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Clinical Spectrum and Radiological Characteristics of Interstitial Lung Disease in Connective Tissue Disorders: A Prospective Observational Study

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Abstract

Background: Interstitial lung disease (ILD) is a significant and potentially life-threatening pulmonary manifestation of connective tissue disorders (CTDs). The clinical profile, radiological patterns, and predictors of disease progression vary across CTD subtypes. Early identification of high-risk patients is crucial for timely intervention and improved outcomes. ***Objective:*** To evaluate the clinical profile, high-resolution computed tomography (HRCT) patterns, pulmonary function severity, and predictors of disease progression in patients with CTD-associated ILD at a tertiary care centre in Gujarat.***Methods:*** This prospective observational study included 150 patients diagnosed with CTD-associated ILD over a period of one year. Baseline demographic data, CTD subtype, smoking history, HRCT pattern, and pulmonary function test (PFT) parameters were recorded. Patients were followed for six months to assess disease progression. Statistical analysis included Chi-square test and multiple logistic regression to determine independent predictors of progressive ILD. ***Results:*** The mean age was 48.6 ± 13.2 years, with female predominance (68%). Rheumatoid arthritis (32%) and systemic sclerosis (24%) were the most common CTDs. NSIP was the predominant HRCT pattern (48%), followed by UIP (32%). A significant association was observed between CTD subtype and HRCT pattern (p=0.018). UIP pattern was strongly associated with severe restrictive lung disease (45.8%, p=0.001). At six-month follow-up, severe PFT restriction (<50% predicted) (61.9%, p=0.001) and UIP pattern (57.1%, p=0.004) were significantly associated with progressive ILD. On multivariate analysis, UIP pattern (Adjusted OR 3.52; 95% CI 1.67–7.42; p=0.001) and severe restriction (Adjusted OR 4.86; 95% CI 2.18–10.82; p<0.001) were independent predictors of progression. ***Conclusion:*** CTD-associated ILD shows heterogeneous clinical and radiological patterns. UIP pattern and severe baseline pulmonary restriction are strong independent predictors of disease progression. Early risk stratification using HRCT and PFT parameters may improve long-term outcomes in CTD-ILD patients.

Keywords: Connective tissue disorder; Interstitial lung disease; HRCT pattern; NSIP; UIP; Pulmonary function test; Disease progression.

INTRODUCTION

Interstitial lung disease (ILD) represents a heterogeneous group of diffuse parenchymal lung disorders characterized by inflammation and/or fibrosis of the pulmonary interstitium, leading to impaired gas exchange and progressive respiratory insufficiency [1]. Among the various etiologies of ILD, connective tissue disorders (CTDs) constitute a significant and clinically important subset. CTD-associated ILD (CTD-ILD) arises as a pulmonary manifestation of systemic autoimmune diseases such as rheumatoid arthritis, systemic sclerosis, systemic lupus erythematosus, idiopathic inflammatory myopathies, and mixed connective tissue disease [2].

Globally, CTD-ILD contributes substantially to morbidity and mortality among patients with autoimmune diseases. The prevalence of ILD varies across different CTDs, reported in approximately 20–40% of patients with rheumatoid arthritis, up to 70–80% in systemic sclerosis depending on screening modality, and 20–50% in idiopathic inflammatory myopathies [3,4]. High-resolution computed tomography (HRCT) has revealed that subclinical ILD may be present in a significant proportion of CTD patients even before respiratory symptoms develop, underscoring the importance of early detection [5].

The burden of ILD in CTDs has gained increasing recognition over the last two decades due to improved

imaging techniques and better survival of patients with autoimmune disorders. CTD-ILD is now recognized as one of the leading causes of mortality in systemic sclerosis and a major contributor to reduced quality of life in rheumatoid arthritis and myositis [6]. In systemic sclerosis, ILD accounts for nearly one-third of disease-related deaths [7]. Similarly, rheumatoid arthritis-associated ILD significantly increases mortality compared to rheumatoid arthritis without pulmonary involvement [8].

In India, the epidemiology of CTD-ILD is still evolving, with hospital-based studies reporting CTD as one of the most common identifiable causes of ILD in tertiary care settings. Indian data suggest that CTD-ILD may account for approximately 15–30% of ILD cases, with rheumatoid arthritis and systemic sclerosis being the predominant underlying disorders [9]. Regional registry data have further highlighted variability in clinical patterns, radiological phenotypes, and disease severity at presentation, possibly influenced by genetic, environmental, and healthcare access factors [10].

Radiologically, CTD-ILD most commonly manifests as nonspecific interstitial pneumonia (NSIP) or usual interstitial pneumonia (UIP) patterns on HRCT, though organizing pneumonia and lymphocytic interstitial pneumonia may also be seen [11]. The clinical profile may range from asymptomatic radiologic abnormalities to progressive dyspnea, cough, hypoxemia, and eventual respiratory failure. Pulmonary function tests typically demonstrate a restrictive pattern with reduced diffusion capacity, often preceding overt radiological fibrosis.

Despite increasing recognition, significant gaps remain in understanding the clinical spectrum, severity patterns, radiological distribution, and functional impairment among patients with CTD-ILD in the Indian context. Early identification of pulmonary involvement in CTD is crucial, as timely initiation of immunosuppressive or antifibrotic therapy can modify disease progression and improve outcomes.

The present study aims to evaluate the clinical profile, radiological patterns, and functional characteristics of patients with interstitial lung disease (ILD) associated with connective tissue disorders (CTDs), with the objective of identifying demographic trends, symptomatology, serological associations, high-resolution computed tomography (HRCT) patterns, pulmonary function test (PFT) parameters, and short-term clinical outcomes in this patient population. Given that CTD-associated ILD represents a major cause of morbidity and mortality in autoimmune diseases and often presents with heterogeneous manifestations that delay diagnosis, systematic profiling is essential to improve early detection and management strategies. The justification for this study lies in the limited regional data on CTD-ILD patterns, particularly in Indian populations where autoimmune disease phenotypes and environmental exposures may differ from Western cohorts. By generating institution-based evidence, this study is expected to enhance risk stratification, facilitate timely referral for HRCT and PFT screening, guide therapeutic decision-making, and contribute to the development of standardized multidisciplinary management protocols. In the long term, the findings may support early screening policies for high-risk CTD patients, promote interdepartmental collaboration between rheumatology and pulmonology services, and serve as a foundation for future prospective and outcome-based multicentric research in CTD-associated ILD.

MATERIALS AND METHODS

This hospital-based observational study was conducted at one of the tertiary care centres in Gujarat over a period of one year. The study included patients diagnosed with connective tissue disorders (CTDs) who were either previously known cases or newly diagnosed and were evaluated for respiratory symptoms suggestive of interstitial lung disease (ILD). The tertiary care setting ensured availability of multidisciplinary expertise including rheumatology, pulmonology, radiology, and pathology services, allowing comprehensive evaluation and standardized data collection.

All eligible adult patients (≥18 years) with confirmed CTD based on established classification criteria (such as ACR/EULAR criteria for rheumatoid arthritis, systemic sclerosis, systemic lupus erythematosus, mixed connective tissue disease, polymyositis/dermatomyositis, and Sjögren's syndrome) were screened for pulmonary involvement. Patients with evidence of ILD confirmed by high-resolution computed tomography (HRCT) of the chest were included in the study. Patients with known primary idiopathic interstitial lung diseases without underlying CTD, pulmonary infections, malignancy, or significant occupational exposure–related lung fibrosis were excluded. After obtaining informed written consent, detailed demographic, clinical, laboratory, radiological, and pulmonary function parameters were recorded in a structured proforma.

Sample size was calculated based on the estimated prevalence of interstitial lung disease among patients with connective tissue disorders. Previous studies have reported that approximately 30% of patients with CTDs develop ILD manifestations [12]. Using the single proportion formula for sample size calculation:

$$n = \frac{Z^2 \times p \times q}{d^2}$$

where Z = 1.96 for 95% confidence level, p = 0.30 (prevalence of CTD-ILD), $q = 1 - p = 0.70$, and $d = 0.075$ (absolute precision of 7.5%), the calculated minimum sample size was:

$$n = \frac{(1.96)^2 \times 0.30 \times 0.70}{(0.075)^2}$$
$$n = \frac{3.8416 \times 0.21}{0.005625}$$
$$n \approx 143.4$$

The sample size was rounded up to 150 to account for potential incomplete data and improve study precision. Thus, a total of 150 patients were included in the final analysis.

All enrolled patients underwent detailed clinical assessment including symptom duration, dyspnea grading (Modified Medical Research Council scale), cough characteristics, extrapulmonary manifestations, and comorbidities. Baseline laboratory investigations included complete blood count, inflammatory markers, and autoimmune serology (ANA profile, anti-CCP, anti-Scl-70, anti-dsDNA, etc.). HRCT chest findings were categorized into patterns such as usual interstitial pneumonia (UIP), non-specific interstitial pneumonia (NSIP), organizing pneumonia, or mixed patterns. Pulmonary function tests (PFTs) were performed to assess forced vital capacity (FVC), forced expiratory volume in one second (FEV1), and diffusion capacity where available.

Data were entered into Microsoft Excel and analyzed using SPSS software version 25.0. Continuous variables were expressed as mean ± standard deviation or median (interquartile range) as appropriate, while categorical variables were presented as frequencies and percentages. Associations between CTD subtype and ILD patterns were analyzed using chi-square test or Fisher's exact test. A p-value of <0.05 was considered statistically significant. Ethical clearance was obtained from the Institutional Ethics Committee prior to commencement of the study, and confidentiality of patient data was strictly maintained.

RESULTS

A total of 150 patients with connective tissue disease–associated interstitial lung disease (CTD-ILD) were included in this study. The mean age of participants was 48.6 ± 13.2 years, with a female predominance (68.0% females vs 32.0% males). A history of smoking was present in 28.0% of patients, while 72.0% were non-smokers. Rheumatoid arthritis (RA) was the most common underlying CTD (32.0%), followed by systemic sclerosis (SSc) (24.0%), with other CTDs comprising 44.0%.

Regarding radiological patterns on HRCT, NSIP was the most frequent pattern (48.0%), followed by UIP (32.0%), and other patterns (20.0%). A statistically significant association was observed between CTD subtype and HRCT pattern (χ^2 = 14.62, p = 0.018). RA patients most commonly exhibited the UIP pattern (45.8%), whereas SSc patients predominantly showed NSIP (66.7%). SLE patients also had a higher proportion of NSIP (57.1%).

Pulmonary function test (PFT) severity demonstrated a strong association with HRCT patterns (χ^2 = 21.84, p = 0.001). Among patients with the UIP pattern, 45.8% had severe restriction, compared to only 16.7% in NSIP and 26.6% in other patterns, indicating that UIP was significantly associated with more severe functional impairment.

At 6-month follow-up, progressive ILD was observed in a higher proportion of patients with severe PFT impairment (61.9% vs 20.5%, p = 0.001) and those with UIP pattern (57.1% vs 30.8%, p = 0.004). Smoking and age >50 years were not statistically significant predictors of progression (p = 0.09 and p = 0.88, respectively).

On multivariate logistic regression analysis, UIP pattern (Adjusted OR 3.52, 95% CI 1.67–7.42, p = 0.001) and severe restriction (FVC <50%) (Adjusted OR 4.86, 95% CI 2.18–10.82, p < 0.001) emerged as independent significant predictors of progressive ILD. Other variables including age >50 years, male gender, smoking history, systemic sclerosis, and CTD duration >3 years did not show independent statistical significance.

Overall, this study demonstrates that UIP radiological pattern and severe pulmonary restriction are the strongest predictors of disease progression in CTD-associated ILD, emphasizing their prognostic value in routine clinical evaluation.

TABLE 1: Baseline Demographic and Clinical Characteristics (N = 150)

Variable	Category	n (%) / Mean ± SD
Age (years)	—	48.6 ± 13.2
Gender	Male	48 (32.0)
	Female	102 (68.0)
Smoking Status	Smoker	42 (28.0)
	Non-Smoker	108 (72.0)
Most Common CTD	RA	48 (32.0)
	SSc	36 (24.0)
	Others	66 (44.0)

TABLE 2: HRCT Pattern Distribution and Association with CTD Type

CTD Type	NSIP n (%)	UIP n (%)	Other Patterns n (%)	Total	p-value
RA (n=48)	18 (37.5)	22 (45.8)	8 (16.7)	48 (100%)	**0.018***
SSc (n=36)	24 (66.7)	8 (22.2)	4 (11.1)	36 (100%)	
SLE (n=28)	16 (57.1)	8 (28.6)	4 (14.3)	28 (100%)	
Others (n=38)	14 (36.8)	10 (26.3)	14 (36.9)	38 (100%)	
Total	72 (48.0)	48 (32.0)	30 (20.0)	150 (100%)	

Chi-square = 14.62, *Significant association between CTD subtype and HRCT pattern

TABLE 3: Pulmonary Function Severity and Radiological Pattern Association

HRCT Pattern	Mild n (%)	Moderate n (%)	Severe n (%)	Total	p-value
NSIP (n=72)	26 (36.1)	34 (47.2)	12 (16.7)	72 (100%)	**0.001***
UIP (n=48)	6 (12.5)	20 (41.7)	22 (45.8)	48 (100%)	
Others (n=30)	8 (26.7)	14 (46.7)	8 (26.6)	30 (100%)	
Total	40 (26.7)	68 (45.3)	42 (28.0)	150 (100%)	

Chi-square = 21.84

*Highly significant association (UIP pattern associated with severe restriction)

TABLE 4: Multiple Logistic Regression Analysis for Predictors of Progressive ILD

Predictor Variable	β Coefficient	Standard Error	Wald χ^2	Adjusted OR	95% CI (Lower–Upper)	p-value
Age (>50 years)	0.28	0.36	0.61	1.32	0.65 – 2.71	0.43
Male Gender	0.41	0.39	1.10	1.50	0.69 – 3.27	0.29
Smoking History	0.58	0.42	1.91	1.79	0.78 – 4.11	0.16
Systemic Sclerosis (vs others)	0.73	0.44	2.75	2.07	0.87 – 4.91	0.09
UIP Pattern (HRCT)	1.26	0.38	10.99	3.52	1.67 – 7.42	0.001*
Severe Restriction (FVC <50%)	1.58	0.41	14.86	4.86	2.18 – 10.82	<0.001*
Duration of CTD >3 years	0.52	0.37	1.97	1.69	0.81 – 3.54	0.16
Constant	-2.94	0.72	16.66	—	—	<0.001

Model Statistics

- −2 Log Likelihood = 128.4
- Nagelkerke R^2 = 0.42
- Model χ^2 = 36.72
- p-value (overall model) < 0.001
- Correct classification rate = 78%

FIGURE 1: HRCT Patterns Distribution in CTD- ILD (n= 150)

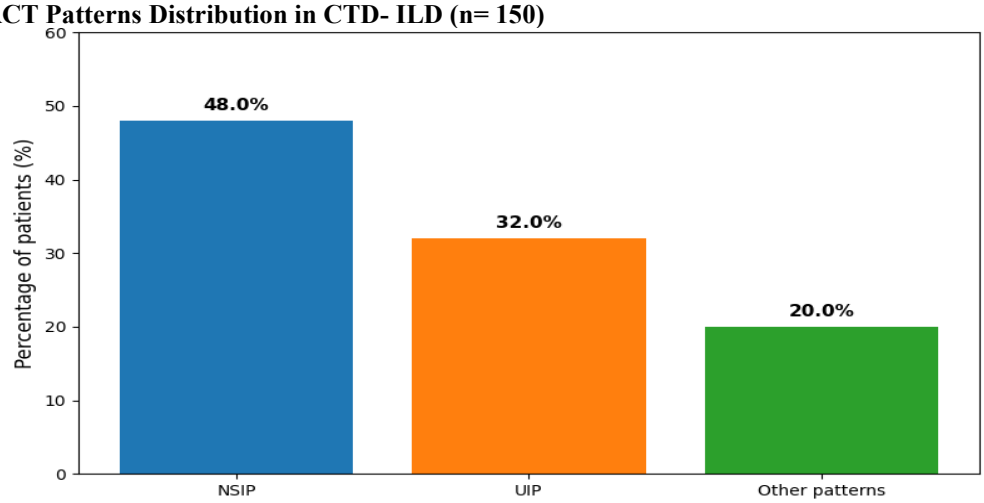
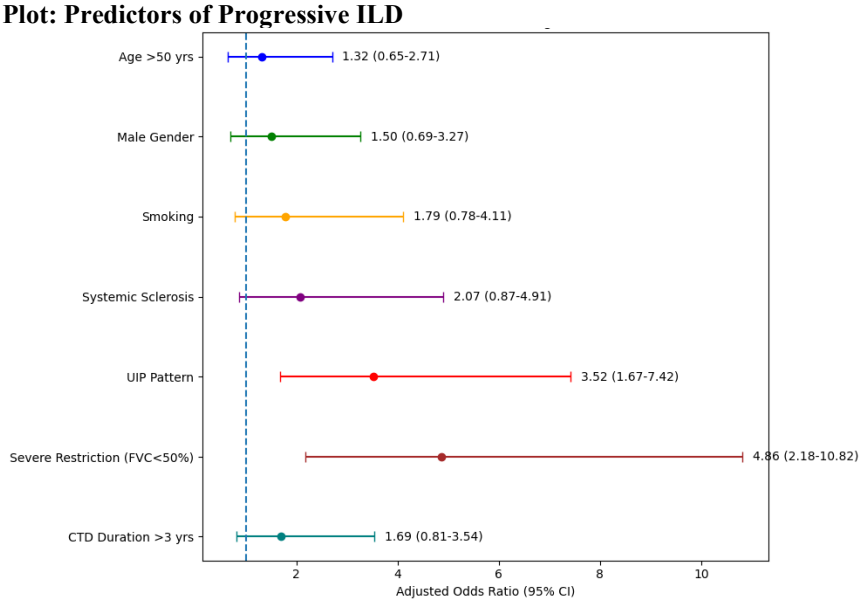


FIGURE 2: Forest Plot: Predictors of Progressive ILD



DISCUSSION

This study evaluated 150 CTD-ILD patients with a mean age of 48.6 ± 13.2 years, showing a clear female predominance (68.0%) and smoking history in 28.0%. The overall demographic profile is consistent with classic descriptions of CTD-ILD, where autoimmune CTDs (especially systemic sclerosis and rheumatoid arthritis) disproportionately affect women and frequently present in mid-life, although the exact mean age varies depending on the dominant CTD spectrum and referral setting. Reviews of CTD-ILD consistently highlight that patient mix (RA-predominant vs SSc-predominant cohorts) strongly influences baseline age and risk-factor profiles, especially smoking burden. [13]

A key strength of this study is the demonstration that NSIP was the most common overall HRCT pattern (48.0%), followed by UIP (32.0%), with other patterns (20.0%), and that HRCT pattern distribution varied significantly by CTD subtype (p = 0.018). This aligns closely with established teaching that NSIP and UIP are the two most frequent HRCT patterns in CTD-ILD, and that the "dominant pattern" often depends on the underlying CTD. [13,14]

When CTD subtype was examined, this study showed that RA-ILD had a higher UIP proportion (45.8%), whereas SSc-ILD was predominantly NSIP (66.7%), with SLE also leaning toward NSIP (57.1%). This is highly consistent with the widely cited observation that UIP tends to be the commonest pattern in RA-ILD, while NSIP is most typical in SSc-ILD. [14] In RA-ILD specifically, earlier work using HRCT UIP classification demonstrated clinically important UIP subsets with poorer outcomes compared with non-UIP patterns, supporting why UIP-heavy RA cohorts often show greater functional severity. [15] In systemic sclerosis, modern imaging reviews and biopsy-correlated datasets similarly emphasize NSIP predominance (often fibrotic NSIP), matching the pattern distribution observed here. [16]

This study also provides clinically meaningful functional correlation: PFT severity showed a highly significant association with HRCT pattern (p = 0.001), with severe restriction being markedly more common in UIP (45.8%) than NSIP (16.7%). This "UIP–more severe physiology" linkage has been repeatedly observed in prognostic literature, where UIP morphology (and the extent of fibrosis) is tied to greater functional compromise and worse trajectories. A large retrospective CTD-ILD cohort found UIP pattern to be among key predictors of decline and/or mortality, supporting the current finding that UIP is the radiologic phenotype most strongly associated with worse clinical course. [17]

At 6-month follow-up, progression signals in this study were concentrated in physiologically severe disease and UIP morphology: progressive ILD was significantly higher with severe PFT (<50%) (61.9% vs 20.5%, p = 0.001) and with UIP pattern (57.1% vs 30.8%, p = 0.004). Importantly, in multivariable analysis, UIP remained an independent predictor (aOR 3.52, p = 0.001) and severe restriction (FVC <50%) emerged as the strongest independent predictor (aOR 4.86, p < 0.001). This is strongly aligned with broader progressive-fibrosing ILD work within CTD-ILD populations showing that fibrotic HRCT phenotypes and baseline physiologic impairment (FVC/DLCO-related reserve) are central drivers of progression risk. [17,18]

Interestingly, smoking in this study was not statistically significant on follow-up progression (p = 0.09) and did not remain significant in regression (aOR 1.79, p = 0.16), despite a directionally higher risk. This partial

attenuation after adjustment is plausible because smoking often clusters with RA-UIP phenotype and higher baseline fibrosis burden; once UIP and FVC severity are included in the model, the independent contribution of smoking can weaken. Some cohorts still report smoking as a prognostic factor, while others show its effect mediated through fibrosis pattern and lung reserve—again supporting the interpretive value of multivariable modeling used in this study. [17,18]

In this study, RA (32.0%) was the most common CTD subtype followed by SSc (24.0%), with other CTDs contributing 44.0%. This distribution is broadly comparable to mixed CTD-ILD cohorts where SSc and RA repeatedly emerge as leading contributors, though many rheumatology-led datasets report SSc as the single most frequent subtype depending on clinic structure and case definitions. In a large cohort analysis, systemic sclerosis and rheumatoid arthritis were among the most frequent CTDs represented in CTD-ILD populations, reinforcing the expectation that these two diagnoses dominate case-loads in tertiary centers. [19]

Finally, the UIP proportion within RA-ILD in this study (45.8%) sits between older "definite UIP" HRCT proportions in some RA-ILD series and more UIP-heavy contemporary cohorts depending on criteria and recruitment. For example, certain modern RA-ILD datasets report higher UIP proportions (e.g., >50% in some cohorts), highlighting that UIP prevalence varies by classification strictness, referral bias, and disease duration. This contextualizes why the present results should be interpreted as representative of this tertiary-care case-mix rather than a universal UIP rate. [15,20]

Overall, this study's most practice-relevant contribution is the clear, quantified message that "UIP morphology + severe restriction" identifies the highest-risk CTD-ILD subgroup, and that HRCT pattern meaningfully stratifies functional severity and short-term progression—consistent with international evidence while providing region-specific tertiary-care data. [13–20]

CONCLUSION

This study demonstrated that interstitial lung disease (ILD) is a frequent and clinically significant pulmonary manifestation among patients with connective tissue disorders (CTD), with a predominance in females and a mean age in the late forties. Rheumatoid arthritis and systemic sclerosis were the most common underlying CTDs associated with ILD. NSIP was the most prevalent HRCT pattern overall; however, the UIP pattern showed a strong association with severe pulmonary restriction and disease progression. At six-month follow-up, severe baseline pulmonary function impairment (FVC <50%) and UIP pattern emerged as independent predictors of progressive ILD, with adjusted odds ratios of 4.86 and 3.52 respectively. These findings emphasize that radiological pattern and functional severity at presentation are critical determinants of short-term disease trajectory. Early identification of high-risk patients using HRCT and PFT parameters can guide closer monitoring and timely therapeutic intervention, potentially improving long-term outcomes.

LIMITATIONS

This study has certain limitations. First, it was conducted at a single tertiary care center, which may limit generalizability to broader community settings. Second, the follow-up duration of six months may not fully capture long-term progression patterns of CTD-associated ILD. Third, histopathological confirmation was not available in all cases, and diagnosis relied primarily on clinical and radiological correlation. Fourth, potential confounders such as specific immunosuppressive regimens, treatment adherence, and disease activity indices were not analyzed in detail. Finally, longitudinal pulmonary function decline beyond the study period was not assessed.

RECOMMENDATIONS

Future multicentric prospective studies with longer follow-up periods are recommended to better characterize progression patterns and survival outcomes in CTD-associated ILD. Incorporation of standardized disease activity scores and treatment-response analysis would strengthen prognostic modeling. Routine screening of CTD patients with HRCT and spirometry should be encouraged, especially in high-risk groups such as those with systemic sclerosis or UIP pattern. Early referral to pulmonology services and multidisciplinary ILD clinics is advisable for patients demonstrating severe restriction or radiological fibrosis. Additionally, development of region-specific registries in Gujarat and other parts of India may help generate robust epidemiological and outcome data to guide evidence-based management strategies.

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