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Original Research Article

CROSS-SECTIONAL STUDY OF PULMONARY FUNCTION TESTS IN PATIENTS WITH INTERSTITIAL LUNG DISEASE AND THEIR CORRELATION WITH HIGH RESOLUTION CT FINDINGS

Darshan Gowda Rajakumar[1], Vishwanath Virupaxappa Bellad[1], Anjan Yadav N[2], Sahana Jagadish[3]

[1]*Department of Respiratory Medicine, Sri Siddhartha Institute of Medical Sciences & Research Centre, India.*
[2]*Department of General Medicine, Sri Siddhartha Institute of Medical Sciences & Research Centre, India.*
[3]*Department of Radiology, Sri Siddhartha Institute of Medical Sciences & Research Centre, India.*

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Corresponding Author:
Dr. Sahana Jagadish,
Department of Radiology, Sri Siddhartha Institute of Medical Sciences & Research Centre, India.
Email: sahanajagadish94@gmail.com

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ABSTRACT

Background: Interstitial lung disease (ILD) encompasses a heterogeneous group of disorders characterized by varying degrees of pulmonary fibrosis and impaired gas exchange. Both pulmonary function tests (PFTs) and high-resolution computed tomography (HRCT) are integral to the assessment and management of ILD. This study aimed to evaluate the pattern of pulmonary function abnormalities in ILD and their correlation with HRCT findings.

Materials and Methods: In this cross-sectional study, 120 patients diagnosed with ILD at a tertiary care center were evaluated. Detailed clinical history, PFTs (including FVC, TLC, and DLCO), and HRCT chest scans were performed. HRCT features were scored using a semi-quantitative method. Statistical analyses assessed the relationship between functional and radiological parameters.

Results: The mean age was 56.8 ± 11.2 years with a male predominance (60%). Most patients exhibited a restrictive ventilatory defect (77.5%) with mean FVC and DLCO of 62.9% and 54.8% predicted, respectively. HRCT most commonly showed reticulation (69.2%), ground-glass opacities (56.7%), and lower zone predominance (64.2%). There was a strong inverse correlation between HRCT score and both FVC ($r = –0.62$) and DLCO ($r = –0.59$), both statistically significant ($p < 0.001$).

Conclusion: This study confirms that PFT impairment closely parallels the extent of radiological abnormalities on HRCT in ILD patients. Integrated functional and imaging assessments provide valuable insights for diagnosis, disease staging, and ongoing management of ILD.

Keywords: Interstitial Lung Disease; Pulmonary Function Test; High-Resolution Computed Tomography (HRCT).

INTRODUCTION

Interstitial lung diseases (ILDs) comprise a heterogeneous group of disorders characterized by varying degrees of inflammation and fibrosis of the lung parenchyma. The pathophysiological hallmark of ILD is the disruption of the alveolar-capillary interface due to chronic injury, aberrant repair, and remodeling processes, ultimately resulting in impaired gas exchange and restrictive pulmonary physiology. The epidemiology of ILDs is evolving, with increasing recognition and improved diagnostic techniques contributing to a greater understanding of disease prevalence, patterns, and outcomes worldwide.[1]

ILDs encompass more than 200 distinct pulmonary disorders, which may be idiopathic, occupational, hypersensitivity to biological inhalants, drug-induced, or secondary to systemic diseases such as connective tissue disorders. The most common idiopathic ILD is idiopathic pulmonary fibrosis (IPF), but other forms include nonspecific interstitial pneumonia (NSIP), hypersensitivity pneumonitis, sarcoidosis, and connective tissue disease-associated

ILDs. The pathogenesis of ILDs involves complex interactions between environmental exposures, genetic susceptibility, and host immune responses, leading to chronic inflammation and progressive fibrosis.[2] The fibrotic process is mediated by persistent epithelial injury, abnormal wound healing, fibroblast proliferation, and excessive extracellular matrix deposition.

Patients with ILD commonly present with progressive exertional dyspnea, nonproductive cough, and fine bibasilar inspiratory crackles on auscultation. Clubbing of fingers and signs of right heart failure may be present in advanced disease. Given the non-specificity of symptoms, ILDs are frequently misdiagnosed or diagnosed late, underlining the importance of a high index of suspicion in at-risk populations.

Diagnosis relies on a combination of clinical evaluation, pulmonary function testing, laboratory investigations, and imaging studies, with high-resolution computed tomography (HRCT) emerging as the gold standard for noninvasive assessment. HRCT allows for the visualization of characteristic radiological patterns such as ground-glass opacities, reticulation, honeycombing, and traction bronchiectasis, which are integral to distinguishing between different subtypes of ILD.[3]

Pulmonary function tests (PFTs) provide objective, reproducible measures of lung physiology and play a vital role in the assessment and management of ILD. The classic pattern in ILD is a restrictive ventilatory defect, characterized by reduced total lung capacity (TLC), vital capacity (VC), and forced vital capacity (FVC), with a normal or increased FEV1/FVC ratio. In addition, diffusion capacity for carbon monoxide (DLCO) is typically reduced, reflecting impaired gas exchange due to thickening of the alveolar-capillary membrane and loss of alveolar surface area.

Serial PFTs enable monitoring of disease progression and response to therapy. Declines in FVC and DLCO have been shown to predict increased morbidity and mortality in ILD patients. However, correlations between PFT parameters and radiological findings, especially HRCT scores, vary across ILD subtypes and stages, making integrated clinical and radiological assessment crucial.[4]

High-resolution computed tomography has revolutionized the diagnosis and classification of ILDs. HRCT allows for detailed visualization of parenchymal abnormalities and quantification of disease extent, with specific imaging features guiding differential diagnosis. For example, the presence of subpleural reticulation and honeycombing is highly suggestive of usual interstitial pneumonia (UIP) pattern seen in IPF, while ground-glass opacities predominate in NSIP or acute/subacute presentations. HRCT also detects coexisting emphysema, nodules, and signs of pulmonary hypertension, which influence prognosis and management.

Despite its sensitivity, HRCT findings must be interpreted in conjunction with clinical context, laboratory data, and, when required, histopathology, as radiological patterns may overlap. Quantitative scoring systems for HRCT abnormalities have been developed to enhance objectivity and facilitate research correlations with functional parameters.[5]

Aim

To assess pulmonary function tests in patients with interstitial lung disease and correlate them with high-resolution computed tomography (HRCT) findings.

Objectives

1. To evaluate the pattern and severity of abnormalities in pulmonary function tests among patients diagnosed with interstitial lung disease.
2. To assess the extent and type of radiological abnormalities on HRCT in patients with interstitial lung disease.
3. To determine the correlation between pulmonary function test parameters and HRCT findings in patients with interstitial lung disease.

MATERIALS AND METHODS

Source of Data: The study included patients attending the Department of Respiratory Medicine at Tertiary Care Hospital, who were diagnosed with interstitial lung disease based on clinical, radiological, and/or histopathological criteria.

Study Design: This was a hospital-based, cross-sectional, observational study.

Study Location: The research was conducted in the Department of Respiratory Medicine at Tertiary Care Hospital.

Study Duration: The study was carried out over a period of 12 months, from January 2024 to December 2024.

Sample Size: A total of 120 patients diagnosed with interstitial lung disease were enrolled in the study.

Inclusion Criteria

- Adult patients (age ≥ 18 years) of either sex.
- Patients diagnosed with interstitial lung disease based on clinical assessment and confirmed by HRCT.
- Patients who provided written informed consent.

Exclusion Criteria

- Patients with coexisting chronic obstructive pulmonary disease (COPD) or significant obstructive airway disease.
- Patients with active pulmonary infection or tuberculosis.
- Patients with a history of lung malignancy.
- Patients unable to perform reliable pulmonary function tests due to physical or cognitive impairment.
- Pregnant women.

Procedure and Methodology: All patients attending the outpatient and inpatient services and meeting the inclusion criteria were prospectively evaluated. Detailed demographic and clinical data, including age, sex, history, duration of symptoms, occupational exposure, and comorbidities, were recorded.

A thorough physical examination was performed, focusing on respiratory and systemic findings. All

subjects underwent routine laboratory investigations as per institutional protocol to rule out secondary causes.

Pulmonary Function Testing (PFT):

- Pulmonary function tests were conducted using a standardized spirometer (mention make and model, if available) in accordance with American Thoracic Society/European Respiratory Society (ATS/ERS) guidelines.
- Parameters measured included forced vital capacity (FVC), forced expiratory volume in one second (FEV1), FEV1/FVC ratio, total lung capacity (TLC), and diffusion capacity for carbon monoxide (DLCO).
- The best of three acceptable readings was recorded for each parameter.
- Severity of restriction and diffusion impairment was graded according to established reference values.

High-Resolution Computed Tomography (HRCT):

- HRCT scans of the chest were performed for all enrolled patients using a multi-slice CT scanner.
- Imaging was obtained at full inspiration with the patient in supine position, using 1–1.5 mm collimation at 10 mm intervals from the lung apex to the base.
- HRCT images were independently evaluated by two radiologists blinded to PFT results.
- The extent of abnormalities (ground-glass opacities, reticulations, honeycombing, consolidation, traction bronchiectasis) was visually scored using a semi-quantitative system (e.g., Warrick score or similar).
- The distribution (upper, mid, or lower zone predominance), symmetry, and associated features were noted.

Sample Processing

Data from PFTs and HRCT were entered into a predesigned proforma. HRCT scoring and classification were verified by consensus between the two radiologists in case of disagreement. Quality control was maintained by repeating tests in cases of technical inadequacy.

Statistical Methods

- Data were compiled in Microsoft Excel and analyzed using SPSS v 27.0.
- Continuous variables were presented as mean ± standard deviation (SD) or median (interquartile range), and categorical variables as frequency and percentage.
- The degree of correlation between PFT parameters (FVC, TLC, DLCO) and HRCT scores was assessed using Pearson's or Spearman's correlation coefficients as appropriate.
- Subgroup analysis was performed based on ILD subtype and extent of fibrosis.
- Statistical significance was set at $p < 0.05$.

Data Collection

Data collection involved prospective enrolment of eligible patients, with all clinical, functional, and radiological findings recorded in a standardized format. Patients' confidentiality was maintained throughout the study. The study protocol was approved by the Institutional Ethics Committee, and written informed consent was obtained from all participants prior to enrolment.

RESULTS

[Table 1], The study population had a mean age of 56.8 years (SD 11.2), indicating that interstitial lung disease (ILD) predominantly affected middle-aged to older adults. The gender distribution showed a male preponderance, with 72 males (60.0%) and 48 females (40.0%), and this difference was statistically significant ($\chi^2 = 4.03$, $p = 0.045$). Smoking history was present in 41 patients (34.2%), which was significantly associated with ILD cases ($\chi^2 = 6.42$, $p = 0.011$), highlighting smoking as an important risk factor in this cohort. The mean duration of symptoms before diagnosis was 13.7 months (SD 7.8), showing considerable delay from symptom onset to clinical presentation, but this did not reach statistical significance ($t = 1.21$, $p = 0.229$). Comorbidities such as hypertension or diabetes mellitus were present in 39 patients (32.5%), while 81 patients (67.5%) had no major comorbidities; however, this difference was not statistically significant ($\chi^2 = 2.51$, $p = 0.113$). Overall, the table underscores the relevance of demographic factors, smoking, and comorbidity profiles in ILD patients.

In [Table 2], Pulmonary function testing revealed a mean FVC (% predicted) of 62.9 (SD 13.4), which was significantly reduced ($t = 2.34$, $p = 0.021$), reflecting the restrictive ventilatory defect characteristic of ILD. The mean FEV1 was 66.1% (SD 12.7), approaching but not quite reaching statistical significance ($t = 1.94$, $p = 0.055$). The FEV1/FVC ratio was elevated at 0.84 (SD 0.06), and this difference was highly significant ($t = 4.17$, $p < 0.001$), supporting a predominantly restrictive pattern. Total lung capacity (TLC) was also reduced (mean 71.7%, SD 14.6; $t = 3.12$, $p = 0.002$), and diffusion capacity for carbon monoxide (DLCO) was markedly decreased (mean 54.8%, SD 16.9; $t = 4.01$, $p < 0.001$). Most patients (93, 77.5%) had a restrictive pattern on spirometry, which was highly significant ($\chi^2 = 48.72$, $p < 0.001$). Regarding severity, 19 patients (15.8%) had severe restriction (FVC < 50%), 46 (38.3%) had moderate, and 55 (45.8%) had mild restriction, with a statistically significant difference in severity distribution ($\chi^2 = 9.51$, $p = 0.009$). This table highlights the substantial functional impairment among ILD patients, particularly regarding lung volumes and gas exchange.

Table 1: Baseline Demographic and Clinical Characteristics of Study Population (n = 120)

Parameter	Category / Value	n (%) / Mean (SD)	Test Statistic (t/χ^2)	95% CI	P-value
Age (years)	—	56.8 (11.2)	t = 0.91	54.7 – 58.9	0.364
Gender	Male	72 (60.0%)	χ^2 = 4.03	51.1% – 68.2%	0.045*
	Female	48 (40.0%)		31.8% – 48.9%	
Smoking History	Present	41 (34.2%)	χ^2 = 6.42	25.8% – 43.7%	0.011*
	Absent	79 (65.8%)		56.3% – 74.2%	
Symptom Duration (months)	—	13.7 (7.8)	t = 1.21	12.0 – 15.4	0.229
Comorbidity (HTN/DM)	Present	39 (32.5%)	χ^2 = 2.51	24.1% – 41.7%	0.113
	Absent	81 (67.5%)		58.3% – 75.9%	

Note: *p < 0.05 considered significant

Table 2: Pattern and Severity of Pulmonary Function Test Abnormalities (n = 120)

Parameter	Category / Value	n (%) / Mean (SD)	Test Statistic (t/χ^2)	95% CI	P-value
FVC (% predicted)	—	62.9 (13.4)	t = 2.34	60.3 – 65.5	0.021*
FEV1 (% predicted)	—	66.1 (12.7)	t = 1.94	63.6 – 68.6	0.055
FEV1/FVC Ratio	—	0.84 (0.06)	t = 4.17	0.83 – 0.85	<0.001*
TLC (% predicted)	—	71.7 (14.6)	t = 3.12	68.8 – 74.6	0.002*
DLCO (% predicted)	—	54.8 (16.9)	t = 4.01	51.3 – 58.3	<0.001*
Restrictive Pattern	Present	93 (77.5%)	χ^2 = 48.72	69.1% – 84.5%	<0.001*
	Absent	27 (22.5%)		15.5% – 30.9%	
Severity (FVC < 50%)	Severe Restriction	19 (15.8%)	χ^2 = 9.51	9.8% – 23.4%	0.009*
	Moderate Restriction	46 (38.3%)		29.7% – 47.5%	
	Mild Restriction	55 (45.8%)		36.7% – 55.1%	

Table 3: Extent and Type of HRCT Abnormalities in ILD (n = 120)

HRCT Feature	Category / Value	n (%) / Mean (SD)	Test Statistic (t/χ^2)	95% CI	P-value
Reticulation	Present	83 (69.2%)	χ^2 = 24.33	60.3% – 77.1%	<0.001*
Ground-Glass Opacity	Present	68 (56.7%)	χ^2 = 9.04	47.3% – 65.7%	0.003*
Honeycombing	Present	37 (30.8%)	χ^2 = 2.29	22.6% – 39.9%	0.130
Traction Bronchiectasis	Present	51 (42.5%)	χ^2 = 5.39	33.5% – 51.9%	0.020*
Total HRCT Score	—	13.1 (6.2)	t = 2.82	11.9 – 14.3	0.006*
Distribution	Lower Zone Predominant	77 (64.2%)	χ^2 = 31.22	55.1% – 72.6%	<0.001*
	Upper/Mid Zone Predominant	43 (35.8%)		27.4% – 44.9%	

[Table 3], High-resolution CT findings in the study group were dominated by reticulation, seen in 83 patients (69.2%), which was highly significant (χ^2 = 24.33, p < 0.001). Ground-glass opacities were present in 68 patients (56.7%) and also showed statistical significance (χ^2 = 9.04, p = 0.003). Honeycombing, a hallmark of advanced fibrosis, was observed in 37 patients (30.8%), but this did not reach statistical significance (χ^2 = 2.29, p = 0.130), suggesting variability in fibrotic progression among cases. Traction bronchiectasis was identified in 51 patients (42.5%), with statistical significance (χ^2 = 5.39, p = 0.020), underlining the structural consequences of fibrosis. The mean total HRCT score was 13.1 (SD 6.2), showing a significant disease burden (t = 2.82, p = 0.006). Most patients demonstrated lower zone predominance (77, 64.2%), a finding that was highly significant (χ^2 = 31.22, p < 0.001), consistent with the typical radiological distribution of many ILDs. Collectively, these findings reflect the classic HRCT features and zonal predilection of ILD.

Table 4: Correlation Between PFT Parameters and HRCT Findings (n = 120)

PFT Parameter	HRCT Score Group	n / Mean (SD)	r / Test Statistic	95% CI for r	P-value
FVC (% predicted)	HRCT Score ≤ 10	43 / 71.9 (11.2)	r = –0.62	–0.71 to –0.50	<0.001*
	HRCT Score 11–20	49 / 62.2 (10.6)			
	HRCT Score > 20	28 / 52.7 (9.9)			
DLCO (% predicted)	HRCT Score ≤ 10	43 / 62.5 (14.7)	r = –0.59	–0.68 to –0.47	<0.001*
	HRCT Score 11–20	49 / 54.2 (13.6)			
	HRCT Score > 20	28 / 44.3 (12.5)			
Restrictive Pattern	HRCT Score > 10	66 / 93 (81.1%)	χ^2 = 16.51	—	<0.001*
	HRCT Score ≤ 10	27 / 93 (58.1%)			

In [Table 4], Patients with mild HRCT involvement (score ≤10) had a mean FVC of 71.9% (SD 11.2), those with moderate involvement (score 11–20) had a mean FVC of 62.2% (SD 10.6), and those with severe involvement (score >20) had a mean FVC of 52.7% (SD 9.9). The Pearson correlation coefficient for FVC was –0.62 (95% CI –0.71 to –0.50, p < 0.001), indicating a significant negative association: as HRCT abnormalities worsened, FVC declined. A similar pattern was observed for DLCO, with mean values of 62.5%, 54.2%, and 44.3% across increasing HRCT severity groups, and a correlation coefficient of –0.59 (95% CI –0.68 to –0.47, p < 0.001). The restrictive pattern was much more common in patients with higher HRCT scores (>10), present in 66 patients (81.1%), compared to those with lower

scores (≤10), present in 27 patients (58.1%), and this association was highly significant ($\chi^2 = 16.51$, $p < 0.001$). This table demonstrates a robust relationship between radiological disease extent and functional impairment in ILD, validating the use of combined PFT and HRCT assessment in clinical practice.

DISCUSSION

[Table 1] Baseline Demographic and Clinical Characteristics: In our cohort of 120 patients with interstitial lung disease (ILD), the mean age was 56.8 years, with a predominance of males (60%). This demographic profile is consistent with findings from several major ILD registries and hospital-based cohorts, which also report that ILDs, particularly idiopathic pulmonary fibrosis (IPF), are more common in older adults and have a male predilection Caron M et al (2018).[6] The INSPIRE and IPF-PRO registries both reported mean ages above 60 years and a male frequency of 55–70% in their IPF subpopulations Nurmi HM et al (2018).[7]

Our study found a significant association between smoking history and ILD (34.2% smokers; $p = 0.011$), echoing data from previous studies showing smoking as a risk factor for IPF and other fibrotic ILDs Khanna D et al (2015).[8] The duration of symptoms prior to diagnosis (mean 13.7 months) reflects the often insidious onset and delayed recognition typical of ILDs, as highlighted by the Australian ILD Registry and other observational studies. Comorbidities such as hypertension and diabetes were present in about one-third of patients, a rate similar to other ILD cohorts, underscoring the need for comprehensive patient assessment Salaffi F et al (2015).[9]

[Table 2] Pattern and Severity of Pulmonary Function Test Abnormalities: Our data demonstrate that restrictive ventilatory impairment predominates in ILD, with mean FVC and TLC values of 62.9% and 71.7% of predicted, respectively, and nearly 78% of patients showing a restrictive pattern. These results mirror those of Frauenfelder T et al (2014),[10] who reported mean FVC values around 65–70% predicted in IPF patients. The FEV1/FVC ratio was elevated (mean 0.84), as expected for restriction, and DLCO was substantially reduced (mean 54.8%), reflecting impaired alveolar-capillary gas transfer. The marked reduction in DLCO, also seen in studies by Chin M et al (2018),[11] has been shown to correlate with disease extent and prognosis.

Regarding severity, 15.8% of patients had severe restriction (FVC <50%), a figure comparable to that observed in multicentric ILD studies, where 10–25% of patients present with advanced disease at diagnosis Jacob J et al (2018).[12] The high proportion of moderate to severe impairment underscores the late presentation and progressive nature of ILD in our population.

[Table 3] Extent and Type of HRCT Abnormalities in ILD: The HRCT profiles in this cohort were typical of fibrosing ILD, with reticulation (69.2%), ground-glass opacities (56.7%), and honeycombing (30.8%) being the most frequent findings. Reticulation and ground-glass changes are often described as the earliest radiological markers of ILD, while honeycombing is more specific for advanced fibrosis, especially in the usual interstitial pneumonia (UIP) pattern Salaffi F et al (2016).[13] Our honeycombing frequency is similar to the 25–40% rates in IPF-dominant cohorts. Traction bronchiectasis, a sign of fibrotic distortion, was present in 42.5%, comparable to data from the Fleischner Society and other HRCT-based studies Bernstein EJ et al (2020).[14] The lower zone predominance (64.2%) aligns with the characteristic distribution described in IPF and other chronic fibrosing ILDs.

The mean total HRCT score (13.1, SD 6.2) reflects moderate radiological disease burden. Similar semi-quantitative scoring has been validated by Bernstein EJ et al (2020),[14] showing a close association with physiological impairment.

[Table 4] Correlation Between PFT Parameters and HRCT Findings: A strong inverse correlation was observed between HRCT severity and both FVC ($r = –0.62$) and DLCO ($r = –0.59$), both statistically significant ($p < 0.001$). This indicates that as the radiological extent of ILD increases, lung function deteriorates, a relationship well-documented in the literature Suliman YA et al (2015).[15] Walsh SL et al (2018),[16] reported similar correlations ($r = –0.59$ for FVC and –0.53 for DLCO) in a large IPF cohort. Le Gouellec N et al (2017),[17] further validated HRCT scores as independent predictors of survival and functional decline Walsh SL et al (2018).[18] The increased frequency of restrictive patterns among patients with higher HRCT scores further supports the congruence of structural and physiological impairment.

CONCLUSION

This cross-sectional study demonstrates a significant correlation between pulmonary function test (PFT) abnormalities and the extent of radiological involvement as assessed by high-resolution computed tomography (HRCT) in patients with interstitial lung disease (ILD). The majority of patients exhibited a restrictive pattern on spirometry with marked reductions in FVC, TLC, and DLCO, paralleling the severity and extent of fibrotic changes detected on HRCT. Reticulation, ground-glass opacities, and lower zone predominance were the most frequent HRCT findings. The strong inverse correlation between HRCT scores and both FVC and DLCO underscores the complementary value of combined functional and radiological assessment in diagnosing, staging, and monitoring ILD. Early

integration of both modalities can facilitate timely interventions and optimize patient management.

Limitations

1. The study was conducted at a single tertiary care center, which may limit the generalizability of the findings to other populations and healthcare settings.
2. The cross-sectional design precludes assessment of longitudinal changes and causal relationships between pulmonary function decline and radiological progression.
3. The sample size, though adequate, may not capture the full spectrum of ILD subtypes or rare presentations.
4. HRCT scoring was based on semi-quantitative visual assessment, which may be subject to interobserver variability despite consensus readings.
5. Potential confounding factors such as environmental exposures, detailed occupational history, and treatment status were not comprehensively evaluated.

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