

Role of high-resolution computed tomography of the chest in the evaluation of patients with interstitial lung diseases: imaging patterns and correlation with clinical and pulmonary function parameters

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Abstract

Background: Interstitial lung diseases (ILDs) comprise a heterogeneous group of diffuse parenchymal lung disorders in which accurate assessment of pulmonary abnormalities and disease extent is essential. High-resolution computed tomography (HRCT) provides detailed evaluation of lung parenchymal morphology and characteristic ILD patterns.

Objective: To evaluate the role of HRCT chest in patients with clinically suspected ILD and to assess the relationship between HRCT findings, clinical features, and pulmonary function parameters.

Materials and Methods: A hospital-based prospective observational study was conducted in the Department of

Radiodiagnosis, Karnataka Medical College and Research Institute, Hubballi, Karnataka, over 18 months. Fifty patients with clinically suspected ILD were included. HRCT was evaluated for parenchymal abnormalities, distribution, predominant ILD pattern, fibrosis, and extent of disease. Pulmonary function parameters including FVC, FEV₁, FEV₁/FVC and DLCO were assessed wherever feasible. Clinical, radiological and pulmonary function findings were correlated.

Results: Dyspnea was the commonest symptom (86.0%), followed by chronic cough (72.0%). Reticular abnormalities (76.0%) and ground-glass opacities (68.0%) were the most frequent HRCT findings. Peripheral/subpleural involvement was observed in

62.0% of patients, while lower-lung predominance was seen in 58.0%. UIP was the most common HRCT pattern (36.0%), followed by NSIP (20.0%). Fibrotic involvement was predominant in 56.0% of patients. Mean FVC and DLCO progressively decreased with increasing HRCT disease extent.

Conclusion: HRCT chest is valuable for characterization and assessment of ILD, providing important information regarding imaging pattern, distribution and disease extent. Correlation of HRCT findings with clinical features and pulmonary function parameters provides a comprehensive assessment of disease severity.

Keywords: Interstitial Lung Disease, HRCT Chest, UIP; NSIP, Pulmonary Function Tests, FVC, DLCO, Pulmonary Fibrosis.

Introduction

Interstitial lung diseases (ILDs) comprise a heterogeneous group of pulmonary disorders characterized by varying degrees of inflammation, alveolar injury, and fibrosis. They include idiopathic interstitial pneumonias, connective-tissue-disease-associated ILD, hypersensitivity pneumonitis, occupational and environmental lung diseases, and drug-related interstitial disorders. Patients commonly present with nonspecific respiratory symptoms such as progressive dyspnea, chronic cough and reduced exercise tolerance, making accurate radiological characterization important for diagnosis and management.

High-resolution computed tomography (HRCT) has become an essential imaging modality in the evaluation of ILD because of its high spatial resolution and ability to demonstrate abnormalities involving the pulmonary interstitium and secondary pulmonary lobules. Important

HRCT findings include ground-glass opacity, reticulation, interlobular septal thickening, traction bronchiectasis, architectural distortion and honeycombing. Evaluation of the morphology and distribution of these abnormalities allows recognition of characteristic patterns and helps narrow the differential diagnosis.^{1,2}

The distribution of abnormalities is particularly important in differentiating major ILD patterns. A usual interstitial pneumonia (UIP) pattern is generally characterized by basal and subpleural predominant reticulation, traction bronchiectasis and honeycombing, whereas nonspecific interstitial pneumonia (NSIP) more commonly demonstrates bilateral ground-glass opacity and fine reticulation. Accurate recognition of these patterns has important implications for diagnosis and subsequent clinical management.^{3,4}

HRCT also provides valuable information regarding the extent and severity of structural lung disease. Reticulation, traction bronchiectasis, architectural distortion and honeycombing indicate varying degrees of fibrotic remodeling. Assessment of the extent and distribution of these abnormalities can therefore provide information beyond simple pattern recognition and may assist in monitoring disease progression.⁵

Pulmonary function testing provides complementary physiological information in patients with ILD. Forced vital capacity (FVC) is commonly used to assess restrictive impairment, whereas diffusing capacity for carbon monoxide (DLCO) provides an indication of impaired pulmonary gas transfer. Studies have demonstrated associations between the extent of abnormalities on HRCT and reductions in pulmonary function, supporting combined radiological and physiological assessment.^{6,7}

Clinical history is also essential because similar HRCT appearances may occur in different ILDs. Smoking, occupational or environmental exposure, connective tissue disease and drug exposure may provide important etiological clues. Consequently, ILD diagnosis increasingly relies on integration of clinical, radiological and physiological findings within a multidisciplinary framework.^{8,9}

The classification of idiopathic interstitial pneumonias has evolved with increasing recognition of characteristic clinical and radiological patterns. HRCT plays a central role in this classification, particularly in distinguishing chronic fibrosing patterns such as UIP and NSIP from other interstitial pneumonia subtypes.¹⁰

Therefore, the present study was undertaken to evaluate the role of HRCT chest in patients with clinically suspected ILD, with particular emphasis on identifying characteristic imaging patterns, assessing the distribution and extent of pulmonary abnormalities, and correlating HRCT findings with clinical and pulmonary function parameters.

Materials and Methods

Study Design and Setting

A hospital-based prospective observational study was conducted in the Department of Radiodiagnosis at Karnataka Medical College and Research Institute (KMCRI), Hubballi, Karnataka. The study was undertaken to evaluate the role of high-resolution computed tomography (HRCT) of the chest in patients with clinically suspected interstitial lung diseases (ILDs), with particular emphasis on identifying characteristic imaging patterns and correlating HRCT findings with clinical and pulmonary function parameters.

Study Duration

The study was conducted over a period of 18 months.

Study Population

The study population comprised patients presenting to the hospital with clinical suspicion of interstitial lung disease based on respiratory symptoms, clinical examination, relevant laboratory findings, or previous imaging abnormalities and who were referred for HRCT evaluation of the chest.

Sample Size

A total of 50 patients fulfilling the predefined eligibility criteria were included in the study.

Inclusion Criteria

Patients were included if they fulfilled the following criteria:

1. Patients with clinical suspicion of interstitial lung disease.
2. Patients presenting with respiratory symptoms such as progressive dyspnea, chronic cough, or exercise intolerance.
3. Patients referred for HRCT chest evaluation.
4. Patients of either sex and appropriate adult age groups.
5. Patients willing to participate in the study and providing informed consent.
6. Patients in whom technically adequate HRCT images could be obtained.
7. Patients who underwent pulmonary function testing wherever clinically feasible.

Exclusion Criteria

Patients were excluded if they had:

1. Acute infective pulmonary disease without clinical suspicion of ILD.
2. Predominantly obstructive airway disease without evidence of interstitial involvement.

3. Known pulmonary malignancy as the primary diagnosis.
4. Previous extensive thoracic surgery causing significant architectural distortion.
5. Inadequate-quality HRCT images due to motion or technical limitations.
6. Incomplete clinical or pulmonary function data.
7. Patients who did not provide consent for participation.

Clinical Evaluation

A detailed clinical history and examination were performed for all enrolled patients. Demographic and clinical details including age, sex, presenting symptoms, duration of symptoms, smoking history, occupational or environmental exposure, history of connective tissue disease, relevant drug exposure, and other associated medical conditions were recorded.

The major presenting respiratory symptoms, including dyspnea, cough, chest discomfort, and exercise intolerance, were documented. Clinical examination included assessment of respiratory rate, oxygen saturation, and relevant respiratory findings such as bilateral basal crepitations.

Pulmonary Function Testing

Pulmonary function tests (PFTs) were performed using standard institutional procedures wherever feasible. The parameters evaluated included forced vital capacity (FVC), forced expiratory volume in one second (FEV1), FEV1/FVC ratio, and diffusing capacity for carbon monoxide (DLCO) when available.

The obtained pulmonary function parameters were recorded and compared with the HRCT findings to assess the relationship between the extent/pattern of structural lung abnormalities and functional impairment.

HRCT Chest Examination

HRCT examination of the chest was performed using a multidetector computed tomography scanner according to the institutional HRCT protocol. Patients were examined in the supine position during suspended full inspiration whenever possible.

Thin-section axial images were obtained with appropriate reconstruction algorithms to provide high spatial resolution of the lung parenchyma. Multiplanar coronal and sagittal reformatted images were also reviewed where required.

Images were evaluated using appropriate lung and mediastinal window settings. Expiratory images were obtained when clinically indicated, particularly in patients with suspected small-airway involvement or air trapping.

HRCT Image Assessment

The HRCT examinations were systematically evaluated for the presence, distribution, and extent of interstitial and associated pulmonary abnormalities.

The following imaging features were assessed:

- Ground-glass opacity
- Reticular opacities
- Interlobular septal thickening
- Intralobular lines
- Honeycombing
- Traction bronchiectasis
- Architectural distortion
- Consolidation
- Nodules
- Cysts
- Air trapping
- Emphysematous changes
- Pleural abnormalities
- Mediastinal lymphadenopathy, where present

The distribution of abnormalities was assessed according to the axial and craniocaudal extent, including peripheral/subpleural, central, peribronchovascular, upper-lung, lower-lung, or diffuse involvement.

Assessment of Interstitial Lung Disease Patterns

Based on the predominant HRCT features and their distribution, patients were categorized into appropriate radiological patterns of interstitial lung disease. Particular attention was given to patterns suggestive of:

- Usual interstitial pneumonia (UIP)
- Probable UIP
- Nonspecific interstitial pneumonia (NSIP)
- Organizing pneumonia
- Hypersensitivity pneumonitis
- Lymphoid interstitial pneumonia
- Other indeterminate or unclassifiable interstitial patterns

The presence of fibrosis was assessed based on findings such as reticulation, traction bronchiectasis, architectural distortion, and honeycombing. The distribution and extent of fibrosis were documented.

Assessment of Disease Extent

The extent of pulmonary involvement on HRCT was assessed by evaluating the proportion of lung parenchyma affected and the distribution of abnormalities. Particular attention was given to the presence and extent of fibrotic changes, ground-glass opacities, reticulation, honeycombing, and traction bronchiectasis.

Where appropriate, HRCT findings were categorized as predominantly fibrotic, inflammatory/non-fibrotic, or mixed based on the dominant imaging characteristics.

Clinical and Radiological Correlation

HRCT findings were correlated with clinical parameters including duration and severity of respiratory symptoms,

smoking history, relevant exposure history, and clinical examination findings.

The imaging patterns were also correlated with pulmonary function parameters, particularly FVC, FEV1, FEV1/FVC ratio, and DLCO, wherever available. The relationship between the extent of HRCT abnormalities and degree of pulmonary functional impairment was assessed.

Image Interpretation

All HRCT examinations were systematically reviewed by a radiologist experienced in thoracic imaging. The findings were recorded using a structured data collection format. When multiple abnormalities were present, each relevant finding was documented separately.

The final radiological impression was based on the predominant HRCT pattern, distribution of abnormalities, presence or absence of fibrosis, and associated findings.

Data Collection and Statistical Analysis

All demographic, clinical, HRCT, and pulmonary function data were entered into a structured database and analyzed using appropriate statistical methods.

Categorical variables were expressed as frequency and percentage, while continuous variables were expressed as mean $\pm$ standard deviation or median with interquartile range, as appropriate.

The association between categorical clinical variables and HRCT patterns was assessed using the Chi-square test or Fisher's exact test, as appropriate. Correlation between HRCT findings and pulmonary function parameters such as FVC and DLCO was assessed using an appropriate correlation test, such as Pearson's or Spearman's correlation coefficient, depending on data distribution. A p-value <0.05 was considered statistically significant.

Results and Observations

A total of 50 patients with clinically suspected interstitial lung disease (ILD) were included in the study. All patients underwent high-resolution computed tomography (HRCT) of the chest, and pulmonary function testing was performed where feasible. HRCT findings were assessed with respect to the predominant imaging pattern, distribution of disease, extent of fibrosis, and associated abnormalities. Clinical and pulmonary function parameters were subsequently correlated with the HRCT findings.

Table 1: Age-wise distribution of study participants

Age group(years)	No. of patients	Percentage (%)
18–30	4	8.0
31–40	8	16.0
41–50	13	26.0
51–60	15	30.0
>60	10	20.0
Total	50	100.0

The majority of patients belonged to the 51–60-year age group (30.0%), followed by those aged 41–50 years (26.0%). Patients aged >60 years constituted 20.0% of the study population.

Table 2: Sex-wise distribution

Sex	No. of patients	Percentage (%)
Male	29	58.0
Female	21	42.0
Total	50	100.0

Males constituted the majority of the study population, accounting for 58.0%, while females accounted for 42.0%.

Table 3: Clinical symptoms of the study participants

Clinical symptom	No. of patients	Percentage %
Dyspnea	43	86.0
Chronic cough	36	72.0

Exercise intolerance	28	56.0
Fatigue	22	44.0
Chest discomfort	12	24.0

Multiple symptoms were present in several patients; therefore, percentages do not total 100%.

Dyspnea was the most frequent presenting symptom (86.0%), followed by chronic cough (72.0%) and exercise intolerance (56.0%).

Table 4: Relevant clinical and exposure history

Clinical/exposure factor	No. of patients	Percentage (%)
Smoking history	18	36.0
Occupational/environmental exposure	14	28.0
Connective tissue disease	10	20.0
Relevant drug exposure	5	10.0
No identifiable risk factor	16	32.0

Categories may overlap because some patients had more than one relevant exposure or risk factor.

Table 5: HRCT findings in the study population

HRCT finding	No. of patients	Percentage (%)
Reticular abnormality	38	76.0
Ground-glass opacity	34	68.0
Traction bronchiectasis	26	52.0
Interlobular septal thickening	24	48.0
Architectural distortion	22	44.0
Honeycombing	20	40.0
Air trapping	12	24.0
Consolidation	8	16.0
Pulmonary nodules	6	12.0
Cysts	5	10.0

Multiple HRCT abnormalities could be present in the same patient.

Reticular abnormalities were the most frequently observed HRCT finding (76.0%), followed by ground-glass opacities (68.0%) and traction bronchiectasis (52.0%). Honeycombing was observed in 40.0% of patients.

Table 6: Distribution of pulmonary abnormalities on HRCT

Distribution	No. of patients	Percentage (%)
Peripheral/subpleural predominance	31	62.0
Lower-lung predominance	29	58.0
Diffuse involvement	20	40.0
Peribronchovascular predominance	12	24.0
Upper-lung predominance	9	18.0

Distribution patterns could overlap.

Peripheral/subpleural involvement was the predominant distribution, seen in 62.0% of patients, while lower-lung predominance was observed in 58.0%.

Table 7: HRCT-based diagnostic patterns

HRCT pattern	No. of patients	Percentage (%)
UIP	18	36.0
NSIP	10	20.0
Probable UIP	8	16.0
Hypersensitivity pneumonitis	6	12.0
Organizing pneumonia	4	8.0
LIP	2	4.0
Indeterminate/unclassifiable	2	4.0

Total	50	100.0
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The usual interstitial pneumonia (UIP) pattern was the most common HRCT pattern (36.0%), followed by NSIP (20.0%) and probable UIP (16.0%).

Table 8: Predominant nature of pulmonary involvement

Predominant involvement	No. of patients	Percentage (%)
Fibrotic	28	56.0
Non-fibrotic/inflammatory	12	24.0
Mixed fibrotic and inflammatory	10	20.0
Total	50	100.0

Fibrotic disease constituted the predominant form of involvement, accounting for 56.0% of the study population.

Table 9: Extent of disease on HRCT

Extent of involvement	No. of patients	Percentage (%)
Mild (<25%)	12	24.0
Moderate (25–50%)	21	42.0
Severe (>50%)	17	34.0
Total	50	100.0

Moderate pulmonary involvement was most frequent (42.0%), followed by severe involvement (34.0%).

Table 10: Pulmonary function parameters

Parameter	Mean $\pm$ SD
FVC (% predicted)	67.4 $\pm$ 15.2
FEV ₁ (% predicted)	70.1 $\pm$ 14.8
FEV ₁ /FVC (%)	86.2 $\pm$ 7.4
DLCO (% predicted)	58.6 $\pm$ 16.5

The pulmonary function profile demonstrated a reduction in FVC and DLCO, consistent with predominantly restrictive and impaired gas-transfer physiology among patients with ILD.

Table 11: Association between HRCT disease extent and FVC

HRCT extent	No. of patients	FVC (% predicted), Mean $\pm$ SD
Mild	12	78.6 $\pm$ 8.9
Moderate	21	67.9 $\pm$ 10.7
Severe	17	57.1 $\pm$ 11.2

A progressive reduction in mean FVC was observed with increasing extent of pulmonary involvement on HRCT.

Table 12: Association between HRCT disease extent and DLCO

HRCT extent	No. of patients	DLCO (% predicted), Mean $\pm$ SD
Mild	12	70.8 $\pm$ 11.4
Moderate	21	59.4 $\pm$ 12.8
Severe	17	48.7 $\pm$ 13.6

Mean DLCO showed a progressive decline with increasing HRCT extent of disease.

Table 13: HRCT pattern and pulmonary function parameters

HRCT pattern	FVC (% predicted), Mean $\pm$ SD	DLCO (% predicted), Mean $\pm$ SD
UIP	59.8 $\pm$ 10.6	51.2 $\pm$ 12.7
Probable UIP	64.2 $\pm$ 9.8	56.8 $\pm$ 11.5
NSIP	72.6 $\pm$ 12.1	63.5 $\pm$ 13.2
Hypersensitivity pneumonitis	69.8 $\pm$ 11.4	61.7 $\pm$ 12.4
Organizing pneumonia	76.5 $\pm$ 8.7	68.2 $\pm$ 10.1
LIP	74.0 $\pm$ 9.2	66.5 $\pm$ 8.4
Indeterminate/unclassifiable	68.5 $\pm$ 7.1	59.5 $\pm$ 9.2

Patients with a UIP pattern demonstrated comparatively lower mean FVC and DLCO values than those with NSIP and other non-UIP patterns.

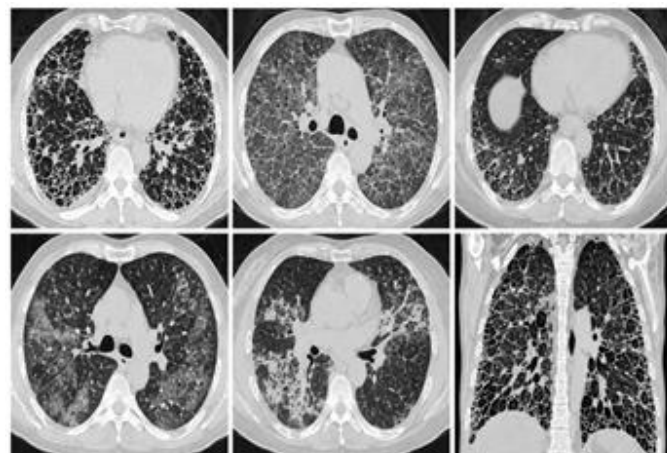


Figure 1: UIP, Figure 2 — NSIP, Figure 3 — Probable UIP, Figure 4 — Hypersensitivity pneumonitis Figure 5 — Organizing pneumonia, Figure 6 — Fibrotic ILD

Discussion

The present study evaluated 50 patients with clinically suspected interstitial lung disease using HRCT of the chest, with assessment of imaging patterns, distribution and extent of pulmonary abnormalities and correlation with pulmonary function parameters. The methodology included systematic evaluation of ground-glass opacity, reticulation, interlobular septal thickening, honeycombing, traction bronchiectasis, architectural distortion and other associated findings.

In the present study, patients in the 51–60-year age group constituted the largest proportion, followed by those aged 41–50 years. A slight male predominance was also observed. The predominance of middle-aged and older patients is consistent with the broad clinical spectrum of ILD, which includes age-associated fibrotic disorders as well as exposure-related, autoimmune and idiopathic diseases. Demographic characteristics, however, are nonspecific and need to be interpreted together with clinical history and imaging findings.

Dyspnea was the most common presenting symptom, followed by chronic cough and exercise intolerance. These symptoms are typical manifestations of diffuse parenchymal lung disease and may reflect reduced lung compliance, impaired gas exchange and progressive loss of functioning pulmonary parenchyma. The presence of respiratory symptoms in combination with characteristic HRCT abnormalities therefore provides an important basis for clinical suspicion of ILD.

Reticular abnormalities were the most frequently observed HRCT finding in the present study, followed by ground-glass opacity and traction bronchiectasis. These findings represent important morphological manifestations of interstitial and fibrotic lung disease. HRCT is particularly useful because thin-section imaging can demonstrate subtle parenchymal abnormalities and their anatomical distribution, facilitating differentiation among various ILD patterns.^{1,2}

Honeycombing was observed in a substantial proportion of patients, together with traction bronchiectasis and architectural distortion. These findings are important indicators of established pulmonary fibrosis. Traction bronchiectasis results from fibrotic retraction of the surrounding lung tissue, while honeycombing represents advanced architectural destruction. The combination of these abnormalities, particularly when associated with basal and subpleural predominance, is strongly relevant to the recognition of a UIP pattern.^{3,5}

Peripheral/subpleural and lower-lung involvement were the predominant distributions in the present study. This distribution is characteristic of several fibrotic ILDs, particularly UIP. Recognition of the axial and craniocaudal distribution of abnormalities is therefore an essential component of HRCT interpretation because the same elementary finding, such as reticulation or ground-

glass opacity, can have different diagnostic implications depending on its distribution.^{3,4}

The UIP pattern was the most frequently identified HRCT pattern in the present study, followed by NSIP and probable UIP. This finding emphasizes the importance of careful assessment of the combination and distribution of fibrotic abnormalities. Current classification systems distinguish definite UIP, probable UIP and indeterminate patterns because these categories contribute to diagnostic decision-making and multidisciplinary assessment.^{3,4,10}

More than half of the patients demonstrated predominantly fibrotic involvement, while the remaining patients showed predominantly non-fibrotic/inflammatory or mixed abnormalities. The distinction between fibrotic and non-fibrotic disease is clinically important because fibrosis is associated with irreversible structural remodeling and can substantially influence pulmonary function. HRCT is particularly valuable for demonstrating the extent of fibrosis through assessment of reticulation, traction bronchiectasis, architectural distortion and honeycombing.⁵

A progressive decline in FVC was observed with increasing HRCT disease extent in the present study. Patients with severe radiological involvement had lower mean FVC compared with those with mild involvement. This observation indicates that increasing structural involvement of the lung is associated with greater restriction of lung volumes. Previous studies have similarly demonstrated relationships between HRCT abnormalities and pulmonary function in fibrotic lung disease.⁶

DLCO also showed a progressive reduction with increasing HRCT disease extent. The decline in DLCO may reflect increasing impairment of the alveolar-

capillary interface and loss of functioning pulmonary vascular and alveolar surface area. The association between HRCT abnormalities and pulmonary function has been demonstrated particularly well in connective-tissue-disease-associated fibrotic lung disease, where HRCT extent and physiological impairment provide complementary information regarding disease severity.^{7,9} Patients with the UIP pattern in the present study demonstrated comparatively lower mean FVC and DLCO than patients with NSIP and several other HRCT patterns. This finding may reflect the greater degree of fibrotic architectural distortion associated with UIP-pattern disease. Nevertheless, HRCT pattern should not be considered an independent surrogate for physiological severity because the degree of fibrosis, disease extent, comorbidities and underlying etiology can all influence pulmonary function.^{4,10}

The findings further emphasize the importance of integrating clinical information with HRCT interpretation. Smoking history, occupational or environmental exposure, connective tissue disease and relevant drug exposure may substantially influence the differential diagnosis. Consequently, the final interpretation of an ILD pattern should be based on the combination of clinical context, HRCT appearance and physiological findings rather than on imaging morphology alone.⁸

The present findings also support the role of systematic HRCT evaluation in ILD. Assessment of individual abnormalities followed by analysis of their distribution, extent and combination permits identification of recognizable radiological patterns. This structured approach is particularly valuable for differentiating fibrotic from predominantly inflammatory disease and

for identifying patients who may benefit from further multidisciplinary evaluation.^{1,5}

The classification of ILDs has increasingly emphasized multidisciplinary integration of clinical, radiological and pathological information. The evolution of the ATS/ERS classification has reinforced the importance of characteristic imaging patterns in the diagnosis of idiopathic interstitial pneumonias, while HRCT has become central to the recognition and categorization of these patterns.¹⁰

Overall, the present study demonstrates the important role of HRCT in the evaluation of suspected ILD. Reticulation, ground-glass opacity and traction bronchiectasis were frequent findings, with subpleural and lower-lung predominance being common. UIP was the most frequent imaging pattern, and increasing HRCT disease extent was associated with progressively reduced FVC and DLCO. These findings support the use of HRCT together with clinical assessment and pulmonary function testing for comprehensive evaluation of patients with ILD.

Conclusion

HRCT chest is a valuable imaging modality for the evaluation of interstitial lung diseases, enabling accurate characterization of disease patterns, distribution, and extent of pulmonary involvement. In the present study, UIP was the predominant HRCT pattern, while increasing radiological disease extent was associated with reduced FVC and DLCO. Integration of HRCT findings with clinical assessment and pulmonary function testing provides a comprehensive approach to the evaluation and severity assessment of ILD.

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