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HRCT Patterns in Interstitial Lung Disease and Correlation With Pulmonary Function Tests

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ABSTRACT:

Background: Interstitial lung disease (ILD) comprises a diverse group of diffuse parenchymal lung disorders characterized by varying degrees of inflammation and fibrosis. High-resolution computed tomography (HRCT) plays a crucial role in detecting characteristic radiological patterns, while pulmonary function tests (PFTs) assess the extent of functional respiratory impairment. Correlating HRCT findings with PFT parameters helps in evaluating disease severity and prognosis. **Aim and Objectives:** To evaluate HRCT patterns in patients with interstitial lung disease and correlate these findings with pulmonary function test parameters. **Materials and Methods:** This hospital-based observational cross-sectional study was conducted in the Department of Radiodiagnosis at Maharishi Markandeshwar Institute of Medical Sciences and Research over a period of 6 months. A total of 50 patients clinically suspected or diagnosed with ILD were included. All patients underwent HRCT thorax and pulmonary function testing. Data were analyzed using SPSS version 27.0 and GraphPad Prism version 5. Statistical significance was considered at $p<0.05$. **Results:** The majority of patients belonged to the 51–60 years age group (36%), with male predominance (64%). Ground-glass opacity was the most common HRCT finding (28%), followed by reticular opacity (20%) and honeycombing (18%). Restrictive ventilatory defect was the predominant PFT abnormality, observed in 72% of patients. Significant inverse correlations were noted between HRCT severity and pulmonary function parameters, particularly forced vital capacity (FVC) and diffusion capacity for carbon monoxide (DLCO) ($p<0.001$). Increasing fibrosis scores on HRCT were associated with progressive decline in pulmonary function. **Conclusion:** HRCT is an essential imaging modality for diagnosing and assessing ILD. Combined evaluation using HRCT and pulmonary function tests provides valuable information regarding disease severity, progression, and functional impairment, thereby aiding in comprehensive patient management.

INTRODUCTION:

Interstitial lung disease (ILD) represents a heterogeneous group of diffuse parenchymal lung disorders characterized by varying degrees of inflammation and fibrosis involving the pulmonary interstitium, alveoli, and small airways. These disorders encompass more than 200 distinct entities, including idiopathic pulmonary fibrosis (IPF), nonspecific interstitial pneumonia (NSIP), hypersensitivity pneumonitis, sarcoidosis, and connective tissue disease-associated ILD. Although individual diseases differ in etiology and progression, most ILDs share common clinical manifestations such as progressive dyspnea, nonproductive cough, reduced exercise tolerance, and impaired pulmonary function. Early diagnosis and accurate characterization are essential because prognosis and therapeutic approaches vary significantly among different ILD subtypes [1].

High-resolution computed tomography (HRCT) has emerged as the cornerstone imaging modality in the evaluation of ILD. Compared with conventional chest radiography, HRCT provides superior spatial resolution and enables detailed assessment of lung parenchymal abnormalities such as ground-glass opacities, reticulations, honeycombing, traction bronchiectasis, nodules, and mosaic attenuation. These radiological patterns often correlate closely with histopathological findings and may obviate the need for invasive lung biopsy in many cases. The introduction of standardized HRCT criteria has significantly improved diagnostic confidence, especially in conditions such as usual interstitial pneumonia (UIP) and idiopathic pulmonary fibrosis [2,3].

Different HRCT patterns are associated with varying degrees of disease severity and functional impairment. For example, honeycombing and extensive fibrosis are usually associated with advanced restrictive ventilatory defects and reduced diffusion capacity, whereas ground-glass opacities may reflect potentially reversible inflammatory changes. Consequently, HRCT not only aids in diagnosis but also provides prognostic information and helps guide treatment decisions. Serial HRCT examinations are also valuable in monitoring disease progression and evaluating response to therapy [4].

Pulmonary function tests (PFTs) constitute another important component in the assessment of ILD. PFT parameters such as forced vital capacity (FVC), forced expiratory volume in one second (FEV1), total lung capacity (TLC), and diffusion capacity for carbon monoxide (DLCO) are widely used to evaluate the physiological impact of interstitial lung involvement. Most ILDs demonstrate a restrictive ventilatory pattern characterized by reduced lung volumes and impaired gas transfer. Decline in pulmonary function parameters over time is often indicative of disease progression and has strong prognostic implications [5,6].

Several studies have demonstrated a significant correlation between HRCT findings and pulmonary function abnormalities in ILD patients. The extent of fibrosis on HRCT has been shown to correlate inversely with FVC and DLCO values, indicating worsening pulmonary impairment with increasing radiological severity. Establishing such correlations is clinically important because it allows a comprehensive understanding of disease burden by integrating structural and functional assessment. Moreover, combined evaluation using HRCT and PFTs improves diagnostic accuracy, facilitates staging, and assists in predicting clinical outcomes [7,8].

In recent years, advances in imaging techniques and quantitative HRCT analysis have further enhanced the role of radiology in ILD evaluation. Artificial intelligence-based image analysis and volumetric quantification are increasingly being explored to objectively assess disease extent and progression. Nevertheless, HRCT and PFTs continue to remain the most practical and widely available tools for routine clinical evaluation of ILD patients [9]. Therefore, studying HRCT patterns and their correlation with pulmonary function tests is essential for better disease characterization, early intervention, and improved patient management [10].

The present study aims to evaluate various HRCT patterns in patients with interstitial lung disease and to correlate these radiological findings with pulmonary function test parameters. The objectives include identifying predominant HRCT abnormalities, assessing the severity of pulmonary involvement, and determining the relationship between imaging patterns and functional respiratory impairment.

MATERIALS AND METHODS:

Study Design: Hospital-based observational cross-sectional study.
Study Population: Patients clinically suspected or diagnosed with interstitial lung disease (ILD) referred to the Department of Radiodiagnosis for HRCT thorax and pulmonary function tests.
Sample Size: Total of 50 patients were included in the study.

Study Duration: The study was conducted over a period of 6 months.
Study Place: Department of Radiodiagnosis, Maharishi Markandeshwar Institute of Medical Sciences and Research.

Inclusion Criteria:
- Patients aged above 18 years.
- Patients with clinical suspicion or confirmed diagnosis of interstitial lung disease.
- Patients willing to undergo HRCT thorax and pulmonary function tests.
- Patients who provided informed consent for participation in the study.

Exclusion Criteria:
- Patients with active pulmonary tuberculosis or lung malignancy.
- Patients with acute respiratory infections at the time of evaluation.
- Patients unable to perform pulmonary function tests adequately.
- Pregnant women.
- Patients unwilling to participate in the study.

Statistical Analysis
The collected data were entered into Microsoft Excel spreadsheets and subsequently analyzed using Statistical Package for the Social Sciences (SPSS) software version 27.0 (SPSS Inc., Chicago, IL, USA) along with GraphPad Prism version 5. Continuous variables were expressed as mean ± standard deviation (SD), while categorical variables were presented as frequencies and percentages.
Comparisons of continuous variables between two independent groups were performed using the unpaired Student's t-test, whereas paired t-test analysis was applied for comparisons within the same group wherever appropriate. Associations between categorical variables were assessed using the Chi-square test or Fisher's exact test depending on the expected cell frequencies and suitability of the test. Correlation analysis between HRCT findings and pulmonary function test parameters was carried out using appropriate statistical methods. A p-value of less than 0.05 was considered statistically significant for all analyses.

RESULT:

Table 1. Age Distribution of Study Population

Age Group (years)	Number of Patients	Percentage (%)	P-value
<40	6	12%	0.032
41–50	10	20%	
51–60	18	36%	
61–70	12	24%	
>70	4	8%	
Total	**50**	**100%**	

Table 2. Gender Distribution of Patients

Gender	Number of Patients	Percentage (%)	P-value
Male	32	64%	0.041
Female	18	36%	
Total	**50**	**100%**	

Table 3. Distribution of HRCT Patterns in ILD Patients

HRCT Pattern	Number of Patients	Percentage (%)	P-value
Ground-glass Opacity	14	28%	0.001
Reticular Opacity	10	20%	
Honeycombing	9	18%	
Traction Bronchiectasis	8	16%	
Nodular Pattern	5	10%	
Mixed Pattern	4	8%	
Total	**50**	**100%**	

Table 4. Pulmonary Function Test (PFT) Pattern among Patients

PFT Pattern	Number of Patients	Percentage (%)	P-value
Restrictive Pattern	36	72%	<0.001
Obstructive Pattern	5	10%	
Mixed Pattern	6	12%	

Normal PFT	3	6%	
Total	**50**	**100%**	

Table 5. Correlation of HRCT Severity with FVC (%)

HRCT Severity	Mean FVC (%) ± SD	Number of Patients	P-value
Mild	78.4 ± 6.2	15	<0.001
Moderate	62.8 ± 7.5	22	
Severe	45.6 ± 8.1	13	
Total	—	**50**	

Table 6. Correlation of HRCT Fibrosis Score with DLCO (%)

HRCT Fibrosis Score	Mean DLCO (%) ± SD	Number of Patients	P-value
Mild Fibrosis	72.5 ± 5.8	17	<0.001
Moderate Fibrosis	58.3 ± 6.7	21	
Severe Fibrosis	39.7 ± 7.2	12	
Total	—	**50**	

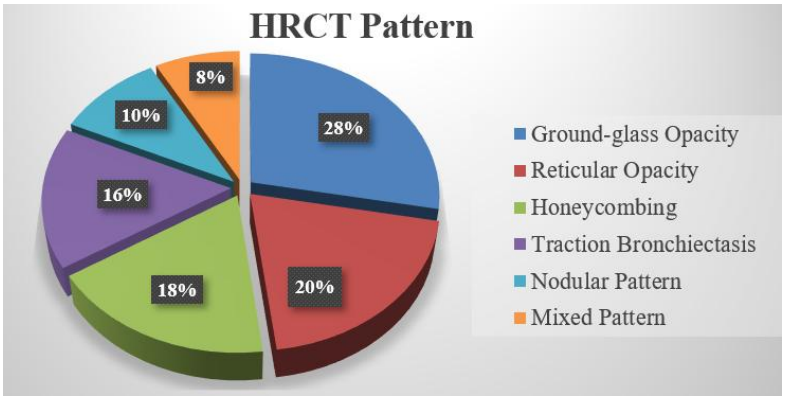

Figure: 1. Distribution of HRCT Patterns in ILD Patients

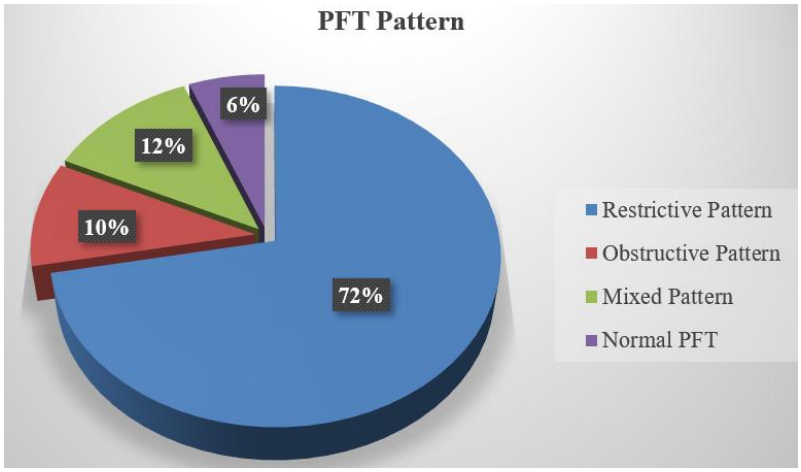

Figure: 2. Pulmonary Function Test (PFT) Pattern among Patients

The majority of patients belonged to the 51–60 years age group, comprising 18 patients (36%), followed by 61–70 years with 12 patients (24%). Patients aged 41–50 years accounted for 10 cases (20%), while 6 patients (12%) were below 40 years of age. Only 4 patients (8%) were above 70 years. The age-wise distribution showed statistical significance (p=0.032), indicating that ILD was more commonly observed in the middle-aged and elderly population.

Among the total 50 patients included in the study, males constituted the majority with 32 cases (64%), whereas females accounted for 18 cases (36%). The male predominance observed in the study was statistically significant (p=0.041).

Ground-glass opacity was the most common HRCT pattern observed in 14 patients (28%), followed by reticular opacity in 10 patients (20%). Honeycombing was noted in 9 cases (18%), while traction bronchiectasis was present in 8 patients (16%). Nodular pattern and mixed pattern were seen in 5 (10%) and 4 patients (8%) respectively. The distribution of HRCT patterns showed a statistically significant association (p=0.001).

Restrictive ventilatory defect was the predominant pulmonary function abnormality observed in 36 patients (72%). Mixed ventilatory pattern was seen in 6 patients (12%), while obstructive pattern was present in 5 patients (10%). Only 3 patients (6%) demonstrated normal pulmonary function tests. The predominance of restrictive impairment among ILD patients was highly statistically significant (p<0.001).

Patients with mild HRCT severity demonstrated a mean FVC of 78.4 ± 6.2%, whereas those with moderate severity showed a reduced mean FVC of 62.8 ± 7.5%. Patients with severe HRCT involvement had markedly decreased FVC values of 45.6 ± 8.1%. The decline in FVC with increasing HRCT severity was statistically highly significant (p<0.001), indicating worsening pulmonary restriction with increasing radiological disease burden.

The mean DLCO value in patients with mild fibrosis was 72.5 ± 5.8%, which decreased to 58.3 ± 6.7% in moderate fibrosis and further declined to 39.7 ± 7.2% in severe fibrosis cases. This progressive reduction in DLCO with increasing fibrosis score on HRCT was statistically highly significant (p<0.001), suggesting a strong inverse correlation between extent of fibrosis and pulmonary diffusion capacity.

DISCUSSION:

In the present study, the majority of patients belonged to the 51–60 years age group (36%), followed by the 61–70 years group (24%), indicating that interstitial lung disease predominantly affects middle-aged and elderly individuals. Increasing age has been recognized as an important risk factor for fibrotic lung diseases because of cumulative environmental exposure, smoking history, occupational factors, and age-related decline in lung repair mechanisms. Similar findings were reported by Raghu et al., who observed that most ILD patients were above 50 years of age, with a peak incidence during the sixth decade of life [11]. Likewise, Antoniou et al. demonstrated that the prevalence of fibrotic ILD increased significantly with advancing age, especially in patients with idiopathic pulmonary fibrosis [12]. The statistically significant age distribution in the present study supports the established understanding that ILD is primarily a disease of older adults.

The current study demonstrated a male predominance, with males accounting for 64% of cases. This finding may be attributed to higher exposure among males to occupational dust, smoking, and environmental pollutants, which are known contributors to interstitial lung injury. Similar male predominance was observed in the study conducted by King et al., where males constituted approximately two-thirds of ILD patients [13]. Gribbin et al. also reported higher incidence rates of idiopathic pulmonary fibrosis among men compared to women, likely due to occupational and smoking-related exposure differences [14]. The significant gender association in the present study is therefore consistent with previously published epidemiological data.

Ground-glass opacity was the most common HRCT pattern identified in the present study, followed by reticular opacities and honeycombing. HRCT plays a pivotal role in identifying characteristic imaging features of ILD and differentiating inflammatory from fibrotic disease patterns. Ground-glass opacity often reflects active alveolitis or early interstitial inflammation, whereas honeycombing represents irreversible fibrosis. Similar observations were reported by Silva et al., who found ground-glass attenuation and reticular abnormalities to be among the most frequent HRCT findings in diffuse parenchymal lung diseases [15]. Lynch et al. also documented that honeycombing and traction bronchiectasis strongly correlate with advanced fibrotic disease and poorer prognosis [16]. The statistically significant distribution of HRCT abnormalities in the present study highlights the importance of HRCT in disease characterization and severity assessment.

Restrictive ventilatory defect was the predominant pulmonary function abnormality observed in this study, affecting 72% of patients. ILD commonly leads to reduced lung compliance and diminished lung volumes due to interstitial fibrosis, resulting in a restrictive pattern on spirometry. Similar findings were reported by Wells et al., who observed restrictive defects as the hallmark physiological abnormality in most forms of ILD [17]. Lama et al. also demonstrated that reductions in FVC and total lung capacity are closely associated with disease progression and mortality in fibrotic ILD [18]. The highly significant predominance of restrictive impairment in the present study correlates well with the known pathophysiological changes associated with diffuse interstitial

lung involvement.

The present study demonstrated a significant decline in mean FVC values with increasing HRCT severity. Patients with severe HRCT involvement showed markedly reduced FVC compared to those with mild disease, indicating worsening restrictive impairment with increasing radiological fibrosis. Similar correlations were reported by Best et al., who found that extensive fibrotic changes on HRCT were strongly associated with lower FVC values and increased mortality risk in idiopathic pulmonary fibrosis [19]. Kazerooni et al. also demonstrated a significant inverse relationship between HRCT fibrosis scores and pulmonary function parameters, especially FVC and TLC [20]. These findings support the role of HRCT severity scoring as an important predictor of functional respiratory impairment in ILD patients.

In the present study, DLCO values progressively decreased with increasing HRCT fibrosis scores, suggesting worsening impairment in alveolar-capillary gas exchange as fibrosis advanced. DLCO is considered one of the most sensitive pulmonary function parameters in ILD because interstitial fibrosis directly disrupts diffusion across the alveolar membrane. Similar observations were made by Wells et al., who reported that DLCO reduction correlated significantly with the extent of fibrotic involvement on HRCT [17]. Best et al. also concluded that increasing radiological fibrosis was associated with marked decline in diffusion capacity and poorer clinical outcomes [19]. The significant inverse correlation observed in the current study reinforces the complementary role of HRCT and pulmonary function testing in assessing disease severity and progression in ILD patients.

CONCLUSION:

The present study highlights the significant role of high-resolution computed tomography (HRCT) in the evaluation and characterization of interstitial lung disease (ILD). HRCT was highly effective in identifying characteristic imaging patterns such as ground-glass opacities, reticular changes, honeycombing, and traction bronchiectasis, which aided in assessing disease severity and extent. Pulmonary function tests (PFTs) demonstrated predominantly restrictive ventilatory defects among ILD patients, reflecting impaired lung mechanics associated with interstitial fibrosis. A significant inverse correlation was observed between HRCT severity scores and pulmonary function parameters, particularly forced vital capacity (FVC) and diffusion capacity for carbon monoxide (DLCO). Increasing radiological fibrosis was associated with worsening functional impairment. The combined use of HRCT and PFTs therefore provides a comprehensive structural and functional assessment of ILD, facilitating early diagnosis, accurate disease staging, prognostic evaluation, and appropriate therapeutic planning. Early recognition and multidisciplinary evaluation remain essential for improving patient outcomes and disease management.

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