

Role of High-Resolution CT in Characterizing Interstitial Lung Diseases and Correlation with Pulmonary Function Tests

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Abstract

Background: Interstitial lung diseases (ILDs) comprise a heterogeneous group of pulmonary disorders characterized by varying degrees of inflammation and fibrosis of the lung parenchyma. High-resolution computed tomography (HRCT) plays an important role in the diagnosis and characterization of ILD by demonstrating characteristic morphological patterns and distribution of lung abnormalities. Pulmonary function tests (PFTs), particularly forced vital capacity (FVC) and diffusing capacity for carbon monoxide (DLCO), provide an objective assessment of functional impairment. Correlation of HRCT findings with PFT parameters may help in assessing disease severity.

Aim: To evaluate the role of high-resolution computed tomography in characterizing interstitial lung diseases

and to correlate HRCT findings with pulmonary function test parameters.

Methods: A prospective observational study was conducted among 50 patients with clinically suspected or diagnosed interstitial lung disease. All eligible patients underwent HRCT of the chest and pulmonary function testing. HRCT images were evaluated for the type and distribution of interstitial abnormalities, including reticulation, ground-glass opacity, honeycombing, traction bronchiectasis, architectural distortion and other associated findings. The predominant HRCT pattern was classified where possible. PFT parameters including FVC, FEV₁, FEV₁/FVC and DLCO were recorded. The relationship between the extent and pattern of HRCT abnormalities and pulmonary function parameters was analyzed statistically.

Results: The study included 29 males (58%) and 21 females (42%), with a mean age of 56.8 ± 12.4 years. Dyspnea was the most common presenting symptom,

occurring in 45 patients (90%), followed by cough in 42 patients (84%). On HRCT, reticular opacities were the most frequent finding (86%), followed by ground-glass opacities (74%), architectural distortion (68%) and traction bronchiectasis (62%). Honeycombing was observed in 48% of cases. A UIP pattern was the most common HRCT pattern (36%), followed by NSIP (20%). Pulmonary function testing demonstrated a restrictive pattern in 34 patients (68%). The mean FVC was $61.7 \pm 17.5\%$ predicted, while the mean DLCO was $54.6 \pm 18.7\%$ predicted. Increasing extent of HRCT involvement was associated with progressive reduction in pulmonary function. A strong negative correlation was observed between HRCT extent and FVC ($r = -0.72$, $p < 0.001$) and between HRCT extent and DLCO ($r = -0.76$, $p < 0.001$). Patients with honeycombing and traction bronchiectasis had significantly lower FVC and DLCO compared with patients without these findings ($p < 0.001$).

Conclusion: HRCT is an important imaging modality for characterizing the pattern, distribution and extent of interstitial lung disease. In this study, increasing radiological involvement, honeycombing and traction bronchiectasis were associated with greater pulmonary functional impairment. Significant correlations between HRCT extent and FVC and DLCO indicate that HRCT findings can provide valuable information regarding disease severity. Combined assessment with HRCT and PFTs provides a more comprehensive evaluation of patients with ILD than either modality alone.

Keywords: Interstitial Lung Disease, HRCT, Pulmonary Function Tests, FVC, DLCO, UIP, NSIP, Pulmonary Fibrosis, HRCT–PFT Correlation.

Introduction

Interstitial lung diseases (ILDs) comprise a large and heterogeneous group of diffuse parenchymal lung disorders characterized by varying degrees of inflammation, alveolar epithelial injury, interstitial fibrosis, and distortion of the normal pulmonary architecture. These disorders include diseases of known and unknown etiology and may be associated with connective tissue diseases, occupational and environmental exposures, drugs, hypersensitivity reactions, infections, and other systemic conditions. A substantial proportion of patients have no identifiable cause and are classified under idiopathic interstitial pneumonias. The clinical course of ILD is highly variable, ranging from slowly progressive disease to rapidly progressive pulmonary fibrosis and respiratory failure^{1,2}. The diagnosis of ILD is often challenging because the clinical manifestations are nonspecific. Progressive exertional dyspnea and chronic cough are the most common presenting symptoms, while physical examination may reveal fine end-inspiratory crackles, particularly in patients with fibrotic disease. Conventional chest radiography may demonstrate bilateral reticular, reticulonodular, or alveolar opacities; however, it has limited sensitivity and specificity, particularly in early disease. Therefore, high-resolution computed tomography (HRCT) has become an essential investigation in the evaluation of patients with suspected ILD^{3,4}.

The diagnosis and classification of ILD require integration of clinical, radiological, physiological, serological, and, when necessary, histopathological information. The international multidisciplinary classification of idiopathic interstitial pneumonias recognizes several distinct radiological and pathological

patterns, including usual interstitial pneumonia (UIP), nonspecific interstitial pneumonia (NSIP), organizing pneumonia, respiratory bronchiolitis-associated interstitial lung disease, desquamative interstitial pneumonia, and acute interstitial pneumonia^{1,5}. Accurate identification of these patterns is important because the diagnosis, prognosis, treatment, and follow-up may differ considerably between individual forms of ILD.

High-resolution computed tomography has revolutionized the evaluation of diffuse parenchymal lung diseases. HRCT provides thin-section images with high spatial resolution and allows detailed assessment of the secondary pulmonary lobule, interlobular septa, intralobular structures, airways, alveolar spaces, and pulmonary architecture. It is considerably more sensitive than conventional chest radiography for detecting early interstitial abnormalities and subtle fibrotic changes⁶.

The major HRCT findings encountered in ILD include ground-glass opacity, reticulation, interlobular septal thickening, intralobular lines, traction bronchiectasis, architectural distortion, honeycombing, nodules, consolidation, and mosaic attenuation. Interpretation of these findings requires assessment of their morphology, distribution, and extent. The distribution of abnormalities with respect to the upper or lower lobes, central or peripheral regions, subpleural areas, and peribronchovascular regions provides important diagnostic information.^{6,7}

Standardized terminology is particularly important in the interpretation of HRCT findings. The Fleischner Society has established standardized definitions for terms such as ground-glass opacity, reticulation, honeycombing, traction bronchiectasis, and architectural distortion. Consistent terminology improves communication between radiologists and clinicians and helps ensure

uniform classification of diffuse lung diseases^{6,7}. One of the most important applications of HRCT is the recognition of a UIP pattern. A typical UIP pattern is characterized by predominantly basal and subpleural reticulation, associated with architectural distortion and honeycombing. Traction bronchiectasis may also be prominent. In contrast, extensive ground-glass opacity, marked upper-lobe predominance, peribronchovascular predominance, or other atypical features may suggest an alternative diagnosis^{8,9}.

HRCT plays a particularly important role in the diagnosis of idiopathic pulmonary fibrosis (IPF). Current international guidelines classify HRCT appearances into categories such as UIP, probable UIP, indeterminate for UIP, and patterns suggestive of an alternative diagnosis. Recognition of these patterns can increase diagnostic confidence and, in appropriate clinical circumstances, may reduce the need for invasive lung biopsy^{2,8}. Fibrotic abnormalities such as reticulation, traction bronchiectasis, and honeycombing are important indicators of established pulmonary fibrosis. Honeycombing represents clustered, usually subpleural cystic air spaces, whereas traction bronchiectasis results from irreversible dilatation of the airways due to surrounding fibrotic retraction. The presence and extent of these abnormalities can provide valuable information regarding the severity of fibrotic lung disease^{6,8}.

HRCT patterns of interstitial lung disease

Different forms of ILD demonstrate characteristic patterns on HRCT. In UIP, abnormalities generally show a basal and subpleural predominance with reticulation, architectural distortion, traction bronchiectasis, and honeycombing. NSIP is more commonly characterized by bilateral symmetrical ground-glass opacity with fine

reticulation and lower-lung predominance, sometimes with relative subpleural sparing^{1,8}.

Hypersensitivity pneumonitis may demonstrate ground-glass opacity, mosaic attenuation, air trapping, centrilobular nodules, and variable degrees of fibrosis. Organizing pneumonia frequently presents with patchy areas of consolidation in a peripheral or peribronchovascular distribution. Other forms of ILD may demonstrate distinctive combinations of ground-glass opacity, cysts, nodules, septal thickening, and fibrosis^{1,5}.

Thus, HRCT provides information not only regarding the presence of interstitial disease but also regarding its **morphological pattern, anatomical distribution, and extent of involvement**. This makes HRCT an important non-invasive tool for characterization and assessment of ILD.

Pulmonary Function Tests In Interstitial Lung Disease

While HRCT provides structural information, pulmonary function tests provide an objective assessment of the physiological consequences of ILD. PFTs are therefore an important complementary investigation in the diagnosis and follow-up of patients with interstitial lung disease.

The typical physiological abnormality in fibrotic ILD is a restrictive ventilatory defect, characterized by reduction in lung volumes. Forced vital capacity (FVC) is one of the most commonly used parameters for assessing the severity and progression of ILD. Forced expiratory volume in one second (FEV₁) may also be reduced; however, the FEV₁/FVC ratio is generally preserved or increased in pure restrictive disease¹⁰.

Spirometry is a simple, non-invasive and reproducible method of assessing pulmonary function. Proper standardization of spirometric technique is essential to ensure accurate measurements. The American Thoracic

Society and European Respiratory Society have provided standardized recommendations for the performance and interpretation of spirometry¹⁰. In addition to spirometry, measurement of the diffusing capacity of the lung for carbon monoxide (DLCO) provides important information regarding gas transfer across the alveolar-capillary membrane. In ILD, fibrosis and thickening of the alveolar-capillary interface, destruction of pulmonary capillary beds, and reduced effective gas exchange surface area can result in decreased DLCO. Therefore, DLCO may provide an important indicator of disease severity^{11,12}. FVC and DLCO are widely used for assessment and monitoring of patients with ILD. A reduction in FVC indicates impaired lung volumes, while reduction in DLCO reflects impaired gas transfer. Serial changes in these parameters can provide useful information regarding disease progression and response to treatment^{2,11}.

Correlation Between HRCT and Pulmonary Function Tests

HRCT and PFTs provide complementary information in patients with ILD. HRCT demonstrates the structural characteristics, distribution, and extent of lung involvement, whereas PFTs quantify the functional consequences of the structural abnormalities.

Several studies have demonstrated significant relationships between the extent of HRCT abnormalities and pulmonary function parameters. Xaubet et al. demonstrated significant correlations between the extent of disease on HRCT and pulmonary function parameters, including FVC and DLCO, in patients with idiopathic pulmonary fibrosis¹³.

Studies involving patients with idiopathic interstitial pneumonias have similarly demonstrated significant correlations between HRCT disease extent and

physiological abnormalities. Greater radiological involvement has generally been associated with lower FVC and DLCO, indicating that increasing structural damage is accompanied by increasing functional impairment¹⁴.

Specific HRCT features may also be associated with the severity of pulmonary dysfunction. Fibrotic changes such as honeycombing, traction bronchiectasis, and extensive reticulation may be associated with greater reductions in lung volumes and diffusion capacity. Recent studies have demonstrated relationships between CT features and PFT parameters in patients with fibrotic interstitial lung diseases¹⁵. However, the relationship between radiological and physiological abnormalities is not always linear. Factors such as emphysema, pulmonary hypertension, obesity, respiratory muscle weakness, and coexisting airway disease may influence pulmonary function independently of the extent of interstitial abnormalities. Therefore, HRCT and PFTs should be considered complementary investigations rather than substitutes for one another.

Clinical significance of HRCT–PFT correlation

Assessment of disease severity is an important component of ILD management. HRCT can identify the extent of structural abnormalities and provide information regarding the predominant disease pattern, while PFTs provide quantitative measures of functional impairment. The presence and extent of reticulation, ground-glass opacity, traction bronchiectasis, architectural distortion, and honeycombing can provide valuable information regarding disease severity. In particular, extensive fibrosis and honeycombing are generally associated with more advanced structural disease^{8,9}. Conversely, significant reductions in FVC and DLCO may indicate clinically important physiological impairment and can

help identify patients requiring closer follow-up. The combined assessment of imaging and pulmonary function may therefore provide a more comprehensive assessment than either method alone.

Serial HRCT and PFT assessment can also be useful during follow-up. Changes in FVC and DLCO provide objective evidence of physiological progression, whereas HRCT can demonstrate progression of fibrosis, development of new abnormalities, or increasing extent of pre-existing disease. Current approaches to progressive pulmonary fibrosis emphasize integration of symptoms, pulmonary physiology, and radiological findings when determining disease progression.²

Although HRCT and PFTs are individually well established in the evaluation of ILD, the relationship between specific radiological findings and physiological impairment may vary according to the underlying ILD pattern and the extent of disease. There is therefore a need to evaluate whether the extent and morphological characteristics of ILD on HRCT correlate with measurable changes in FVC, FEV₁, FEV₁/FVC, and DLCO. Establishing such a relationship may improve understanding of the clinical significance of radiological findings and may help clinicians interpret the severity of structural disease in terms of functional impairment. The present study was undertaken to evaluate the role of high-resolution computed tomography in characterizing interstitial lung diseases and to correlate HRCT findings with pulmonary function tests. The study assesses the various HRCT patterns and their distribution and examines their relationship with pulmonary function parameters in patients with ILD. An integrated assessment using HRCT and PFTs may therefore provide a more comprehensive evaluation of patients with interstitial lung disease, assist in determining disease

severity, and contribute to improved clinical assessment and follow-up.

Materials And Methods

Study Design

A **prospective observational study** was conducted to evaluate the role of HRCT in characterizing interstitial lung diseases (ILDs) and to correlate HRCT findings with pulmonary function tests (PFTs).

Study Setting and Duration

The study was conducted in the Departments of General Medicine and Radiodiagnosis for a period of 18 months.

Study Population

A total of 50 adult patients with clinical or radiological suspicion of ILD were included by consecutive sampling.

Inclusion Criteria

- Age ≥ 18 years.
- Patients clinically suspected or diagnosed with ILD.
- Patients willing to undergo HRCT and PFT.
- Written informed consent obtained.

Exclusion Criteria

- Patients unable to undergo HRCT or reliable PFT.
- Significant coexisting cardiac, neuromuscular or airway disease affecting PFT interpretation.
- Acute respiratory infection at the time of testing.
- Patients unwilling to participate.

Study Procedure

Detailed history and clinical examination were performed. HRCT chest was done to assess the pattern, distribution and extent of interstitial abnormalities, including reticulation, ground-glass opacity, traction bronchiectasis, architectural distortion and honeycombing.

HRCT patterns were categorized as UIP, probable UIP, NSIP, hypersensitivity pneumonitis, organizing pneumonia, or other/indeterminate patterns.

Pulmonary function testing was performed using standardized spirometry. FVC, FEV₁, FEV₁/FVC and DLCO were recorded where available.

HRCT Extent

Lung involvement was categorized as:

- Mild: <25%
- Moderate: 25–50%
- Severe: >50%

Statistical Analysis

Data were expressed as mean $\pm$ SD and frequency/percentage. Correlation between HRCT extent and PFT parameters was assessed using Pearson/Spearman correlation, as appropriate. Chi-square/Fisher's exact test and appropriate comparative tests were used for group comparisons. A p-value <0.05 was considered statistically significant.

Results

A total of 50 patients with clinically suspected/interstitial lung disease who fulfilled the inclusion criteria were included in the study. All patients underwent HRCT chest and pulmonary function testing. The HRCT findings were analyzed and correlated with PFT parameters.

Table 1: Age distribution of study participants (n=50)

Age group (years)	Number of cases	Percentage
20–30	3	6%
31–40	5	10%
41–50	9	18%
51–60	15	30%
61–70	13	26%
>70	5	10%
Total	50	100%

Mean age: 56.8 ± 12.4 years.

The study included 50 patients. The majority of patients belonged to the 51–60 years age group (30%), followed by the 61–70 years age group (26%). Patients aged 41–50

years constituted 18%, while 31–40 years accounted for 10%. The youngest age group, 20–30 years, represented 6% of cases, and 10% of patients were above 70 years. The mean age of the study population was 56.8 ± 12.4 years, indicating that ILD was predominantly observed among middle-aged and elderly patients.

Table 2: Sex distribution

Sex	Number of cases	Percentage
Male	29	58%
Female	21	42%
Total	50	100%

Among the 50 patients, 29 (58%) were males and 21 (42%) were females, giving a male-to-female ratio of approximately 1.38:1. Thus, there was a slight male predominance in the study population.

Table 3: Presenting clinical symptoms

Symptom	Number of cases	Percentage
Dyspnea	45	90%
Cough	42	84%
Fatigue	27	54%
Chest discomfort	12	24%
Fever	8	16%
Weight loss	7	14%
Hemoptysis	2	4%

Multiple symptoms could be present in the same patient. Dyspnea was the most common presenting symptom, reported in 45 patients (90%), followed by cough in 42 patients (84%). Fatigue was present in 27 patients (54%). Chest discomfort was reported in 12 patients (24%), while fever and weight loss were present in 16% and 14% respectively. Hemoptysis was uncommon, occurring in only 2 patients (4%). Since patients could have more than one symptom, the percentages do not add up to 100%.

Table 4: Duration of symptoms

Duration	Number of cases	Percentage
<6 months	14	28%
6–12 months	18	36%
1–2 years	11	22%
>2 years	7	14%
Total	50	100%

The majority of patients, 18 (36%), had symptoms for 6–12 months. Fourteen patients (28%) had symptoms for less than 6 months, while 11 (22%) had symptoms for 1–2 years. Seven patients (14%) reported symptoms for more than 2 years. Thus, most patients presented with a symptom duration of less than 1 year.

HRCT Findings

Table 5: Major HRCT findings in the study population

HRCT finding	Number of cases	Percentage
Reticular opacities	43	86%
Ground-glass opacities	37	74%
Traction bronchiectasis	31	62%
Honeycombing	24	48%
Interlobular septal thickening	21	42%
Architectural distortion	34	68%
Volume loss	28	56%
Nodules	9	18%
Mosaic attenuation/air trapping	11	22%
Consolidation	6	12%

Multiple HRCT findings could be present in individual patients.

The most frequent HRCT abnormality was reticular opacity, observed in 43 patients (86%). Ground-glass opacity was present in 37 patients (74%), while architectural distortion and traction bronchiectasis were

seen in 34 (68%) and 31 (62%) patients, respectively. Honeycombing was identified in 24 patients (48%). Interlobular septal thickening and volume loss were observed in 42% and 56% respectively. Nodules, mosaic attenuation/air trapping and consolidation were less frequent. These findings demonstrate the varied morphological manifestations of ILD on HRCT.

Table 6: Distribution of HRCT abnormalities

Distribution	Number of cases	Percentage
Bilateral involvement	47	94%
Unilateral involvement	3	6%
Peripheral/subpleural predominance	38	76%
Basal predominance	35	70%
Upper-lobe predominance	8	16%
Peribronchovascular predominance	12	24%

Bilateral lung involvement was observed in 47 patients (94%), indicating that ILD was predominantly bilateral. A peripheral/subpleural distribution was present in 38 patients (76%), while basal predominance was seen in 35 patients (70%). Upper-lobe predominance was relatively uncommon, occurring in 16% of cases. Peribronchovascular predominance was observed in 24% of patients. Overall, bilateral, peripheral and basal involvement was the predominant distribution pattern.

Table 7: HRCT pattern of interstitial lung disease

HRCT pattern	Number of cases	Percentage
UIP pattern	18	36%
Probable UIP	7	14%
NSIP pattern	10	20%
Hypersensitivity pneumonitis pattern	6	12%

Organizing pneumonia pattern	3	6%
Lymphoid interstitial pneumonia pattern	2	4%
Other/indeterminate pattern	4	8%
Total	50	100%

The UIP pattern was the most common HRCT pattern, identified in 18 patients (36%), followed by NSIP in 10 patients (20%). Probable UIP was seen in 7 patients (14%), while hypersensitivity pneumonitis accounted for 12%. Organizing pneumonia and LIP were less frequent. Four patients (8%) had other or indeterminate patterns. Thus, fibrotic patterns, particularly UIP/probable UIP, constituted a substantial proportion of cases.

Pulmonary Function Test Results

Table 8: Spirometric pattern

PFT pattern	Number of cases	Percentage
Restrictive pattern	34	68%
Obstructive pattern	4	8%
Mixed pattern	5	10%
Normal	7	14%
Total	50	100%

A restrictive ventilatory defect was the predominant PFT abnormality, observed in 34 patients (68%). Five patients (10%) demonstrated a mixed pattern, while an obstructive pattern was observed in 4 patients (8%). Seven patients (14%) had normal spirometry. The predominance of restrictive physiology is consistent with the expected functional impairment associated with interstitial lung disease.

Table 9: Distribution according to FVC (% predicted)

FVC (% predicted)	Number of cases	Percentage
≥80%	7	14%
70–79%	9	18%

60–69%	13	26%
50–59%	12	24%
<50%	9	18%
Total	50	100%

Mean FVC: $61.7 \pm 17.5\%$ predicted.

FVC was $\geq 80\%$ predicted in only 7 patients (14%). The largest group consisted of patients with FVC between 60–69% predicted (26%), followed by 50–59% (24%). Eighteen percent had FVC below 50% predicted. The mean FVC was $61.7 \pm 17.5\%$ predicted, indicating that a substantial proportion of patients had clinically significant reduction in lung volume.

Table 10: FEV₁ (% predicted)

FEV ₁ (% predicted)	Number of cases	Percentage
$\geq 80\%$	11	22%
70–79%	10	20%
60–69%	12	24%
50–59%	10	20%
<50%	7	14%
Total	50	100%

Mean FEV₁: $67.2 \pm 18.1\%$ predicted.

FEV₁ was $\geq 80\%$ predicted in 11 patients (22%). Twenty percent had FEV₁ between 70–79%, while 24% had values between 60–69%. FEV₁ was below 50% predicted in 14% of patients. The mean FEV₁ was $67.2 \pm 18.1\%$ predicted. The reduction in FEV₁ in many patients was compatible with the restrictive pattern observed on spirometry.

Table 11: FEV₁/FVC ratio

FEV ₁ /FVC	Number of cases	Percentage
$\geq 80\%$	34	68%
70–79%	10	20%
<70%	6	12%
Total	50	100%

A preserved FEV₁/FVC ratio of $\geq 80\%$ was observed in 34 patients (68%). Ten patients (20%) had a ratio of 70–79%, while 6 patients (12%) had a ratio below 70%. The relatively preserved ratio in most patients supports the predominance of a restrictive rather than obstructive ventilatory abnormality.

Table 12: DLCO (% predicted)

DLCO (% predicted)	Number of cases	Percentage
$\geq 80\%$	6	12%
60–79%	14	28%
40–59%	18	36%
<40%	12	24%
Total	50	100%

Mean DLCO: $54.6 \pm 18.7\%$ predicted.

DLCO was $\geq 80\%$ predicted in only 6 patients (12%). The largest proportion, 18 patients (36%), had DLCO between 40–59% predicted, while 12 patients (24%) had DLCO below 40%. The mean DLCO was $54.6 \pm 18.7\%$ predicted, demonstrating significant impairment of gas transfer in a considerable proportion of patients.

HRCT Severity and PFT Correlation

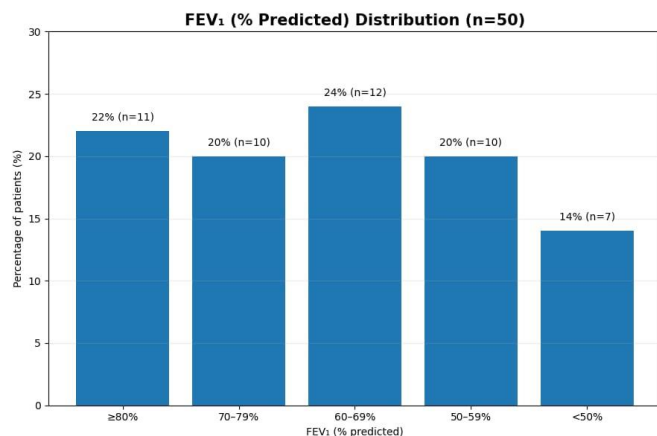
Table 13: HRCT extent of lung involvement and FVC

HRCT extent of involvement	No. of cases	Mean FVC (% predicted)
Mild (<25%)	11	78.4 ± 8.6
Moderate (25–50%)	20	63.1 ± 10.2
Severe (>50%)	19	48.2 ± 11.4
Total	50	61.7 ± 17.5

There was a progressive reduction in mean FVC with increasing extent of HRCT involvement.

Patients were categorized according to the extent of lung involvement on HRCT. Those with mild involvement (<25%) had the highest mean FVC of 78.4%, whereas patients with moderate involvement had a mean FVC of 63.1%. Patients with severe involvement (>50%) had the

lowest mean FVC of 48.2%. This shows a progressive decline in pulmonary function with increasing radiological extent of disease.



Graph 1: FEV representation

Table 14: HRCT pattern and mean PFT parameters

HRCT pattern	No.	Mean FVC (%)	Mean FEV ₁ (%)	Mean DLCO (%)
UIP	18	51.8	57.9	43.6
Probable UIP	7	59.7	64.2	50.8
NSIP	10	68.9	73.4	61.2
Hypersensitivity pneumonitis	6	65.1	69.3	58.7
Organizing pneumonia	3	72.4	75.8	65.3
LIP	2	70.2	73.1	62.5
Other/indeterminate	4	60.5	65.7	52.1

Patients with a UIP pattern demonstrated the greatest functional impairment, with mean FVC of 51.8% and mean DLCO of 43.6% predicted. Patients with organizing pneumonia and NSIP showed comparatively better pulmonary function. Overall, the table demonstrates variation in pulmonary function according to the underlying HRCT pattern, with more fibrotic patterns showing greater functional impairment.

Table 15: Correlation between HRCT extent and PFT parameters

Parameter	Correlation coefficient (r)	p-value	Interpretation
HRCT extent vs FVC	-0.72	<0.001	Strong negative correlation
HRCT extent vs FEV ₁	-0.61	<0.001	Moderate-strong negative correlation
HRCT extent vs DLCO	-0.76	<0.001	Strong negative correlation
HRCT extent vs FEV ₁ /FVC	-0.18	0.21	Not statistically significant

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A strong negative correlation was observed between HRCT extent and FVC ($r = -0.72$, $p < 0.001$), indicating that greater radiological involvement was associated with lower FVC.

Similarly, HRCT extent showed a strong negative correlation with DLCO ($r = -0.76$, $p < 0.001$), indicating that increasing radiological disease burden was associated with worsening gas-transfer capacity.

FEV₁ also showed a significant negative correlation with HRCT extent ($r = -0.61$, $p < 0.001$). In contrast, the correlation between HRCT extent and FEV₁/FVC was weak and statistically non-significant ($r = -0.18$, $p = 0.21$).

Thus, FVC and DLCO showed the strongest relationship with the extent of ILD on HRCT.

Table 16: Presence of honeycombing and pulmonary function

HRCT finding	No. of cases	Mean FVC (%)	Mean DLCO (%)
Honeycombing present	24	49.6 ± 12.1	42.8 ± 14.3
Honeycombing absent	26	72.9 ± 13.6	65.5 ± 16.2
p-value		<0.001	<0.001

Patients with honeycombing demonstrated significantly lower FVC and DLCO compared with patients without honeycombing.

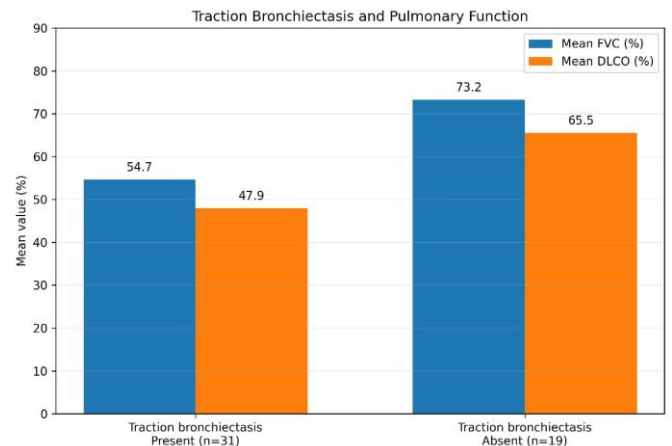
Patients with honeycombing had substantially lower pulmonary function compared with those without honeycombing. The mean FVC was 49.6% in patients with honeycombing compared with 72.9% in those without, while mean DLCO was 42.8% and 65.5%, respectively. Both differences were statistically significant ($p < 0.001$). This indicates that the presence of honeycombing was associated with more severe physiological impairment.

Table 17: Presence of traction bronchiectasis and PFT

Traction bronchiectasis	No. of cases	Mean FVC (%)	Mean DLCO (%)
Present	31	54.7 ± 14.5	47.9 ± 15.6
Absent	19	73.2 ± 14.2	65.5 ± 16.1
p-value		<0.001	<0.001

Patients with traction bronchiectasis demonstrated lower pulmonary function than patients without this finding. Mean FVC was 54.7% versus 73.2%, while mean DLCO was 47.9% versus 65.5%, respectively. Both differences were statistically significant ($p < 0.001$). Therefore, the

presence of traction bronchiectasis on HRCT was associated with greater functional impairment.



Graph 2: Presence of traction bronchiectasis and PFT

Among the 50 cases, the majority were in the 51–70-year age group, with a slight male predominance. Dyspnea and cough were the most frequent presenting symptoms. On HRCT, reticular opacities, ground-glass opacities, architectural distortion and traction bronchiectasis were the predominant findings. A UIP pattern was the most common HRCT pattern. PFT demonstrated a restrictive ventilatory defect in 68% of patients. Mean FVC was $61.7 \pm 17.5\%$ predicted, while mean DLCO was $54.6 \pm 18.7\%$ predicted.

Increasing HRCT extent of interstitial involvement was associated with progressively lower FVC and DLCO. A strong negative correlation was observed between HRCT extent and FVC ($r = -0.72$) and DLCO ($r = -0.76$), suggesting that greater radiological involvement was associated with greater physiological impairment.

Discussion

Interstitial lung diseases (ILDs) constitute a heterogeneous group of disorders characterized by varying degrees of inflammation, fibrosis and distortion of the pulmonary architecture. Accurate diagnosis and assessment of disease severity require integration of clinical findings, high-resolution computed tomography

(HRCT) and pulmonary function tests (PFTs). The present study evaluated 50 patients with suspected ILD and assessed the relationship between HRCT findings and pulmonary function parameters.

Age Distribution

In the present study, the mean age of the study population was 56.8 ± 12.4 years, with the majority of patients belonging to the 51–60 and 61–70 year age groups. This predominance of middle-aged and elderly patients is consistent with the recognized epidemiology of several fibrotic ILDs, particularly idiopathic pulmonary fibrosis (IPF), which predominantly affects older adults.^{1,2}

Raghu et al. reported that IPF is primarily a disease of older adults and is more frequently encountered in individuals above 60 years of age². The increasing prevalence of fibrotic lung disease with advancing age may reflect cumulative exposure to environmental factors, age-related epithelial injury and impaired mechanisms of pulmonary repair.¹⁶

Sex Distribution

The present study demonstrated a slight male predominance, with 58% males and 42% females. A male predominance has been described in several forms of fibrotic ILD, particularly IPF^{2,8}. Differences in occupational exposure, smoking history, environmental exposure and other demographic factors may contribute to this observation.¹⁶

However, the sex distribution varies according to the specific ILD. Connective-tissue-disease-associated ILD and certain autoimmune interstitial pneumonias may show a female predominance, whereas IPF is more frequently reported in males^{1,17}.

Clinical Presentation

Dyspnea was the most common symptom (90%), followed by cough (84%) in the present study. These

findings are consistent with the typical clinical presentation of ILD. Progressive exertional dyspnea and persistent dry cough are among the most common symptoms reported in patients with fibrotic interstitial lung disease^{1,2}.

The high frequency of dyspnea in the present study may reflect the substantial proportion of patients with moderate-to-severe radiological involvement. As fibrosis progresses, lung compliance decreases and gas exchange becomes impaired, resulting in progressive exercise limitation and breathlessness.¹⁸

HRCT Findings

HRCT demonstrated a variety of abnormalities in the present study. Reticular opacities were the most frequent finding (86%), followed by ground-glass opacity (74%), architectural distortion (68%), traction bronchiectasis (62%) and honeycombing (48%).

These findings are consistent with the recognized HRCT manifestations of ILD. Reticulation represents thickening of the interstitial structures and is commonly encountered in fibrotic interstitial lung diseases. Ground-glass opacity may represent inflammation, partial alveolar filling, interstitial thickening or early fibrosis, depending on the clinical and radiological context^{6,7}.

Traction bronchiectasis and architectural distortion are important indicators of fibrotic remodeling. Honeycombing represents advanced structural destruction and is particularly characteristic of established UIP-pattern fibrosis.^{8,19}

The relatively high prevalence of traction bronchiectasis and honeycombing in the present study suggests that a substantial proportion of patients had established fibrotic disease at the time of evaluation.

HRCT Distribution

In the present study, 94% of patients demonstrated bilateral lung involvement, while peripheral/subpleural and basal predominance were seen in 76% and 70%, respectively.

A basal and subpleural distribution is characteristic of UIP-pattern disease and is an important feature in differentiating UIP from alternative patterns [8,9]. The predominance of peripheral and basal abnormalities in the present study is therefore compatible with the relatively high frequency of UIP/probable UIP patterns.

HRCT assessment of disease distribution is important because the combination of morphology and distribution often provides greater diagnostic information than either feature alone.^{6,8}

HRCT Patterns

The UIP pattern was the most common pattern in the present study (36%), followed by NSIP (20%) and probable UIP (14%). This finding is in agreement with the importance of UIP as a major fibrotic pattern encountered in adult ILD populations.^{8,9}

Lynch et al. emphasized the importance of identifying UIP and probable UIP patterns on HRCT in the evaluation of suspected IPF⁸. The presence of basal and subpleural reticulation with architectural distortion, traction bronchiectasis and honeycombing increases confidence in a UIP diagnosis.

NSIP was the second most common pattern in our study. NSIP typically demonstrates bilateral ground-glass opacity and fine reticulation with a relatively symmetrical lower-lung distribution and may be associated with connective tissue diseases.^{1,5}

Pulmonary Function Tests

A restrictive ventilatory pattern was observed in 68% of patients in the present study. This was the predominant

physiological abnormality and is consistent with the expected functional consequences of diffuse interstitial fibrosis.

The mean FVC was $61.7 \pm 17.5\%$ predicted. Reduced FVC reflects impaired lung expansion resulting from reduced pulmonary compliance and fibrotic remodeling. FVC is widely used as an objective measure of disease severity and progression in ILD^{2,10}.

The mean FEV₁ was $67.2 \pm 18.1\%$ predicted, while the FEV₁/FVC ratio was relatively preserved in most patients. This pattern supports the predominance of restrictive rather than obstructive physiology.

DLCO Findings

The mean DLCO in the present study was $54.6 \pm 18.7\%$ predicted, with 60% of patients demonstrating DLCO below 60% predicted.

Reduction in DLCO is a common physiological abnormality in ILD and reflects impaired gas transfer caused by thickening and destruction of the alveolar-capillary interface, loss of pulmonary capillary bed and reduced effective gas exchange surface^{11,12}.

DLCO may provide important additional information regarding disease severity, particularly when spirometric abnormalities are relatively modest. Previous studies have demonstrated significant associations between reduced DLCO and the extent of fibrotic disease on CT^{13,20}.

Correlation Between HRCT Extent and FVC

A strong negative correlation was observed between HRCT extent and FVC in the present study ($r = -0.72$, $p < 0.001$). Patients with mild HRCT involvement had a mean FVC of 78.4%, whereas those with severe involvement had a mean FVC of 48.2%.

This finding indicates that increasing structural involvement of the lung is associated with progressive reduction in lung volume. Similar relationships between

radiological extent and pulmonary function have been reported in patients with idiopathic pulmonary fibrosis and other fibrotic ILDs^{13,20}.

Xaubet et al. demonstrated significant correlations between CT abnormalities and pulmonary function parameters in IPF, supporting the concept that radiological disease burden reflects physiological impairment.¹³

Correlation Between HRCT Extent and DLCO

The strongest correlation in the present study was observed between HRCT extent and DLCO ($r = -0.76$, $p < 0.001$). Patients with greater radiological involvement had substantially lower diffusion capacity.

This finding is physiologically plausible because increasing interstitial fibrosis results in greater disruption of the alveolar-capillary membrane and pulmonary vascular bed. Previous studies have similarly demonstrated a significant association between CT extent and DLCO.^{14,20,21}

The strong relationship observed in the present study supports the usefulness of DLCO as a functional marker of the severity of interstitial pulmonary involvement.

Honeycombing and Pulmonary Function

In the present study, patients with honeycombing had significantly lower mean FVC and DLCO than patients without honeycombing. Mean FVC was 49.6% versus 72.9%, while mean DLCO was 42.8% versus 65.5%, respectively, with both differences being statistically significant ($p < 0.001$).

Honeycombing is generally considered a marker of established and advanced fibrosis. Its association with reduced pulmonary function in our study is therefore consistent with the expected pathophysiology of advanced fibrotic remodeling^{8,19}.

Studies evaluating quantitative and visual CT assessment have similarly demonstrated associations between fibrotic CT abnormalities and physiological impairment.^{20,21}

Traction Bronchiectasis and Pulmonary Function

Traction bronchiectasis was present in 62% of patients in the present study. Patients with traction bronchiectasis had significantly lower FVC and DLCO compared with patients without this finding.

Mean FVC was 54.7% in patients with traction bronchiectasis compared with 73.2% in those without, while mean DLCO was 47.9% and 65.5%, respectively. Both differences were statistically significant ($p < 0.001$). Traction bronchiectasis reflects distortion and retraction of the lung architecture due to fibrosis and is therefore an important marker of established fibrotic disease^{6,19}. The findings of the present study support the use of traction bronchiectasis as a radiological marker associated with physiological impairment.

Relationship Between HRCT Pattern and PFT

Patients with a UIP pattern in the present study had lower mean FVC and DLCO compared with most other HRCT pattern groups. The mean FVC and DLCO in UIP were 51.8% and 43.6% predicted, respectively.

Fibrotic UIP is associated with progressive architectural distortion, reduced lung compliance and impaired gas transfer. Consequently, patients with extensive UIP may demonstrate greater physiological impairment than patients with predominantly inflammatory or less fibrotic patterns^{2,8,22}.

However, HRCT pattern alone should not be considered a direct measure of disease severity. The extent of abnormality, degree of fibrosis and presence of additional abnormalities are also important determinants of pulmonary function^{20,21}.

Comparison with Previous Studies

The findings of the present study are broadly consistent with previous literature demonstrating a relationship between radiological extent and physiological impairment.

Xaubet et al. demonstrated significant correlations between HRCT findings and pulmonary function in patients with IPF²¹. Similarly, studies evaluating HRCT in idiopathic interstitial pneumonia have shown that greater radiological involvement is associated with worsening pulmonary function¹⁴.

Best et al. reported that quantitative CT measures of fibrosis could provide information related to pulmonary function and disease severity in fibrotic lung disease²⁰. In addition, studies using quantitative CT analysis have demonstrated that the extent of fibrotic abnormalities correlates with FVC and DLCO²¹.

Recent approaches to progressive pulmonary fibrosis also emphasize that disease progression should be assessed using a combination of clinical symptoms, physiological changes and radiological progression rather than relying on a single parameter.^{2,22}

Clinical Implications

The results of the present study highlight the complementary roles of HRCT and PFT in patients with ILD. HRCT provides detailed structural information regarding the pattern, distribution and extent of lung involvement, whereas PFT provides objective information regarding functional impairment.

The significant negative correlations between HRCT extent and both FVC and DLCO suggest that increasing radiological involvement is accompanied by deterioration in pulmonary function. Therefore, combining HRCT with PFT may provide a more comprehensive assessment of disease severity than either investigation alone.

The identification of honeycombing and traction bronchiectasis on HRCT may also alert clinicians to the presence of more advanced fibrotic disease and the likelihood of greater functional impairment.

Conclusion

The present study evaluated the role of high-resolution computed tomography (HRCT) in characterizing interstitial lung diseases (ILDs) and its correlation with pulmonary function tests in 50 patients. HRCT demonstrated a wide spectrum of interstitial abnormalities, with reticulation, ground-glass opacity, architectural distortion, traction bronchiectasis and honeycombing being the predominant findings. The UIP pattern was the most commonly observed HRCT pattern. Pulmonary function testing showed a predominantly restrictive ventilatory defect, with significant reductions in FVC and DLCO in a considerable proportion of patients. A significant negative correlation was observed between the extent of HRCT involvement and FVC ($r = -0.72$, $p < 0.001$) as well as DLCO ($r = -0.76$, $p < 0.001$). Patients with honeycombing and traction bronchiectasis also demonstrated significantly poorer pulmonary function. Thus, the study concludes that HRCT is an important non-invasive investigation for characterizing the pattern, distribution and extent of ILD, while PFT provides objective assessment of its physiological impact. The significant HRCT–PFT correlation indicates that combined evaluation with HRCT and PFT provides a more comprehensive assessment of disease severity than either modality alone.

Therefore, HRCT and PFT should be considered complementary tools in the diagnosis, characterization and functional assessment of patients with interstitial lung disease.

Limitations

The study was limited by the small sample size of 50 patients and its single-centre design, which may limit generalizability.

The study was observational and used semi-quantitative HRCT assessment, limiting assessment of long-term disease progression.

Declarations

Consent to participate: We have consent to participate.

Author's contributions: All the authors equally contributed the work.

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