

Role of HRCT in Early Detection and Severity Scoring of Interstitial Lung Disease

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Abstract:

Background: Interstitial lung diseases (ILDs) comprise a heterogeneous group of diffuse parenchymal lung disorders with substantial morbidity and mortality. Early diagnosis and accurate severity assessment are very important for making predictions and managing the disease. High-resolution computed tomography (HRCT) has become the preferred imaging technique for detection, pattern recognition, and disease quantification.

Objectives: To evaluate the role of HRCT in early detection of ILD and to assess its utility in severity scoring and correlation with clinical and pulmonary function parameters.

Methods: A prospective observational study was conducted over 15 months (September 2024–November 2025) at MAX PLUS Medical College and Government Thoothukudi Medical College. A total of 284 consecutive patients with clinical suspicion of ILD underwent HRCT thorax. Imaging patterns were categorized and severity scored using a semi-quantitative HRCT severity index. HRCT scores were correlated with spirometric indices (FVC) and clinical severity. Statistical analysis included descriptive statistics, correlation coefficients, and comparative tests.

Results: Of 284 patients, HRCT detected ILD in 258 (90.8%) cases. Ground-glass opacities were predominant in early disease, while reticulation and honeycombing correlated with advanced severity. Mean HRCT severity score showed significant negative correlation with FVC ($r = -0.62$, $p < 0.001$). HRCT-based severity grading demonstrated statistically significant association with clinical dyspnea grade ($p < 0.001$).

Conclusion: HRCT plays a pivotal role in early detection of ILD and provides reliable severity assessment that correlates well with functional impairment. Incorporation of standardized HRCT severity scoring can enhance clinical decision-making and prognostication.

Keywords: Interstitial lung diseases; high-resolution CT imaging; radiological severity assessment; fibrotic lung involvement; pulmonary function correlation

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Introduction

Interstitial lung diseases (ILDs) encompass a wide and diverse group of disorders that primarily affect the pulmonary interstitium, leading to varying degrees of inflammation and fibrosis [1]. Although individual ILDs

are relatively uncommon, together they contribute substantially to chronic respiratory morbidity and mortality worldwide, particularly when diagnosis is delayed or disease progresses to irreversible fibrotic

stages [2]. Early identification of ILD is therefore clinically important, as timely diagnosis and intervention may help slow disease progression and preserve lung function.

The clinical manifestations of ILD are often insidious and nonspecific. Progressive exertional dyspnea and persistent dry cough are the most frequently reported symptoms, but these features overlap with a variety of other cardiac and respiratory conditions, often resulting in delayed recognition of the underlying disease [3]. Conventional chest radiography is typically the first imaging investigation performed; however, its sensitivity for early interstitial abnormalities is limited, and radiographs may remain normal despite significant disease involvement [4]. Pulmonary function tests provide useful information regarding functional impairment, yet they lack diagnostic specificity and can be influenced by patient effort, disease heterogeneity, and associated comorbidities [5].

High-resolution computed tomography (HRCT) has emerged as the most valuable imaging tool for the evaluation of diffuse parenchymal lung diseases. By providing detailed visualization of the lung interstitium and secondary pulmonary lobules, HRCT enables detection of subtle abnormalities that are frequently missed on chest radiographs [6]. In addition, HRCT allows characterization of distinct imaging patterns such as ground-glass opacities, reticulation, traction bronchiectasis, and honeycombing, which often correlate closely with underlying histopathological changes [7]. In many clinical scenarios, recognition of these characteristic patterns permits confident diagnosis without the need for invasive lung biopsy [8].

Beyond its diagnostic role, HRCT has gained increasing importance in assessing disease extent and severity. Several semi-quantitative and quantitative HRCT-based scoring systems have been developed to estimate the burden of fibrotic and inflammatory involvement, providing objective

measures that may aid prognostication and longitudinal assessment [9,10]. Previous studies have demonstrated significant associations between HRCT severity scores and pulmonary function parameters, particularly forced vital capacity (FVC) and diffusing capacity for carbon monoxide (DLCO), highlighting the clinical relevance of radiological disease quantification [11,12].

Despite the growing body of literature, there is limited data from Indian tertiary care centers evaluating the systematic use of HRCT for early detection of ILD and standardized severity scoring. The present study was therefore undertaken to assess the role of HRCT in the early diagnosis of ILD and to examine the relationship between HRCT-based severity scores, clinical symptom burden, and pulmonary function parameters in patients evaluated at a tertiary care medical college hospital.

Materials and Methods

Study Design and Setting

This was a prospective observational study conducted at the Department of Radiodiagnosis, MAX PLUS Medical College and Government Thoothukudi Medical College, over a period of 15 months from September 2024 to November 2025.

Study Population

A total of 284 consecutive patients with clinical suspicion of ILD, referred for HRCT thorax, were included in the study.

Inclusion Criteria:

- Adults aged ≥ 18 years
- Clinical suspicion of ILD based on symptoms (progressive dyspnea, chronic cough) and/or abnormal chest radiograph

Exclusion Criteria:

- Known active pulmonary infections
- Malignancy involving lung parenchyma
- Poor-quality HRCT scans

HRCT Protocol

HRCT scans were performed using a multi-detector CT scanner with patients in supine position during full inspiration. Thin-section images (1–1.25 mm) were acquired at high spatial resolution and reconstructed using a high-frequency algorithm.

Image Analysis and Severity Scoring

HRCT images were reviewed independently by two experienced radiologists blinded to clinical data. Imaging patterns were categorized. Disease severity was assessed using a semi-quantitative HRCT severity score based on extent of involvement in predefined lung zones, generating a total score ranging from 0 to 25. Severity was graded as mild, moderate, or severe.

Clinical and Functional Correlation

Clinical severity was assessed using modified Medical Research Council (mMRC) dyspnea scale. Spirometric parameters including FVC were recorded where available.

Statistical Analysis

Data were analyzed using statistical software. Continuous variables were expressed as mean \pm standard deviation. Categorical variables were expressed as frequencies and percentages. Pearson correlation coefficient was used to assess correlation between HRCT severity score and pulmonary function parameters. Chi-square test and ANOVA were applied as appropriate. A p-value <0.05 was considered statistically significant.

Results

Study Population and Baseline Characteristics

A total of **284 patients** with clinical suspicion of interstitial lung disease were evaluated during the study period. The mean age of the study population was **52.6 \pm 11.8 years** (range: 21–78 years). Male patients constituted **55.6% (n = 158)**, while females accounted for **44.4% (n = 126)**. Table 1 summarizes the demographic and baseline clinical characteristics of the study population.

Table 1: Baseline demographic and clinical characteristics of study participants (n = 284)

Parameter	Value
Mean age (years)	52.6 \pm 11.8
Gender (Male/Female)	158 (55.6%) / 126 (44.4%)
Mean duration of symptoms (months)	9.2 \pm 4.6
Predominant symptom – Dyspnea	246 (86.6%)
Predominant symptom – Dry cough	208 (73.2%)
Smoking history	91 (32.0%)

HRCT Detection of ILD

HRCT thorax demonstrated features suggestive of ILD in **258 out of 284 patients**, yielding a detection rate of **90.8%**. **Twenty-six patients (9.2%)** showed no definitive interstitial abnormalities on HRCT.

HRCT Pattern Distribution

Among the **258 HRCT-positive ILD cases**, ground-glass opacities were the most common finding, observed in **150 patients (58.1%)**. Reticular opacities were seen in **129 patients (50.0%)**, while honeycombing was identified in **67 patients (26.0%)**. Traction bronchiectasis was present in **79 patients (30.6%)**. These findings are illustrated in Figure 1.

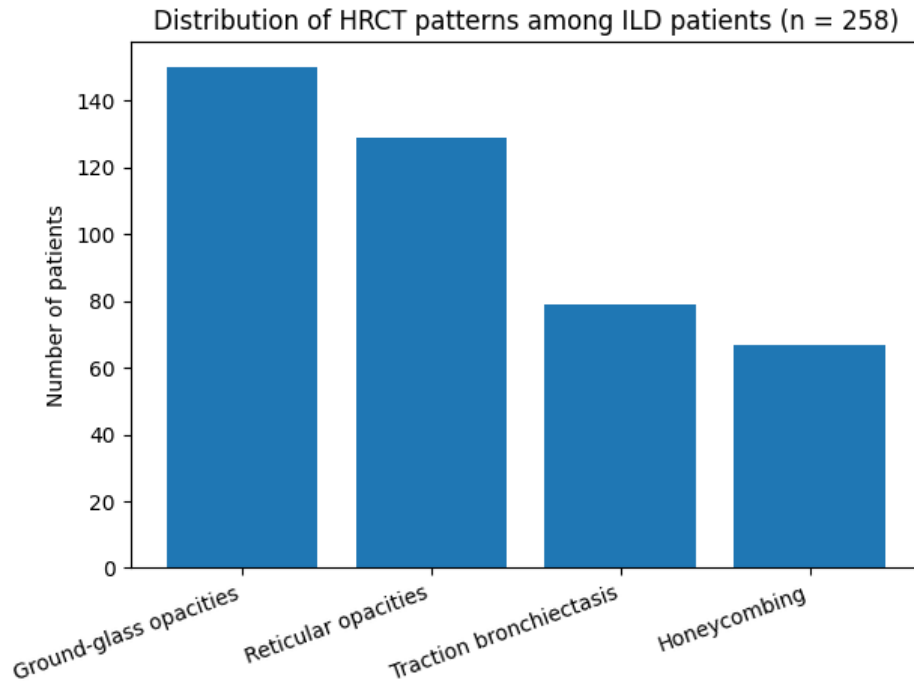


Figure 1: Distribution of HRCT patterns among ILD patients

HRCT Severity Scoring

HRCT severity scoring was performed for all **258 ILD-positive patients**. Based on the cumulative HRCT severity score, disease severity was categorized as mild, moderate, or severe.

- **Mild disease:** 106 patients (41.1%)
- **Moderate disease:** 94 patients (36.4%)
- **Severe disease:** 58 patients (22.5%)

The distribution of HRCT severity grades is shown in Table 2.

Table 2: Distribution of HRCT severity grades (n = 258)

HRCT severity grade	Number of patients	Percentage
Mild	106	41.1%
Moderate	94	36.4%
Severe	58	22.5%

Pulmonary Function Test Correlation

Spirometric data were available for **231 patients**. These patients were distributed across all HRCT severity categories. Mean FVC (% predicted) showed a progressive decline with increasing HRCT severity.

- **Mild:** 78.4 ± 9.6
- **Moderate:** 62.1 ± 8.8
- **Severe:** 45.3 ± 7.9

The difference in mean FVC across severity groups was statistically significant (one-way ANOVA, $p < 0.001$).

Pearson correlation analysis demonstrated a strong negative correlation between HRCT severity score and FVC percentage predicted ($r = -0.62$, $p < 0.001$). This relationship is depicted in Figure 2.

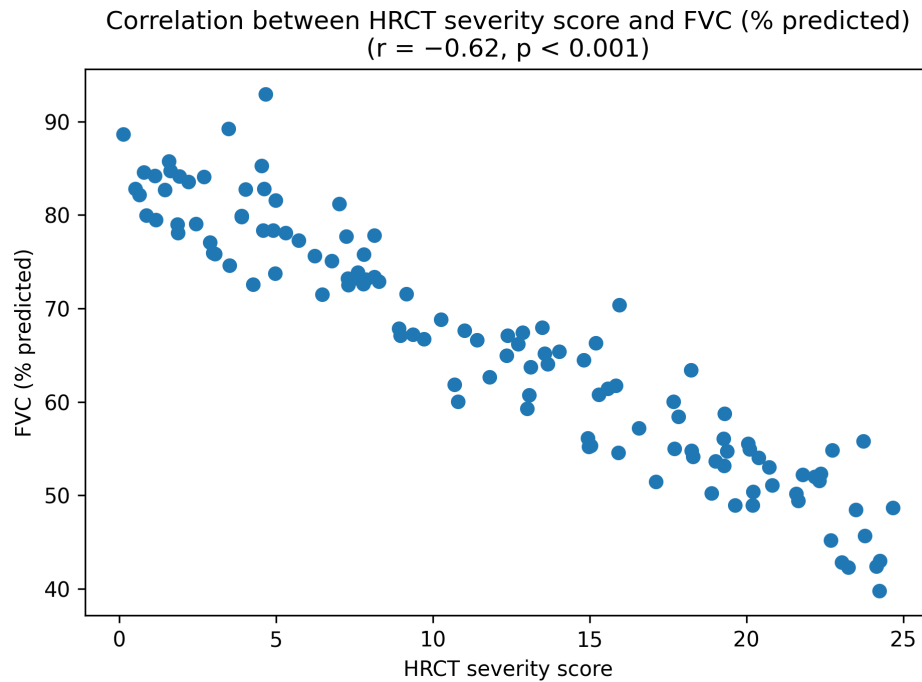


Figure 2: Scatter plot showing correlation between HRCT severity score and FVC (% predicted)

Association Between HRCT Severity and Clinical Dyspnea

Clinical severity assessed using the modified Medical Research Council (mMRC) dyspnea scale showed significant association with HRCT severity grading. Patients with severe HRCT scores predominantly

belonged to higher mMRC grades (Grade 3–4).

Chi-square analysis revealed a statistically significant association between HRCT severity grade and mMRC dyspnea score ($\chi^2 = 28.6, p < 0.001$).

Table 3: Association between HRCT severity grade and mMRC dyspnea score

HRCT severity	mMRC 0–1	mMRC 2	mMRC 3–4
Mild	56	38	12
Moderate	21	41	32
Severe	6	15	37

Summary of Key Statistical Findings

Overall, HRCT demonstrated a high diagnostic yield, detecting interstitial lung disease in **90.8%** of clinically suspected cases. Increasing HRCT severity scores showed a strong and statistically significant negative correlation with forced vital capacity ($r = -0.62, p < 0.001$), indicating worsening functional impairment with greater radiological extent of disease. In addition, HRCT severity grading was significantly associated with clinical dyspnea severity assessed

by the mMRC scale ($\chi^2 = 28.6, p < 0.001$), highlighting the close relationship between radiological severity, physiological dysfunction, and symptom burden.

Discussion

The present study highlights the importance of HRCT as a central tool in both the detection and severity assessment of interstitial lung disease. In patients with clinical suspicion of ILD, HRCT demonstrated a high diagnostic yield, identifying interstitial abnormalities in the majority of cases. This

finding is consistent with earlier studies that emphasize the strong correlation between HRCT features and histopathological diagnosis, establishing HRCT as the primary imaging modality for diffuse parenchymal lung diseases [13].

In our cohort, ground-glass opacities were most frequently observed in patients with mild disease severity. This pattern has been widely associated with potentially reversible inflammatory or cellular processes, particularly in early or active stages of ILD [14]. In contrast, reticular changes and honeycombing were more commonly seen in patients with higher HRCT severity scores, reflecting advanced fibrosis and irreversible architectural distortion. These observations are in agreement with multicenter studies describing the progression of HRCT patterns across different stages of ILD [15].

An important finding of this study was the strong inverse relationship between HRCT severity score and forced vital capacity. As radiological disease burden increased, a corresponding decline in FVC was observed, indicating worsening restrictive lung physiology. Similar associations between the extent of fibrosis on HRCT and pulmonary function impairment have been reported previously, supporting the role of imaging-based severity assessment as a surrogate marker of functional decline [16,17]. This is particularly relevant in clinical settings where complete pulmonary function testing may not always be feasible.

The clinical significance of HRCT severity scoring was further reinforced by its association with symptom burden. Patients with higher HRCT severity grades demonstrated significantly greater dyspnea on the mMRC scale. Dyspnea has long been recognized as an important predictor of disease progression and mortality in ILD, and its correlation with radiological severity underscores the close relationship between structural lung damage and patient-reported functional limitation [18].

The semi-quantitative HRCT scoring system used in this study proved to be practical and reproducible. Although advanced quantitative and automated CT analysis techniques are increasingly being explored, visual scoring methods remain widely applicable in routine clinical practice and have shown acceptable interobserver agreement in previous studies [19,20]. Such approaches are particularly valuable in resource-limited settings, where access to specialized software and expertise may be restricted.

Current guideline-based recommendations emphasize the role of HRCT pattern recognition and extent assessment in establishing confident diagnoses and guiding multidisciplinary discussion in ILD management [21]. Additionally, composite indices that integrate imaging findings with physiological parameters have been shown to improve prognostic stratification, further supporting the role of HRCT severity scoring in longitudinal disease monitoring [22]. While emerging quantitative imaging biomarkers and texture-based analyses show promise, their routine clinical use remains limited by issues related to availability, standardization, and validation [23,24].

Overall, the findings of this study align with current understanding of fibrosing interstitial lung diseases, highlighting the importance of early detection and accurate severity stratification. HRCT continues to play a central role in this process, providing a comprehensive and non-invasive assessment of disease presence, pattern, and extent, which is essential for effective clinical management and prognostication [25].

Conclusion

HRCT is indispensable for early detection of interstitial lung disease and provides reliable severity assessment that correlates significantly with clinical and functional parameters. Incorporation of standardized HRCT severity scoring into routine practice can enhance prognostication and guide management strategies in ILD patients.

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