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Diffusion lung capacity for carbon monoxide correlates with HRCT findings in patients with diffuse parenchymal lung disease

Ezzelregal G. Hieba[1*], Eldiasty E. Shaimaa[2], Sheha S. Dina[3] and Ahmed O. Noha[1]

Abstract: Diffusion lung capacity for carbon monoxide correlates with HRCT findings in patients with diffuse parenchymal lung disease.

Background: Diffuse parenchymal lung diseases (DPLDs) affect the alveolar epithelium, pulmonary capillary endothelium, basement membrane, and perivascular and perilymphatic tissues. High-resolution computed tomography (HRCT) of the chest is the gold standard modality for diagnosing DPLD. Pulmonary function tests usually show a restrictive defect in spirometry. Single breath diffusion lung capacity for carbon monoxide (DLCO-SB) technique is used to assess the diffuse parenchymal lung diseases, as there is thickening of the alveolar membrane and diminished total lung capacity due to interstitial processes with severe decline in the transfer factor. The aim of this work was to correlate between Warrick's HRCT fibrosis score and DLCO-SB in DPLD and to assess the possibility of using DLCO as an only tool to follow up DPLD to avoid repeated radiation exposure of the patients in HRCT chest (decrease need for radiological follow-up) or vice versa.

Results: This work recruited 89 patients over a period of 10 months duration, 74.2% of them were females. The Warrick's score, ground-glass opacity, irregular pleural margin, subpleural cyst, honeycombing, and septal and subpleural lines were represented as 96.6%, 70.8%, 55.1%, 49.4%, and 48.3% respectively in HRCT of DPLD. Warrick's score and its subscores (severity score, extent score, alveolitis score, and fibrosis score) were associated with a highly significant decrease in different pulmonary function indices (FVC, FEV[1], TLC, and DLCO) with P value 0.001. A highly significant correlation between DLCO grades and total score grades was found with P value 0.001, and 86.8% of the patients with severe DLCO affection showed severe degree of total fibrosis score.

Conclusions: Both DLCO-SB and HRCT fibrosis scores were significantly correlated. Lifelong follow-up of function and structure of the lung in DPLD is needed by HRCT and DLCO. In an attempt to minimize repeated radiation exposure and reduce cost, we suggest DLCO to be used alone for longer follow-up periods rather than HRCT chest.

Keywords: Fibrosis score, DLCO, HRCT, DPLD

* Correspondence: drhebaezz111213@gmail.com
[1]Lectureres of Chest Diseases, Chest Department, Ain Shams University, Cairo, Egypt
Full list of author information is available at the end of the article

Background

Diffuse parenchymal lung diseases (DPLDs) affect the alveolar epithelium, pulmonary capillary endothelium, basement membrane, and perivascular and perilymphatic tissues. Compromising a heterogeneous group of diseases, it occurs when an abnormal healing response was induced by injury to the lungs [1, 2].

Investigations are aiming to reach the etiology of DPLD. The most important part of the workup of patients with DPLD is a detailed and proper history taking to identify the possible etiology including occupational or drug exposures, for signs of conditions like connective tissue and autoimmune diseases, sarcoidosis, and infection [3].

HRCT of the chest is the gold standard modality for diagnosis of DPLD. It provides 10 times more resolution than the conventional, as it reveals details that cannot otherwise be visualized [4]. The most common CT patterns of fibrotic interstitial lung disease (ILD) are ground-glass opacities, reticulations, traction bronchiectasis, and honeycombing. Those patterns have specific and broadly agreed definitions [5].

Pulmonary function tests usually show a restrictive defect in spirometry. DLCO-SB technique is used to assess the DPLD, as there is a thickening of the alveolar membrane and a diminished total lung capacity (TLC) due to interstitial processes [6].

Semi-quantitative scoring methods help to provide a more precise assessment of quantity and type of ILD abnormalities in HRCT chest. Using semi-quantitative scoring systems on HRCT has been shown consistently to be significantly and inversely correlated with forced vital capacity (FVC %), TLC, and DLCO predicted [7, 8]. One scoring system that has been used in several studies was developed and published by Warrick et al. [7].

In terms of assessing disease progression, it was found that patients with more severe fibrosis at baseline (or higher fibrosis scores) had a greater mean of decline in FVC and DLCO compared to groups with no or moderate fibrosis [9].

A clinico-radiological physiological scoring system is used to follow up patients with interstitial pulmonary fibrosis [10]. However, intending to reduce the frequency of performing HRCT during follow-up of patients with DPLD, we aimed to correlate between Warrick's HRCT fibrosis score and DLCO-SB in DPLD, to assess the possibility of using DLCO alone as a tool for follow-up of DPLD patients to minimize the radiation exposure of the patients in HRCT chest (decrease need for radiological follow-up) or vice versa.

Methods

This prospective cross-sectional study recruited 89 patients having DPLD attending the Outpatient Clinics and Inpatient Departments of Pulmonology, Immunology, and Rheumatology at Ain Shams University Hospitals in the period from June 2019 to March 2020 as shown in Fig. 1.
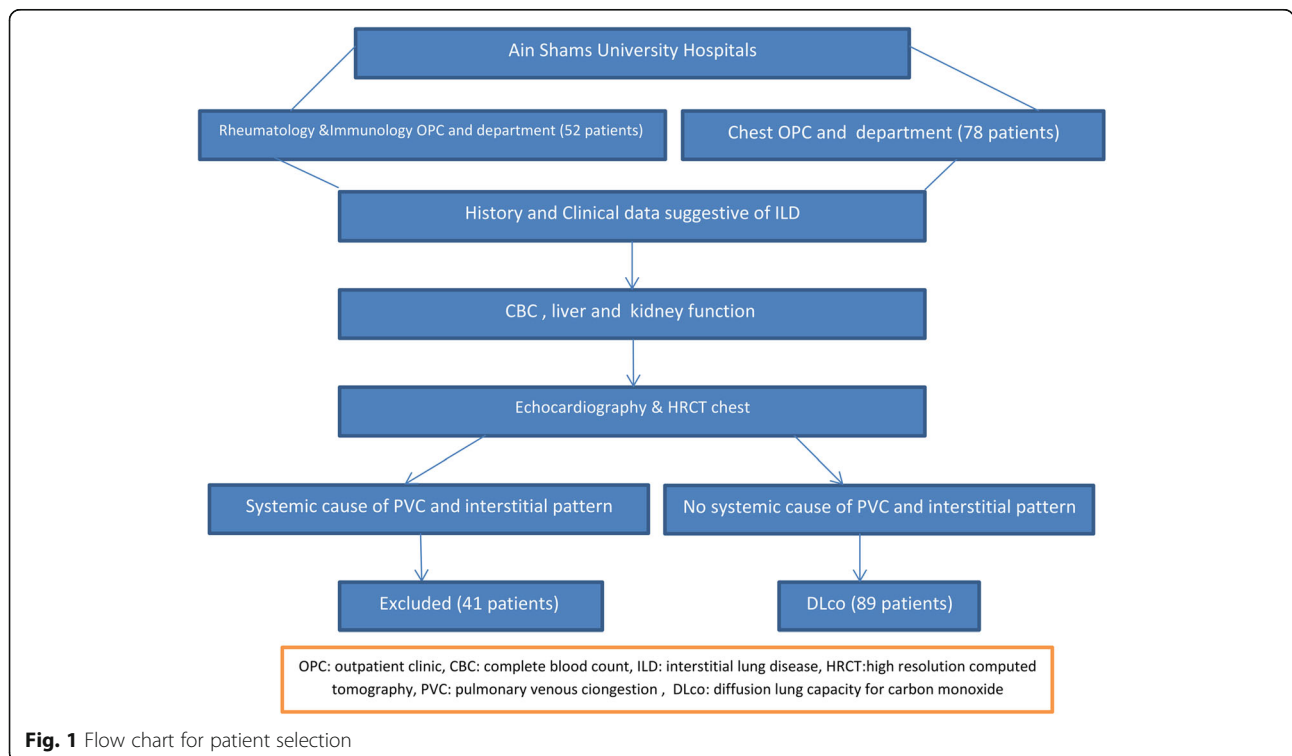

Fig. 1 Flow chart for patient selection

Inclusion criteria

Patients older than 18 years old with DPLD either newly or previously diagnosed clinically dry dyspnea, dry cough and any other symptoms related to the etiology, and radiologically by HRCT Chest with different patterns without any of the exclusion criteria.

Exclusion criteria

Exclusion criteria were patients with comorbid cardiac, renal, or hepatic affection that may cause pulmonary venous congestion, patients with pulmonary or extrapulmonary malignancy, patients receiving radiotherapy and/or chemotherapy and/or biological therapy, patients with vanishing lung syndrome, and those refusing to participate in the study.

A written informed consent was taken from all patients prior to enrollment, and all patients were subjected to the following:

1- *History taking* for occupational, environmental exposures, autoimmune diseases, family history, and any relevant pulmonary or systemic symptoms.
2- *Laboratory investigations*: CBC, liver, kidney function, and collagen markers if not with the patient.
3- Echocardiography: To exclude heart as a cause of interstitial affection.
4- *Spirometry and DLCO-SB*: Performed according to the standard practice previously discussed in details [11, 12] using Viasys Healthcare Diffusion with built-in spirometer, D-97204 Hochberg, Germany. The spirometry indices recorded were forced expiratory volume in first second (FEV_1), forced vital capacity (*FVC*), and FEV_1/FVC *ratio*. Also, *DLCO-SB %* (best/predicted) was recorded after correction with the patient hemoglobin. By an online calculator available at https://www.uptodate.com/contents/calculator-diffusing-capacity-for-carbon-monoxide-dlco-correction-of-predicted-value-for-anemia-conventional-units.
5- HRCT chest: The study was done in the CT unit at Ain Shams University Hospitals by General Electric Bright Speed Elite 16 slices CT device, USA. Ethical approval was obtained to use the data stored on (PACS) picture archiving and communication system.

Method of HRCT examination

Thin sections were acquired with an interval of 1-2 cm between the two sets of images and were considered sufficient to detect abnormalities in diffuse lung diseases.

Fundamental technical protocols are as follows:

- Slice thickness: 0.625-1.25 mm
- Scan time: 0.5-1 s
- kV: 120
- mAs: 100-200
- Collimation: 1.5-3 mm
- Matrix size: 768 × 768 or the largest available
- FOV: 35 cm
- Reconstruction algorithm: high spatial frequency
- Window: lung window (window level, −700 HU; window width, 1500 HU)
- Patient position: supine (routinely), from lung apices to the bases.
- Level of inspiration: full inspiration (routinely recommended).

Estimation of the *total Warrick's score* 30 points maximum with extent score and severity score as previously described by Warrick et al. [7] (Table 1).

Total score was expressed as follows:

a. *Normal*: zero point "no normal cases were involved in this work"
b. *Mild*: less than 8 points
c. *Moderate*: from 8 to 15 points.
d. *Severe*: more than 15 points.

Also, two more scores were added

a. *Alveolitis score* (ground-glass opacity (GGO) plus its severity score)
b. *Fibrosis score* (CT abnormalities other than GGOsplus its severity score)

Ethical consideration

The study was approved by the Ethical Committee Board of Ain Shams University and was carried out in accordance with the Declaration of Helsinki.

Statistical data analysis

Data was analyzed using computer program SPSS (Statistical Package for the Social Science; SPSS Inc., Chicago, IL, USA) release 15 for Microsoft Window (2006). Qualitative variables were presented as percentage and quantitative variables were presented as mean ± SD. Student's *t* test and Pearson's correlation coefficient were used as the test of significance; *P* value less than 0.05 was considered as significant.

Results

This was a prospective study that recruited 89 patients presenting with DPLD, 74.2% of them were females; their mean age was 49.98 ± 12.56 years, range from 23 to 75 years old. Nine percent of the patients were farmers, and 15.7% were smokers. DPLD of unknown cause was found in 24.7% of patients (Tables 2)

Table 1 Warrick's total score and its subscores

Severity score		Extent score	
Abnormality	Grading	Number of each pulmonary segment involved	Grading
Ground glass	1	1 to 3 segments	1
Irregular pleural margin	2	4 to 9 segments	2
Septal or subpleural lines	3	> 9 segments	3
Honeycombing	4	N.B: extent of the disease measured for each abnormality	
Subpleural cyst	5		
Maximal score	15	Maximal score	15

Quoted from Warrick J et al. 1991 [7]

spiorometric and DLCO Parameters of the studied population were shown (Table 3).

As regards Warrick's score, the total score mean ± SD was 17.38 ± 5.90 ranging from 7 to 29. Alveolitis score and fibrosis score were 2.99 ± 1.07 and 14.40 ± 5.32 respectively. Severity score and extent score were 8.63 ± 3.75 and 8.63 ± 3.08 respectively. GGO, irregular pleural margin, subpleural cyst, honeycombing, and septal and subpleural lines were found in 96.6%, 70.8%, 55.1%, 49.4%, 48.3% of the patients respectively (Table 4).

Warrick's score and its subscores (severity score, extent score, alveolitis score, and fibrosis score) were associated with a highly significant decrease in different pulmonary function indices (FVC, FEV1, TLC, and DLCO-SB). No significant correlation was found between FEV1/FVC ratio and Warrick's scores (Table 5).

The current study showed a significant decrease in FVC in patients with honeycombing in HRCT compared to patients without honeycombing (59.33 ± 19.59 versus 68.51 ± 21.01) with P value 0.036. Also, a highly significant decrease in FVC was noted in patients with subpleural cyst than those without (57.4 ± 21.78 versus 72.02 ± 16.27) with P value 0.001 (Table 6). A highly significant decrease in FEV1 was noticed in patients with

Table 2 Demographics and associated risk factors or etiology of ILD among the studied population

	Total no. = 89
Age	
Mean ± SD	49.98 ± 12.56
Range	23-75
Sex	
Female	66 (74.2%)
Male	23 (25.8%)
Comorbidities	
DM	31.5%
HTN	43.8%
Hypothyroid	4.5%
Associated risk factor or etiology	
Idiopathic	22 (24.7%)
Smoking	14 (15.7%)
Scleroderma	6 (6.7%)
Methotrexate	3 (3.4%)
Bird breeder	9 (10.1%)
Rheumatoid arthritis	16 (17.9%)
Systemic lupus	5 (5.6%)
Farmer	8 (9.0%)
Asbestos	5 (5.6%)
Sarcoidosis	1 (1.1%)
Collagen markers	
Negative	60 (67.4%)
Positive	29 (32.6%)

DM diabetes mellitus, HTN hypertension

Table 3 Spirometry and diffusion parameters among the studied population

Spirometry and DLCO-SB	Total no. = 89
FVC	
Mean ± SD	63.97 ± 20.73
Range	24.7-112
FEV$_1$	
Mean ± SD	61.93 ± 16.97
Range	26.8-98
FEV$_1$/FVC	
Mean ± SD	79.32 ± 6.17
Range	56-88
TLC	
Mean ± SD	66.91 ± 13.54
Range	42.8-98
DLCO-SB %	
Mean ± SD	44.13 ± 18.50
Range	11.8-79

FVC forced vital capacity, FEV$_1$ forced expiratory volume in the first second, TLC total lung capacity, DLCO-SB diffusion lung capacity for carbon monoxide single breath

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Table 4 Warrick's score and its characteristics among the studied population

Characteristics of Warrick's score	Total no. = 89
GGO	
Absent	3 (3.4%)
Present	86 (96.6%)
Irregular pleural margin	
Absent	26 (29.2%)
Present	63 (70.8%)
Septal, subpleural lines	
Absent	46 (51.7%)
Present	43 (48.3%)
Honeycombing	
Absent	45 (50.6%)
Present	44 (49.4%)
Subpleural cyst	
Absent	40 (44.9%)
Present	49 (55.1%)
Severity score	
Mean ± SD	8.63 ± 3.75
Range	1-15
Warrick extent score	
Mean ± SD	8.63 ± 3.08
Range	3-15
Alveolitis score	
Mean ± SD	2.99 ± 1.07
Range	0-4
Fibrosis score	
Mean ± SD	14.40 ± 5.32
Range	4-25
Total score	
Mean ± SD	17.38 ± 5.90
Range	7-29

GGO ground-glass opacity

Table 6 Correlation between forced vital capacity and Warrick's score indices

	FVC		Test value	P value	Sig.
	Mean ± SD	Range			
GGO					
Absent	77.33 ± 3.79	73-80	1.138[a]	0.258	NS
Present	63.51 ± 20.92	24.7-112			
Irregular pleural margin					
Absent	69.15 ± 22.84	24.7-112	1.525[a]	0.131	NS
Present	61.84 ± 19.58	26-100			
Septal, subpleural lines					
Absent	68 ± 21.7	26-100	1.926[a]	0.057	NS
Present	59.66 ± 18.94	24.7-112			
Honeycombing					
Absent	68.51 ± 21.01	26-112	2.131[a]	0.036	S
Present	59.33 ± 19.59	24.7-100			
Subpleural cyst					
Absent	72.02 ± 16.27	34.4-100	3.517[a]	0.001	HS
Present	57.4 ± 21.78	24.7-112			

GGO ground glass opacity, *FVC* forced vital capacity, *P* value > 0.05: non-significant; *P* value < 0.05: significant; *P* value < 0.01: highly significant
[a]Independent *t* test

subpleural cyst than those without (55.69 ± 15.9 versus 69.57 ± 15.16 (with *P* value 0.001 (Table 7).

This study showed a highly significant correlation between different DLCO-SB degrees of affection and total Warrick's score degrees with *P* value 0.001. Most patients (86.8% from 38 patients) with severe degree of diffusion defect showed severe degree of total Warrick's score (Table 8).

Patients with GGO in HRCT showed a significant decrease in DLCO-SB than patients without GGO in HRCT chest (43.3 ± 18.17 versus 68 ± 12.12) with *P* value 0.022. Also, a highly significant decrease in DLCO-SB was noted in patients with subpleural cyst and honeycombing with *P* value 0.001 and 0.002 respectively (Table 9).

The validity of DLCO-SB for the prediction of GGO was assessed, and the area under the receiver operating

Table 5 Correlation between Warrick's score and different pulmonary function indices among the studied population

	FVC		FEV$_1$		FEV$_1$/FVC		TLC		DLCO-SB%	
	R	P value	R	P value	R	P value	R	P value	R	P value
Severity score	−0.471	0.001	−0.460	0.001	−0.009	0.932	−0.391	0.001	−0.575	0.001
Extent score	−0.502	0.001	−0.524	0.001	−0.050	0.644	−0.451	0.001	−0.619	0.001
Alveolitis score	−0.632	0.001	−0.555	0.001	−0.037	0.728	−0.639	0.001	−0.890	0.001
Fibrosis score	−0.532	0.001	−0.538	0.001	−0.025	0.819	−0.428	0.001	−0.618	0.001
Total score	−0.581	0.001	−0.570	0.001	−0.022	0.836	−0.496	0.001	−0.713	0.001

FVC forced vital capacity, *FEV$_1$* forced expiratory volume in the first second, *TLC* total lung capacity, *DLCO-SB* diffusion lung capacity for carbon monoxide single breath

Table 7 Correlation between forced expiratory volume in the first second and Warrick's score indices

HRCT findings	FEV₁		Test value	P value	Sig.
	Mean ± SD	Range			
GGO					
Absent	73.67 ± 2.52	71-76	1.222[a]	0.225	NS
Present	61.52 ± 17.11	26.8-98			
Irregular pleural margin					
Absent	65.26 ± 17.83	30-98	1.193[a]	0.236	NS
Present	60.55 ± 16.55	26.8-91.9			
Septal, subpleural lines					
Absent	64.15 ± 18.37	26.8-98	1.283[a]	0.203	NS
Present	59.55 ± 15.17	34-89			
Honeycombing					
Absent	64.74 ± 16.45	26.8-89	1.594[a]	0.115	NS
Present	59.05 ± 17.2	30-98			
Subpleural cyst					
Absent	69.57 ± 15.16	34-98	4.184[a]	0.001	HS
Present	55.69 ± 15.9	26.8-88			

GGO ground glass opacity, *FEV₁* forced expiratory volume in the first second, *P* value > 0.05: non-significant; *P* value < 0.05: significant; *P* value < 0.01: highly significant
[a] Independent *t* test

Table 9 Correlation between DLCO-SB and Warrick's score indices

HRCT findings	DLCO-SB		Test value	P value	Sig.
	Mean ± SD	Range			
GGO					
Absent	68 ± 12.12	55-79	2.330[a]	0.022	S
Present	43.3 ± 18.17	11.8-76			
Irregular pleural margin					
Absent	49.15 ± 18.49	12-79	1.659[a]	0.101	NS
Present	42.06 ± 18.25	11.8-76			
Septal, subpleural lines					
Absent	47.4 ± 18.57	11.8-76	1.741[a]	0.085	NS
Present	40.64 ± 17.99	12-79			
Honeycombing					
Absent	50.12 ± 17.11	11.8-79	3.253[a]	0.002	HS
Present	38.01 ± 18.03	12-70			
Subpleural cyst					
Absent	52.73 ± 13.82	23-76	4.345[a]	0.001	HS
Present	37.11 ± 18.99	11.8-79			

DLCO-SB diffusion lung capacity for carbon monoxide single breath, *GGO* ground-glass opacity, *P* value > 0.05: non-significant; *P* value < 0.05: significant; *P* value < 0.01: highly significant
[a]Independent *t* test

characteristic (ROC) curve was 0.870. A value of ≤ 54.2 diffusion defect was statistically proposed as a cutoff value to predict presence of GGO (Fig. 2). Also, regarding the validity of DLCO-SB for the prediction of honeycombing in HRCT chest, the area under ROC curve was 0.685. A value of ≤ 43 diffusion defects was statistically proposed as a cutoff value to predict the presence of honeycombing (Fig. 3).

Discussion

HRCT of the chest is the gold standard modality for the diagnosis of DPLD [4]. The most common CT patterns of fibrotic ILD are GGO, reticulations, tractions bronchiectasis, and honeycombing [5]. Pulmonary function tests

Table 8 Correlation between degree of diffusion lung capacity for carbon monoxide and degree of total Warrick's score

	DLCO-SB			Test value	P value	Sig.
	Mild	Moderate	Severe			
	No. = 24	No. = 27	No. = 38			
Warrick's total score						
Mild	1 (4.2%)	1 (3.7%)	0 (0.0%)	30.343	0.001	HS
Moderate	19 (79.2%)	12 (44.4%)	5 (13.2%)			
Severe	4 (16.7%)	14 (51.9%)	33 (86.8%)			

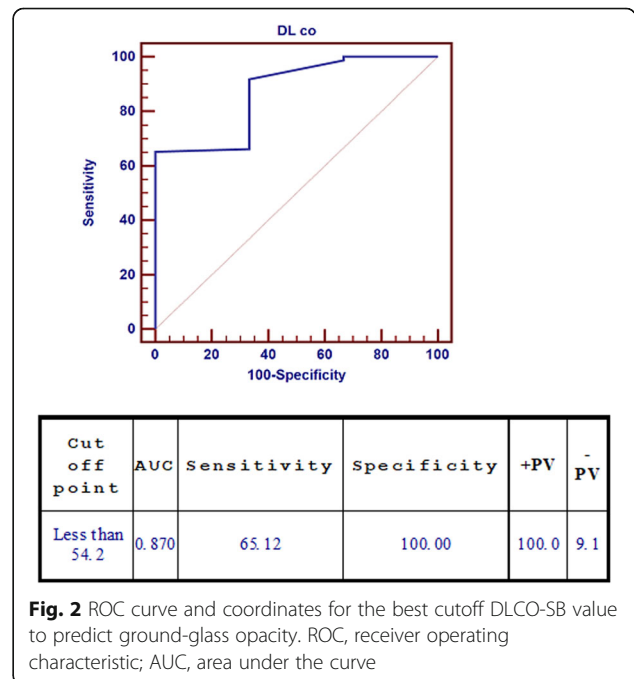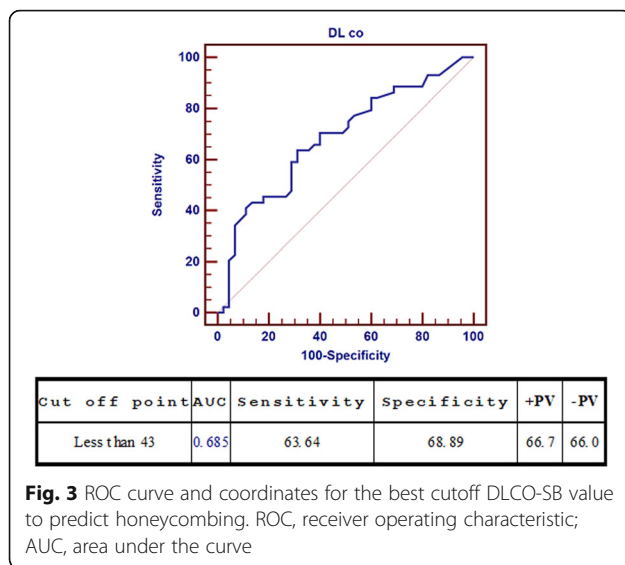*DLCO-SB* diffusion lung capacity for carbon monoxide single breath, *HS* highly significant

Fig. 2 ROC curve and coordinates for the best cutoff DLCO-SB value to predict ground-glass opacity. ROC, receiver operating characteristic; AUC, area under the curve

Fig. 3 ROC curve and coordinates for the best cutoff DLCO-SB value to predict honeycombing. ROC, receiver operating characteristic; AUC, area under the curve

Cut off point	AUC	Sensitivity	Specificity	+PV	-PV
Less than 43	0.685	63.64	68.89	66.7	66.0

usually show a restrictive defect in spirometry. As there is thickening of the alveolar membrane, DLCO-SB is also diminished [6].

This study aimed to evaluate the extent of DPLD using a semi-quantitative Warrick's HRCT score to determine the disease severity and its possible correlation with PFT including spirometry and DLCO-SB. They have been the only parameters considered to date to follow up cases with DPLD aiming to replace one of them by the other either to decrease cost or decrease radiation exposure.

This prospective study recruited 89 patients diagnosed with DPLD, 74.2% of them were females; their mean age was 49.98 ± 12.56 years. The age group was matched with the results of Abou Youssuf H. et al.; however, the official ATS/ERS/JRS/ALAT guidelines 2011 stated that IPF occurs in the sixth and seventh decades [13, 14]. The higher incidence of DPLD in the female population in the studied group was consistent with Abou Youssuf et al. and Rifaat et al. who found out that the majority of the studied population were females [13, 15]. Additionally, it was in agreement with Hassan who studied the comparison of FVC, FVC/DLCO, and TLC/DLCO as an indicator for interstitial lung disease in patients with scleroderma [16].

DPLD was idiopathic in 24.7% of the cases. The observations of Kundu S et al. were similar; they concluded that unknown etiology was the most common cause of DPLD representing 38.04% [17]. This was in contrast with A Kheliouen. et al. who found that sarcoidosis was the most common disease, followed by ILD associated with connective tissue diseases. The discrepancy might be due to lack of open lung biopsy in the study population [18].

DPLD as one of the restrictive lung diseases affecting the alveolar-capillary membrane is associated with lower

FVC% and DLCO-SB especially in severe degrees as shown by this work and others [13, 19]. A recent study was not totally in agreement with this work results in this issue, which might be related to the difference in the number of patients recruited and the variability in the characteristics of the studied populations [20].

FEV_1, FEV_1/FVC, and the TLC changes were consistent with Riad N et al. during their assessment of ILD with DLCO-SB and spirometry [21].

In the current study, Warrick's score and its subscores (severity score, extent score, alveolitis score, and fibrosis score) were associated with a highly significant decrease in different pulmonary function indices (FVC, FEV_1, TLC, and DLCO-SB). Previous studies showed the same results considering fibrosis score as interstitial score [22, 23].

Similar to the previous published data [24–27], we demonstrated that Warrick's semi-quantitative score was able to determine the severity of DPLD correlated well with FVC, TLC, and DLCO.

In other words, the current study aimed to investigate the comparative value of DLCO-SB and HRCT in diagnosing DPLD, and showed a highly significant correlation between different DLCO-SB degrees of diffusion defects and total Warrick's score degrees. These findings are consistent with Khanna et al. who found that most of the patients with severe fibrosis in HRCT were with severe diffusion defect [9].

Decline in spirometric indices and DLCO-SB were associated significantly with the different radiological patterns of CT chest. FVC was significantly decreased in patients with honeycombing and subpleural cyst in HRCT. Highly significant decrease in FEV_1 was noted in patients with subpleural cyst. Also, this work demonstrated a highly significant decrease in DLCO-SB in patients with subpleural cyst and honeycombing and a significant decrease in DLCO-SB in patients with GGO.

These data are in accordance with Hussein et al. who found that FVC and DLCO-SB were significantly lower in fibrotic DPLD [28]. Also, Araki et al. who studied the effect of pulmonary cysts on DLCO-SB supported this work result [29]. Many other related studies went hand in hand with the current study results [30–32].

These significant correlations encouraged us to determine the cutoff values between DLCO-SB and the two extremes of HRCT structural changes of the lung, GGO, and honeycombing, to predict the value of DLCO-SB associated with these changes. A value of ≤ 54.2 diffusion defect was statistically proposed as a cutoff value to predict the presence of ground-glass opacity "alveolitis score" with better area under the ROC curve 0.870. Also, the validity of DLCO-SB for prediction of honeycombing in HRCT chest was assessed, the area under ROC curve was 0.685. A value of ≤ 43 diffusion defect was statistically proposed as a cutoff value to predict presence of

honeycombing. So first baseline HRCT in patients with DPLD to determine the pattern and extent of radiological affection could be enough then follow up with DLCO-SB and less frequently with HRCT to limit radiation exposure and decrease the cost.

This study had some limitations; the small number of studied population and the shorter duration of the work with no follow-up data. HRCT other scores may be needed to correlate with the functional assessment of the lung on a larger number of patients. Longer follow-up periods are recommended to validate this study's results and estimate the percentage of change of DLCO-SB with each HRCT radiological pattern and with each type of ILD.

Conclusion
Structural changes in the lung can be detected by HRCT chest, and functional changes can be assessed by spirometry and more precisely by DLCO-SB; in this work, both were significantly correlated. Since DPLD patients need lifelong follow-up, assessment of function and structure of the lung by HRCT chest and DLCO-SB at the first visit, with subsequent follow-up of lung function mainly by DLCO-SB to decrease follow-up times with HRCT appeared to be satisfactory with less cost and minimizing repeated radiation exposure.

Abbreviations
FVC: Forced vital capacity; FEV$_1$: Forced expiratory volume in the first second; TLC: Total lung capacity; DLCO-SB: Diffusion lung capacity for carbon monoxide single breath; GGO: Ground-glass opacity; FEV$_1$/FVC: Ratio between forced expiratory volume in the first second and forced vital capacity; HRCT chest: High-resolution CT chest; DPLD: Diffuse parenchymal lung disease; ILD: Interstitial lung disease

Authors' contributions
HG put the design of the study and made major contributions to data acquisition and analysis, interpreted the data, and revised it. SE shared with CT interpretation, data interpretation, and extensively revised the work. DS shared in patient recruitment and extensively revised and edited the manuscript. NO helped in data analysis and revised it and was a major contributor in writing the manuscript. All authors have read and approved the final manuscript.

Availability of data and materials
The data sets used during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate
The study was approved by the Ethical Committee Board of Ain Shams University and in accordance with the Declaration of Helsinki (FWA: 00017585).
A written informed consent was taken from all enrolled patients; all patient were adults.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

Author details
^{1}Lectureres of Chest Diseases, Chest Department, Ain Shams University, Cairo, Egypt. ^{2}Lecturer of Radiology, Radiology Department, Ain Shams University, Cairo, Egypt. ^{3}Associate Professor of Allergy and Immunology, Internal Medicine Department, Ain Shams University, Cairo, Egypt.

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