two-dimensional mode, the mobility was measured through the M-mode, from the amplitude of cranio-caudal diaphragmatic excursion during quiet breathing (QB) and deep breathing (DB). To record the ultrasound at DB, all subjects were asked to perform a maximum inspiratory effort (maximum inspiratory capacity manoeuvre) for at least 2s, to attain a maximal lung volume close to the total lung capacity (TLC).

For diaphragmatic thickness evaluation, a linear transducer (6–13 MHz) was placed longitudinally parallel to the long axis of the body over the zone of apposition of the diaphragm to the rib cage, typically between the eighth and tenth intercostal space midway between the right anterior and medial axillary lines. Using the two-dimensional mode, the diaphragm was observed as a structure composed of a non-echogenic central bordered by two hyperechogenic (peritoneal and pleural) layers [22,23]. Diaphragmatic thickness was measured from the deepest pleural line to the deepest peritoneal line. First, we measured the thickness during QB at FRC (Tmin) and then, after a maximal DB, at TLC (Tmax). Then, diaphragm's thickening fraction (TF) was calculated as $TF = [(Tmax - Tmin)/Tmin] \times 100$.

At least three measurements of the diaphragm excursion and thickness were taken for all subjects and the average of the individual values were reported. Dyspnea grade, lung function variables (FVC & FEV1), 6MWD and Warrick score were correlated with ultrasound findings, diaphragmatic excursion (during QB and DB) and thickening (at FRC & TLC) using appropriate statistical tests.

Statistical analysis

Quantitative data was summarized as median (interquartile range) and categorical variables were presented as n (%). Comparison of quantitative and categorical variables were done using student Mann-Whitney test and Chi square test/Fischer exact test, respectively. Spearman correlation coefficient was used to find correlation between diaphragmatic USG parameters and mMRC dyspnea, lung functions variables, 6MWD and Warrick score. Multiple logistic regression analysis was performed using forward LR approach and odds ratio (OR) (with 95% confidence interval) was calculated to find association between different variables and thickening fraction on diaphragmatic USG. All statistical tests were two-sided with $p<0.05$ taken as statistically significant. All statistical calculations were done using computer program SPSS (IBM SPSS Statistics 21.0; Armonk, NY, USA).

Results

A total of 55 patients were enrolled. The median age of the patients was 59(46-68) years with equal male to female ratio (M=27). 10 (18%) patients had history of diabetes and 11 (20%) were ever smokers. The median duration of symptoms was 24 months (4-60 months). Cough and breathlessness were the predominant symptoms seen in 80% of the patients. Approx two-third of the patients (n=36) patients had mMRC dyspnoea grade of $\geq$2. Among the extra-pulmonary symptoms, joint pain was the most common, seen in 10 patients.

Types of ILD

Idiopathic pulmonary fibrosis (n=15) was the most common ILD seen in the study cohort followed by CTD-ILD (n=14), hypersensitivity pneumonitis and idiopathic Non-specific interstitial pneumonia (NSIP) (8 each) (Figure 1). On HRCT, definite Usual interstitial pneumonia (UIP) pattern was seen in 30 patients whereas 19 were inconsistent for UIP pattern (Table 1).

Assessment of ILD severity

All patients had arterial oxygen saturation of $\geq$ 90% (mean 96.8$\pm$1.5) on room air. In the lung functions, the median FVC% and FEV_1% of the patients was 60 (48-74) & 68 (53-90). Forty-four patients had FVC <80% predicted.

Out of 55, 52 patients completed 6MWT. The median 6-minute walk distance (6MWD) was 360 (245-400) mts. 33 patients showed a significant drop in oxygen saturation after the test. The median Warrick score of the patients was 18 (14-22). 33 & 21 patients had Warrick score in severe and moderate grade respectively (Figure 2).

Ultrasound parameters and their association with markers of ILD severity

The median diaphragmatic excursion during tidal breathing and deep breathing were 1.94 (1.58-2.5) & 3.9 (3.15-4.7) cm respectively. The diaphragmatic thickness at FRC and TLC were 0.18 (0.15-0.20) & 0.28 (0.21-0.39) mm. The median thickening fraction was 55% (32-97). Out of 55, 44 patients had TF<101%

On Spearman rank correlation, diaphragmatic excursion during deep breathing and diaphragmatic thickness at TLC and thickening fraction showed statistically significant correlation with FVC%, FEV_1%, 6MWD and Warrick score. (Figure 3) Out of the 3 USG parameters, thickening fraction had the strongest corelation with all the 5 standard variables (Table 2).

Patients were divided into 2 groups based on cutoff value of 101% for defining reduced TF as per a previous study [15]. On comparison, FEV1%, FVC, mMRC dyspnea grade and Warrick score were statistically different between the 2 groups (Table 3). These variables were also evaluated in the multivariate stepwise logistic regression model with forward LR approach to find out independent predictors of reduced thickening fraction in ILD patients. Out of these, only FVC was found to independently predict thickening fraction (adjusted OR-1.08; 95% confidence interval-1.03-1.13; p=0.003)

Discussion

The present study was conducted to evaluate the role of diaphragmatic ultrasound in assessing the severity of ILD. The results showed a significant correlation between lower deep breathing (DB) diaphragmatic excursion and thickness and worse lung functions, increased dyspnoea, decreased exercise tolerance and increased extent of disease on HRCT ($p<0.05$).

The diaphragmatic thickness at FRC and TLC and excursion during QB and DB in the present study were similar to a study by Santana et al [0.20 (0.17-0.23) & 0.34 (0.26-0.45) cm] [15]. In contrast to the current study, authors in that study also calculated the diaphragmatic parameters in healthy controls and found lower values for diaphragmatic mobility (at DB) and thickening (at TLC) as compared to healthy controls. The present study did not enrol healthy controls as the study was primarily designed to evaluate the role diaphragmatic USG in assessing disease severity by comparing it with existing markers like lung functions and exercise capacity. Moreover, in the absence of standard reference values/equations and nature of USG investigation, the role of USG in diagnosing ILD seems less relevant. Nevertheless, the decreased diaphragmatic mobility and thickness in ILD patients reflect the increased load on respiratory muscles posed by fibrosed/stiff ILD lungs that decreases the diaphragm's ability to thicken and contract effectively.

In the present study, diaphragmatic excursion during DB showed a moderate positive correlation with FVC% (r=0.58; p<0.001). Similar association was also seen in the previous studies, though the strength of correlations varied widely with correlation coefficient (r) ranging from 0.31 to 0.79 [12,15,16,24,25]. This could likely be due to small sample size and heterogenous group of ILD patients enrolled in these studies. Few studies also evaluated FEV_1% and found its positive association with diaphragmatic excursion, similar to our study [11,15]. The results seem relevant as diaphragm is the principal muscle of respiration and its movement determines the volume of air moving in and out of the lungs.

Degree of breathlessness is an important patient centred clinical marker of disease severity. Previous evidence has shown that as dyspnoea severity increases in ILD, diaphragmatic dysfunction worsens [15,25]. The present study also showed that patients with severe dyspnoea (mMRC≥2) had poorer diaphragmatic excursion during DB (p=0.021) as compared to those with mMRC<2 breathlessness. On the similar lines, 6MWD also showed a mild correlation (r=0.42) with the diaphragmatic mobility during DB in the present study. The result was also similar (r=0.44) to a previous study conducted on 24 IPF patients [24]. It is pertinent to note here that in contrast to DB, diaphragmatic excursion during QB did not correlate with FVC% or 6MWD. This is likely due to the fact that deep breathing corresponds more closely with FVC manoeuvre as well as the breathing pattern seen during 6MWT than the quiet breathing. The training effect due to rapid shallow breathing (during QB) seen in ILD may also contribute to the lack of association between lung functions/6MWT and diaphragmatic mobility during QB. Lastly, this association also suggest that DB diaphragmatic excursion may be a more sensitive marker of disease severity than QB excursion, yielding a positive association in the early stage of disease. However, the study was not designed to compare the sensitivity of these ultrasound variables.

Apart from diaphragmatic excursion, Diaphragmatic thickness (DT) at TLC was another USG parameter that correlated with FVC%, 6MWD and mMRC dyspnea grade in ILD patients. Though less evaluated, it was also found to have positive correlation with FVC% in a previous study [15]. Instead of DT, thickness fraction (TF) has been more widely evaluated and accepted USG parameter. This also seems justified as TF is a dynamic measure, representing change in DT, and hence seems more useful rather than the static, one point DT. The present study showed a moderate correlation between TF and all the clinical and lung function variables studied. Considering a cut-off value of TF to be 101% [15], it was seen that patients with TF<101% had significantly lower FVC [59% (46-70)] as compared to those with TF>101% [FVC 82 (63-96); p<0.001] (Table 3). Previous studies by Santana et al [15] and Banerjee et al [16] also showed a positive correlations of TF with FVC (r= 0.68 & 0.46 respectively) and resting dyspnea (r=0.54) [15], However, a recent study on 24 IPF patients didn't yield significant association with FVC [24]. This could be due to enrolment of patients with less severity that preserved the thickening fraction.

The effect of ILD on diaphragmatic parameters is multifactorial in nature. On one hand, increase respiratory overwork posed by stiff lungs tends to increase diaphragmatic thickness/

strength as well as mobility due to the training effect [13]. On the other hand, increase oxidative and inflammatory stress seen in ILD patients coupled by inactivity, malnutrition and steroid use tend to accentuate the diaphragmatic weakness and atrophy [26,27]. The net effect of these opposing forces determines the strength of association between diaphragmatic parameters and different clinical and investigational variables. Notably, effect of steroid use was not evident in our study as majority of non-IPF patients (n= 31) were treatment naïve and remaining (n=9) were on a low dose of prednisolone (<15mg/day).

Besides the functional parameters, association of USG parameters with anatomical extent of ILD (expressed as Warrick score) was also explored in the study. Warrick's score showed significant correlation with all the 3 USG parameters described above, though the strength of association was weaker as compared to the functional parameters (Table 2). These findings suggest that individuals with severe pulmonary fibrosis (lower Warrick scores) tend to have impaired diaphragmatic function. To the best of our knowledge, Warrick score has not been evaluated in comparison to USG parameters previously. In contrast, a study by Banerjee et all evaluated HRCT fibrosis score and found a negative correlation with the DB diaphragmatic excursion (r=-0.425, p=0.006) [16]. To validate the effects of anatomical distribution of ILD on diaphragmatic parameters, we performed a subgroup analysis and compared USG variables between patients with and without HRCT UIP pattern. The results showed that diaphragmatic excursion during DB ($p<0.004$), diaphragmatic thickness at TLC ($p<0.05$) and thickening fraction ($p<0.004$) were lesser in patients with UIP pattern as compared to those without definite UIP pattern.

The present study showed that diaphragmatic parameters- excursion during DB and thickness at TLC and thickening fraction correlate significantly with different functional (dyspnea grade, FVC and FEV_1, 6MWD) and radiological variables (Warrick score). It was also seen that even after adjusting for the UIP pattern, the association between DE and dyspnea (r=-0.35; p=0.009), FVC (r=0.42; p=0.001) and 6MWD (r=0.36; p=0.008) still remained significant. Positive correlations with multiple standard severity markers validate the utility of diaphragmatic ultrasound in assessing ILD severity. Also, these positive associations suggest that lower diaphragmatic excursion and thickening fraction values might also predict response to pulmonary rehabilitation (PR) in ILD patients. Previous studies have shown the role of diaphragmatic ultrasound in predicting response to PR in COPD patients [28,29]. However, a longitudinal study is required in ILD patients to validate the hypothesis.

Despite valuable insights, few limitations must be acknowledged. First, the sample size of 55 patients was relatively small and drawn from a specific geographical area. The relatively small sample size may limit the statistical power of the study and restrict the generalizability of the findings to broader ILD populations. Future studies with larger and more diverse sample population from multicentre cohorts and ensuring adequate representation of individual ILDs could enhance the robustness and applicability of the results. Due to the cross-sectional nature of the study, temporal changes between ultrasound parameters and disease progression could not be studied. Longitudinal studies are recommended in future to evaluate changes in the diaphragmatic parameters over time as well as to assess their predictive value for different clinical outcomes. Thirdly, the study didn't include controls, as a result of which, normal cut-off values of various diaphragmatic parameters were not available for comparison. However, the study was not designed to diagnose diaphragmatic dysfunction on USG but to evaluate association between USG variables and different clinical and radiological markers of disease severity. Nevertheless, future studies should include a healthy control group to enhance the interpretability and clinical utility of diaphragmatic ultrasound parameters. Establishing normative values for diaphragmatic excursion and thickness would allow for better differentiation between normal and pathological states, thereby strengthening the diagnostic and prognostic relevance of the findings.

Conclusions

The present study validates the beneficial role of diaphragmatic ultrasound in assessing the disease severity in ILD patients. It seems to be a valuable tool that can supplement clinical monitoring, lung functions and HRCT thorax in assessing the ILD severity. The results also suggest that this imaging modality can also be used for serial monitoring of disease progression as well as assessment of treatment response. Future research should aim to address the limitations by employing large, more diverse samples, with longitudinal designs and enhanced measurement tools that may help to validate the utility of diaphragmatic ultrasound over time and across different patient populations, ultimately supporting its integration into routine clinical practice.

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Table 1. High-resolution computed tomography patterns seen in different interstitial lung disease types.

	HRCT Pattern	IPF	HP	CT-ILD	Idiopathic NSIP	Sarcoidosis	Cystic ILD	IPAF	CPFE	RB ILD	Total
1	Definite UIP	15	4	7		2		1	1		30
2	Probable UIP			3				2			5
3	Indeterminate UIP			1							1
4	Inconsistent with UIP		4	3	8	1	2			1	19

UIP, usual interstitial pneumonia; HRCT, high-resolution computed tomography.

Table 2. Correlation between ultrasound parameters and lung functions, 6-minute walk distance, modified Medical Research Council dyspnea grade, and Warrick score.

	Diaphragmatic parameter	FVC%		FEV_1%		6MWD		mMRC dyspnea		Warrick score	
		r*	p	r	p	r	p	r	p	r	p
1	Diaphragmatic excursion at quiet breathing	0.14	0.39	0.07	0.65	0.13	0.16	0.12	0.37	-0.006	0.96
2	Diaphragmatic excursion at deep breathing	**0.58**	**<0.001**	**0.52**	**<0.001**	**0.42**	**0.001**	**-0.45**	**<0.001**	**-0.29**	**0.03**
3	Diaphragmatic thickness at FRC	0.09	0.49	0.07	0.59	0.21	0.13	0.06	0.67	-0.14	0.29
4	Diaphragmatic thickness at TLC	**0.48**	**<0.001**	**0.46**	**<0.001**	**0.43**	**0.006**	**-0.22**	**0.11**	**-0.34**	**0.03**
5	Thickening fraction	**0.60**	**<0.001**	**0.58**	**<0.001**	**0.55**	**0.01**	**-0.37**	**0.005**	**-0.37**	**0.006**

***Spearman rank correlation**; FVC%, forced vital capacity; FEV1%, forced expiratory volume in 1st second; 6MWD, 6-minute walk distance; mMRC, modified Medical Research Council.

Table 3. Distribution of various clinical and investigational parameters between patients with thickening fraction <101 and >101%.

	Parameters	TF<101% (n=44)	TF>101% (n=11)	P value
1	Age (years)	58.5 (47.7-67.5)	62 (46-72)	0.95
2	Females	23 (52.3%)	5 (45.5%)	0.74
3	FVC%	59 (46-70)	82 (63-96)	**<0.001**
4	FEV_1%	63 (52-76)	90 (77-116)	**0.001**
5	6MWD (mts)	340 (240-390)	394 (340-420)	0.21
6	Pre SaO_2	97 (96-98)	97 (96-98)	0.61
7	Post SaO_2	91(87-96)	96 (85-97)	0.45
8	dyspnoea mMRC$\geq$2	33 (75%)	3 (27.3%)	**0.005**
9	Warrick score	19(15-22)	15 (13-19)	**0.045**
10	Warrick severity	10(6-11)	9(6-10)	0.21
11	Warrick extent	9.5(8-11)	7(5-9)	**0.008**

Values are shown as median (IQR) or n(%). TF, thickening fraction; FVC%, forced vital capacity; FEV1%, forced expiratory volume in 1st second; 6MWD, 6-minuite walk distance; mMRC, modified Medical Research Council; SaO_2, arterial oxygen saturation

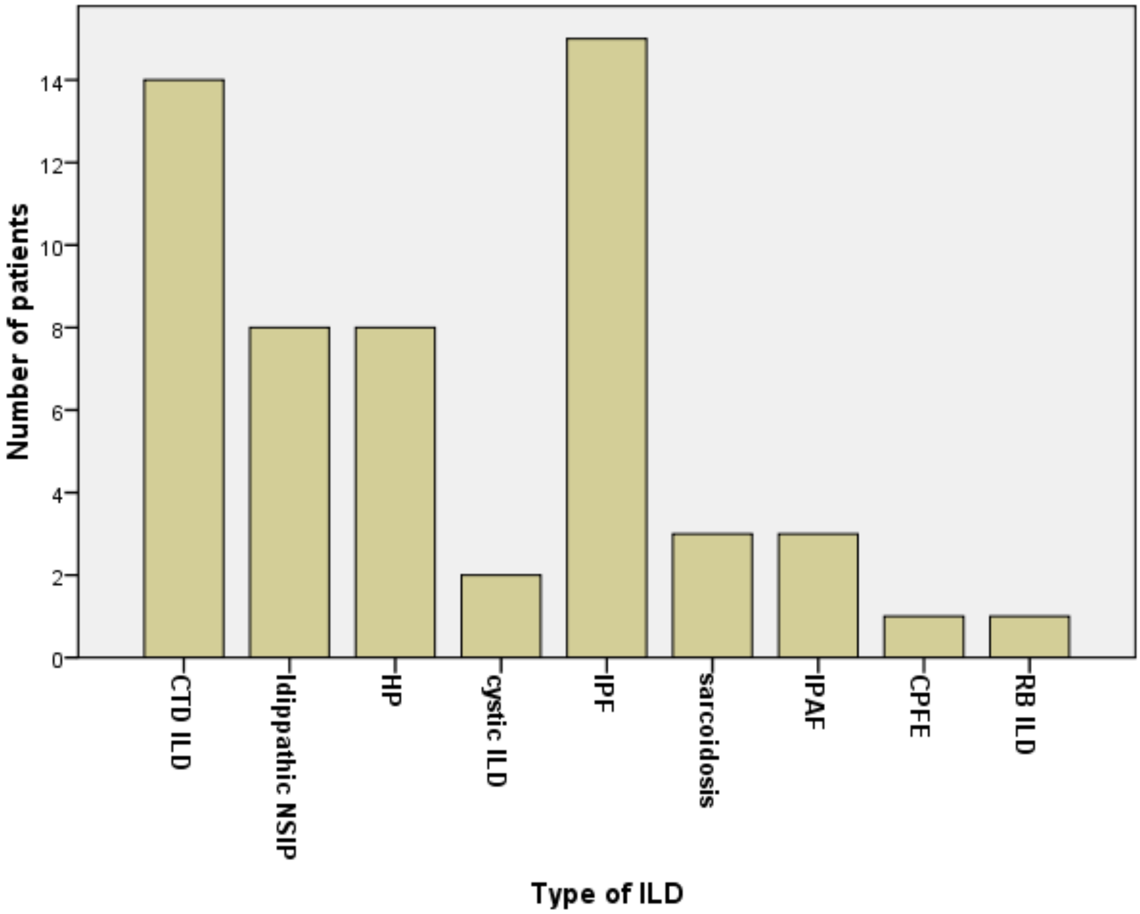

Figure 1. Bar graph showing the frequency of different types of interstitial lung disease. IPF, idiopathic pulmonary fibrosis; CTD-ILD, connective tissue disease-ILD; HP, hypersensitivity pneumonitis; IPAF, interstitial pneumonia with autoimmune features; CPFE, combined pulmonary fibrosis and emphysema; RB-ILD, respiratory bronchiolitis-interstitial lung disease.

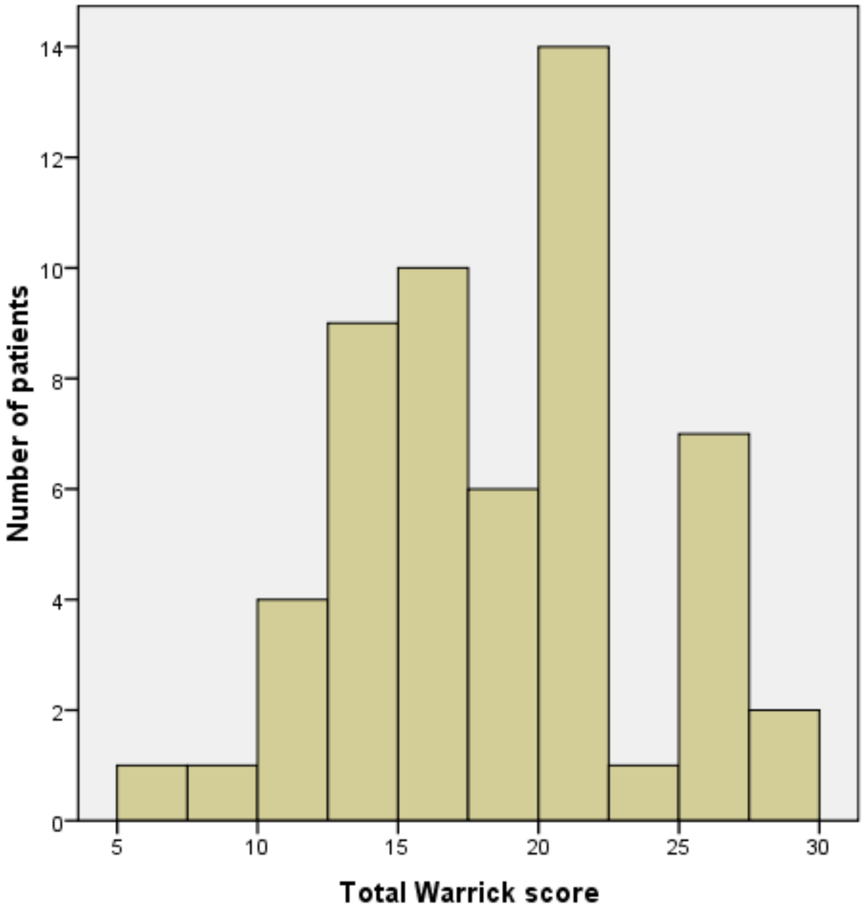

Figure 2. Histogram showing distribution of the Warrick score among interstitial lung disease patients.

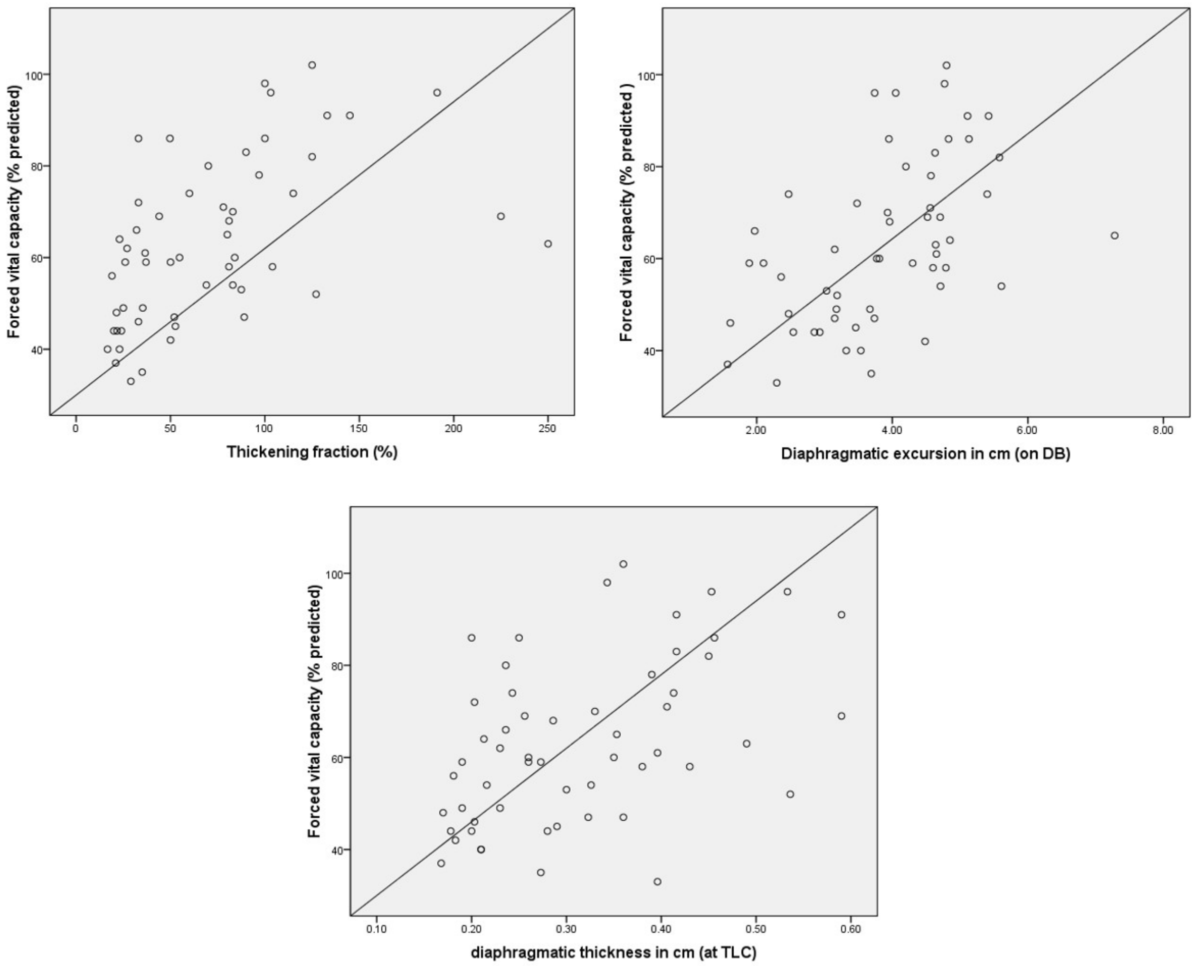

Figure 3. Scatter plot showing correlation between forced vital capacity and different diaphragmatic ultrasound parameters.