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High-Resolution CT: The Cutting-Edge Tool Transforming Interstitial Lung Disease Diagnosis

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ABSTRACT

Introduction: Interstitial Lung Diseases (ILDs) comprise a diverse group of disorders that primarily affect the lung interstitium, leading to inflammation or fibrosis, which impairs gas exchange and diminishes quality of life. Accurate diagnosis and classification of ILD types are crucial for effective management, and High-Resolution Computed Tomography (HRCT) has emerged as a superior diagnostic tool compared to conventional imaging methods. **Objective:** This study aims to evaluate the role of HRCT in the diagnosis of ILD, emphasizing its diagnostic accuracy and pattern recognition capabilities in a diverse patient population. **Methods:** A cross-sectional study was conducted over 24 months at the Department of Radiodiagnosis, Sri Siddhartha Medical College & Hospital, Tumkur, including 98 patients with suspected ILD. HRCT scans were performed using a 16-slice CT scanner, and findings were analyzed to identify specific ILD patterns such as ground-glass opacities, honeycombing, and traction bronchiectasis. Statistical analysis was performed using SPSS with significance set at $p < 0.05$. **Results:** The study found that ground-glass opacities were the most common HRCT pattern, present in 72.45% of cases, followed by traction bronchiectasis and subpleural involvement. Idiopathic Pulmonary Fibrosis (IPF) was the most frequent diagnosis, comprising 28.57% of cases. The study population had a balanced gender distribution, with a predominance of middle-aged and older adults. Smoking was notably prevalent in IPF patients. **Conclusion:** HRCT plays a critical role in the accurate diagnosis and classification of ILDs, allowing for better management and improved patient outcomes. The study highlights the importance of HRCT in identifying distinct ILD patterns and underscores the impact of factors such as age and smoking status on disease prevalence.

INTRODUCTION

Interstitial lung diseases (ILDs) encompass a diverse group of disorders affecting the lung interstitium, which is the tissue between the alveolar epithelium and capillary endothelium. Although the primary injury occurs in the interstitium, ILDs can also impact airway spaces and blood vessels. These diseases vary widely in etiology, clinical and radiological presentation, and histopathologic features. ILDs are characterized by the infiltration of cellular or non-cellular material into the lung parenchyma, leading to inflammation or fibrosis. This impairs gas exchange, causing breathlessness, reduced exercise tolerance, and a diminished quality of life, with outcomes differing across ILD types [1].

Interstitial lung diseases (ILDs) are a diverse group of disorders that primarily affect the lung interstitium, the tissue between the alveolar epithelium and capillary endothelium. While the main site of injury is the interstitium, these diseases can also impact the airway spaces and blood vessels. ILDs are characterized by the infiltration of cellular or non-cellular material into the lung parenchyma, leading to inflammation or fibrosis. This disruption in the interstitial space impairs gas exchange, resulting in symptoms like breathlessness, reduced exercise tolerance, and decreased quality of life. The etiology, clinical and radiological presentations, histopathologic features, and clinical course of ILDs vary widely. Outcomes differ significantly depending on the specific type of

ILD, reflecting the heterogeneous nature of these diseases and the varied impact they have on the lungs [3].

The diagnosis of interstitial lung disease (ILD) has become increasingly complex due to recent revisions in definitions and diagnostic criteria, necessitating an extensive workup. Although there are over 200 recognized ILD entities, a few, such as idiopathic pulmonary fibrosis, sarcoidosis, and connective tissue disease-related ILDs, comprise most clinical cases. When evaluating a patient with suspected ILD, the clinician must first confirm the disease's presence and then work to identify its underlying cause or associated clinicopathologic syndrome. Medical history, clinical context, and radiologic findings are crucial in guiding the diagnostic process and prioritizing potential diagnoses for ILD. This approach allows for a more accurate and targeted diagnosis, essential for effective management and treatment planning in patients with ILD [4].

Diagnosing a specific form of interstitial lung disease (ILD) and creating a personalized management plan to achieve remission or stabilization can be challenging for clinicians. An accurate diagnosis is crucial for providing prognostic information and developing an effective treatment plan that alleviates symptoms and improves quality of life. A comprehensive patient history and physical examination are vital, and when combined with laboratory tests, imaging, and potentially a tissue biopsy, they can lead to a confident ILD diagnosis. High-resolution computed tomography (HRCT) of the thorax is a key component in this process, offering a detailed view of the lung parenchyma [5]. Unlike chest radiographs, which may appear normal in early disease stages, HRCT provides a clear depiction of the lung, helping to prioritize diagnostic possibilities. Technological advances in physiologic testing, lung imaging, bronchoalveolar lavage, surgical lung biopsy, and histopathologic assessment have significantly enhanced the understanding and management of ILDs, allowing for more precise and targeted treatment approaches.

Diagnosing interstitial lung disease (ILD) and creating a personalized treatment plan are challenging tasks for clinicians. Accurate diagnosis is essential for prognosis and effective symptom management. A thorough patient history, physical examination, and appropriate tests-including lab work, imaging, and possibly a tissue biopsy-are crucial in confirming ILD. High-resolution computed tomography (HRCT) is particularly important, offering a detailed view of the lung parenchyma that surpasses chest radiographs, which may appear normal in early disease stages. Technological advances in physiologic testing, lung imaging, bronchoalveolar lavage, surgical lung biopsy, and histopathologic assessment have greatly improved our understanding of ILDs [6]. These tools enable more precise diagnoses and tailored treatment strategies to improve patients' quality of life.

Diagnosing interstitial lung disease (ILD) and deve-

-oping a personalized treatment plan are complex challenges for clinilcians. Accurate diagnosis is vital for providing prognostic insight and guiding effective symptom management. A detailed patient history, thorough physical examination, and targeted tests-including laboratory work, imaging studies, and sometimes tissue biopsy-are essential in confirming ILD. High-resolution computed tomography (HRCT) plays a critical role by offering detailed images of the lung parenchyma, which are far more revealing than chest radiographs that may appear normal in early stages [8]. Advances in physiologic testing, lung imaging, bronchoalveolar lavage, surgical lung biopsy, and histopathologic analysis have significantly improved our ability to understand and manage ILDs. These tools facilitate more accurate diagnoses and enable the development of tailored treatment strategies that enhance patient outcomes and quality of life.

High-resolution computed tomography (HRCT) is more sensitive than chest radiography or conventional CT in detecting interstitial lung disease (ILD) and is central to ILD diagnosis according to the latest American Thoracic Society/European Respiratory Society guidelines. HRCT helps identify specific ILD patterns and assess severity, particularly in cases like chronic hypersensitivity pneumonitis and connective tissue disease-related fibrotic lung disease, where traction bronchiectasis and honeycombing are mortality predictors. With thin collimation and detailed anatomical views, HRCT often eliminates the need for surgical biopsy and aids in prognosis and tracking disease progression, making it a crucial tool in ILD management.

The effectiveness of High-Resolution Computed Tomography (HRCT) in diagnosing interstitial lung disease (ILD) by leveraging its advanced capabilities. HRCT outperforms traditional diagnostic tools such as X-rays in identifying various ILD types, including detailed sub-classifications of connective tissue disease-related ILDs (CTD-ILDs), and differentiating between early and progressive disease stages. The study sought to evaluate HRCT's role specifically in diffuse interstitial lung disease [9]. By highlighting HRCT's ability to provide detailed imaging and improve diagnostic accuracy, the study underscores the critical role of this technology in enhancing the understanding and management of ILD, ultimately contributing to more precise and effective patient care[10].

AIMS AND OBJECTIVES

This study examined High-Resolution Computed Tomography (HRCT) for diagnosing interstitial lung disease (ILD), demonstrating its superiority over traditional methods like X-rays. HRCT enables precise identification and classification of ILD types, including early and progressive stages, making it crucial for accurate diagnosis and effective management of ILD.

MATERIAL AND METHODS

This cross-sectional study evaluates the role of High-Resolution Computed Tomography (HRCT) in diagn-

-osing Interstitial Lung Disease (ILD) over a 24-month period at the Department of Radiodiagnosis, Sri Siddhartha Medical College & Hospital, Tumkur. The study includes patients with suspected ILD referred for HRCT, excluding those with COPD, congestive cardiac failure, and lobar consolidation. Purposive sampling was used, with a calculated sample size of 98. Data collection involved clinical assessments, HRCT imaging, and analysis of specific ILD patterns such as ground-glass opacities, honeycombing, and traction bronchiectasis. HRCT imaging was performed using a 16-slice CT scanner, with findings classified to identify ILD types. Statistical analysis will include descriptive and inferential statistics, with significance determined at $p<0.05$ using SPSS. The study will examine age, gender, smoking status, symptoms, HRCT patterns, and ILD types. Ethical guidelines will be followed, with informed consent and confidentiality maintained. Potential limitations include selection bias and limited generalizability due to the single-center design. This study aims to improve diagnostic accuracy and patient management by enhancing the understanding of HRCT patterns in ILDs.

RESULTS

The study group's smoking habits, indicate that most participants are non-smokers. Of the 98 individuals, 59 participants (60.20%) reported not smoking, while 39 participants (39.79%) indicated that they do smoke. This suggests that although smoking is common within the group, non-smokers constitute the majority. The age distribution, shows a predominance of participants in the 41-50 and over-60 age brackets, accounting for 28.57% and 27.55% of the group, respectively. The 51-60 age group also has significant representation, making up 24.49% of participants. Younger age groups (21-30 and 31-40 years) are less prevalent, comprising 6.12% and 13.27% of the study population. This distribution indicates a higher occurrence or reporting of the studied condition among middle-aged and older adults. The gender distribution, shows a nearly equal split, with 55.10% males and 44.90% females, ensuring balanced demographic representation.

Table 1: Distribution of Study Group According to Presenting Complains and Symptoms

Presenting Complains and Symptoms		Frequency	Percent (%)
Dyspnea		98	100
Cough		96	97.96
Fever		30	30.61
Weight Loss		36	36.74
Exposure to organic dust	43	43.88	

The study group's symptoms reveal that dyspnea is universal, affecting 100% of participants, followed closely by cough at 97.96%. Weight loss and exposure to organic dust are reported by 36.74% and 43.88% of participants, respectively. Fever is the least common symptom, occurring in 30.61% of cases. These findings underscore the predominance of respiratory issues, particularly dyspnea and cough, and suggest underlying chronic conditions or environmental factors affecting participants' health

Table 2: Distribution of Study Group According to Durationo Symptoms

Duration (Months)	Frequency	Percent (%)
<1	13	13.26
2-6	34	34.69
>6	51	52.04
Total	98	100

The distribution of the study group based on the duration of symptoms shows a high prevalence of long-term symptoms. A majority, 52.04%, experienced symptoms for more than six months. Meanwhile, 34.69% reported symptoms lasting between two and six months, and a smaller group, 13.26%, had symptoms for less than a month. This indicates that prolonged symptoms are common within the study group, highlighting the chronic nature of their conditions.

Table 3: Distribution of Study Group According to HRCT Thorax Patterns

Findings	No. ofCases	%
Septal	36	36.74
Nodules	51	52.04
Reticular	51	52.04
Abg	38	38.78
Ggo	71	72.45
Cyst	20	20.41
Honey Combing	34	34.69
Hilar Adenopathy	51	52.04
Traction Bronchiectasis	55	56.12
Consolidation	55	56.12
Subpleural	59	60.20
Peri Bronco Vascular	43	43.88

The distribution of HRCT thorax patterns shows significant variability among the study group. Ground-glass opacities (GGO) were the most common, present in 72.45% of cases. Traction bronchiectasis and consolidation appeared in 56.12% of cases, while subpleural involvement was noted in 60.20%. Nodules and reticular patterns were each found in 52.04% of cases. Other notable findings included septal thickening (36.74%), air bronchogram (38.78%), and peribronchovascular distribution (43.88%). Cysts and honeycombing were less common, seen in 20.41% and 34.69% of cases, respectively.

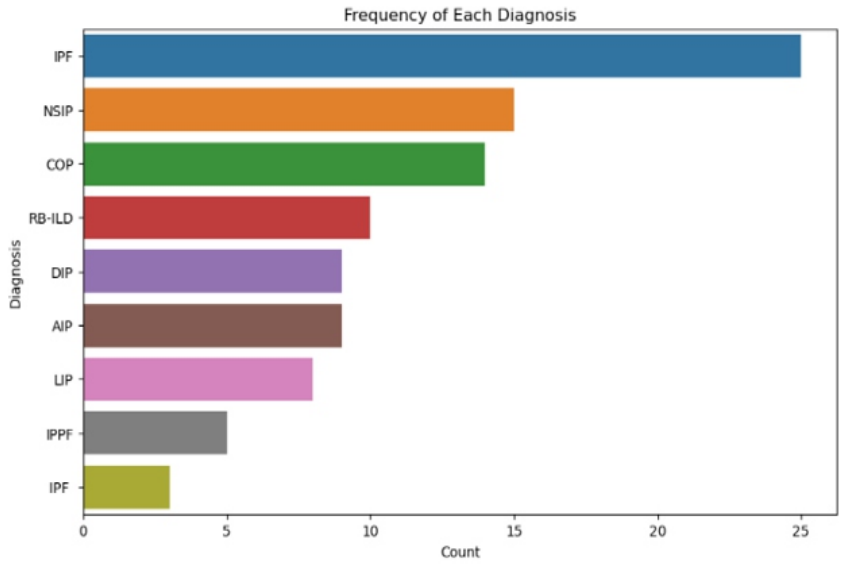

Figure 1: Diagnosis Count and Frequency Distribution

The dataset reveals the prevalence of various interstitial lung diseases (ILDs) in a specific population. Idiopathic Pulmonary Fibrosis (IPF) is the most common, comprising 28.57% of cases, highlighting its clinical significance. Cryptogenic Organizing Pneumonia (COP) and Nonspecific Interstitial Pneumonia (NSIP) follow at 14.29% and 15.31%, respectively. Acute Interstitial Pneumonia (AIP) and Desquamative Interstitial Pneumonitis (DIP) each make up 9.18% of cases, indicating less frequency or recognition. Rare Idiopathic

Pleuroparenchymal Fibroelastosis (IPPF) accounts for 5.10%, while Lymphocytic Interstitial Pneumonia (LIP) and Respiratory Bronchiolitis-Associated ILD (RB-ILD) are found in 8.16% and 10.20% of cases, reflecting their prevalence and diagnostic patterns.

Table 4: Distribution of Complains and SymptomS with Diagnosis

Diagnosis	Smoking		Dyspnea		Cough		Fever		Wt. Loss		Exposure to organic dust	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
AIP	3	6	9	0	9	0	7	2	3	6	2	7
COP	9	5	14	0	13	1	4	10	5	9	5	9
DIP	3	6	9	0	9	0	2	7	4	5	5	4
IPF	18	10	28	0	27	1	8	20	8	20	14	14
IPPF	0	5	5	0	5	0	3	2	3	2	2	3
LIP	4	4	8	0	8	0	1	7	5	3	7	1
NSIP	10	5	15	0	15	0	2	13	5	10	3	12
RB-LLD	9	1	10	0	10	0	3	7	3	7	5	5

Smoking is a significant risk factor in Idiopathic Pulmonary Fibrosis (IPF), with 64.3% of patients being smokers. Similarly, 64.3% of Chronic Obstructive Pulmonary disease (COP) patients are smokers, suggesting a link between smoking and disease prevalence. Conversely, Idiopathic Pleuroparenchymal Fibroelastosis (IPPF) shows 0% smokers, indicating a distinct etiological profile. Dyspne-a is a universal symptom across all diagnoses, while cough is nearly as prevalent, except in COP (92.9%). Fever varies, being more common in Acute Interstitial Pneumonia (70%) than in COP (28.6%). Weight loss is less prominent in IPF (28.6%) but more common in Lymphocytic Interstitial Pneumonia (62.5%), with significant organic dust exposure noted in LIP cases (87.5%).

Table 5: Distribution of Chest X Ray and Diagnosis

Diagnosis	Reticulo Nodular		Brochiectasis	
	Yes	No	Yes	No
AIP	0	9	0	9
COP	14	0	14	0
DIP	0	9	0	9
IPF	20	8	24	4
IPPF	5	0	0	5
LIP	8	0	8	0
NSIP	8	7	8	7
RB-LLD	0	10	0	10

Idiopathic Pulmonary Fibrosis (IPF) and Cryptogenic Organizing Pneumonia (COP) both have high smoking rates (64.3%), indicating smoking as a significant risk factor. In contrast, Idiopathic Pleuroparenchymal Fibroelastosis (IPPF) has no smokers. Dyspnea is universal, while cough is nearly universal (92.9% in COP). Fever prevalence varies, with 28.6% in COP and 70% in Acute Interstitial Pneumonia (AIP). Weight loss is less common in IPF (28.6%) but more frequent in Lymphocytic Interstitial Pneumonia (LIP) (62.5%). LIP also correlates strongly with organic dust exposure (87.5%).

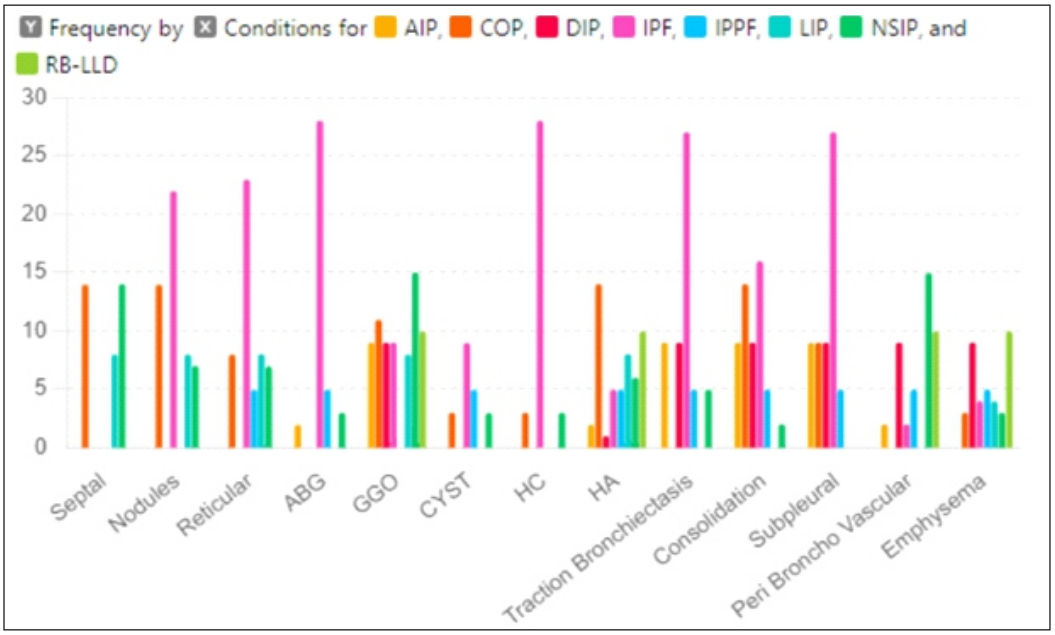

Figure 2: Distribution of HRCT with Diagnosis

The bar chart illustrates the prevalence of various radiologic patterns (Septal, Nodules, Reticular, ABG, GGO, CYST, HC, HA, Traction Bronchiectasis, Consolidation, Subpleural, Peri-Broncho Vascular, and Emphysema) across lung conditions like AIP, COP, DIP, IPF, IPPF, LIP, NSIP, and RB-ILD. Notably, IPF (pink) shows high frequencies of Septal, Reticular, GGO, HC, and Traction Bronchiectasis. COP (orange) is prominent for Nodules, ABG, GGO, and Consolidation. NSIP (green) is prevalent in Reticular, GGO, and Peri-Broncho Vascular patterns, emphasizing the role of these patterns in diagnosing and distinguishing lung conditions.

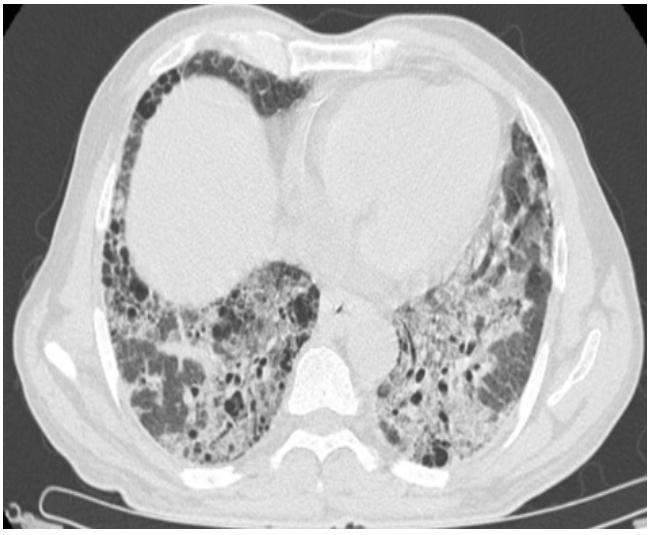

Figure 3: Subpleural Honeycoming with Traction Bronchiectasis

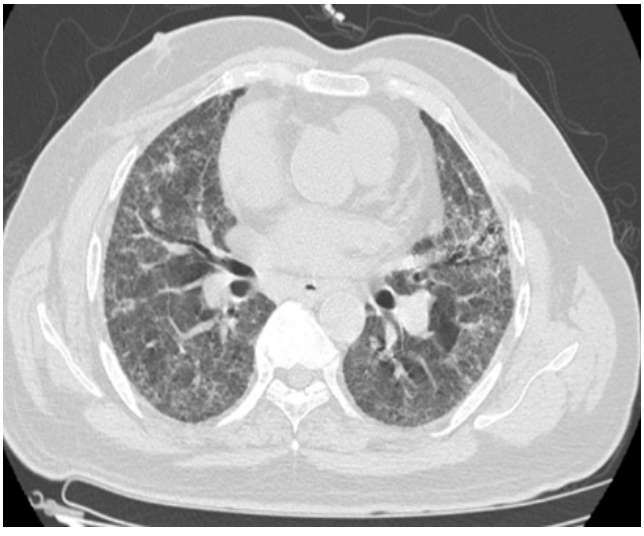

Figure 4: Bilateral Peripheral Ground Glass Opacities Noted Diffusely in Bilateral Lung Parenchyma

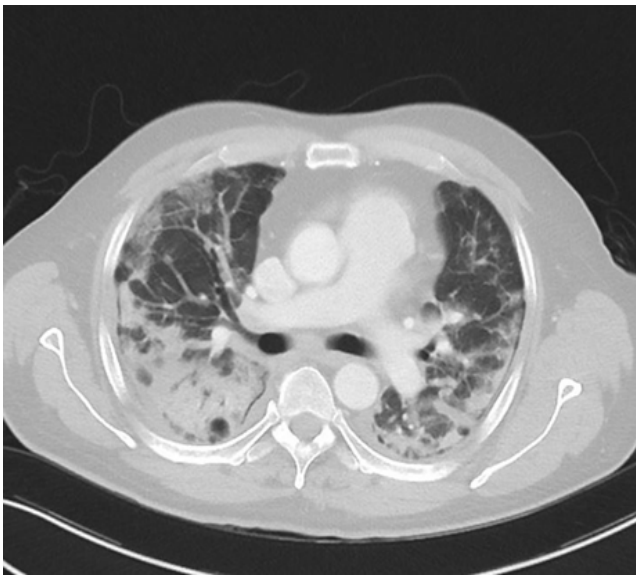

Figure 5: Extensive Patchy Airspace Opacity with Few Areas of Air Bronchograms and Some Cavitation on the Right. Areas of Groundglass Opacity.

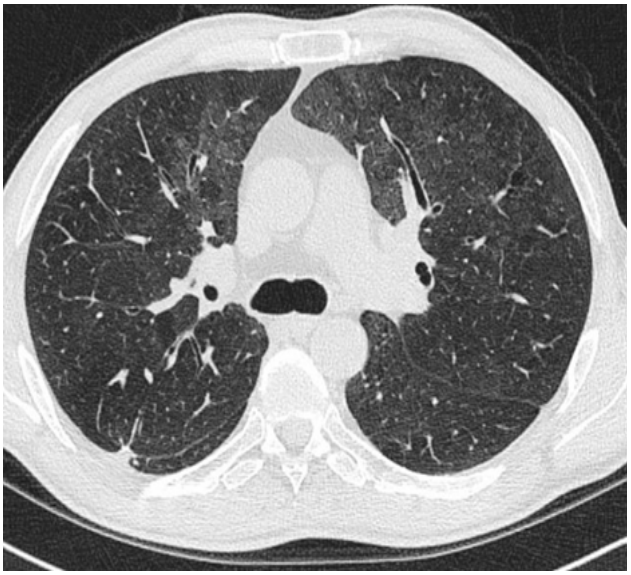

Figure 6: Minor Deterioration in the Ground Glass Infiltrate is Noted in the Posterior Aspect of the Right Upper Lobe and In the Posterior Aspect of the Right Lower Lobe

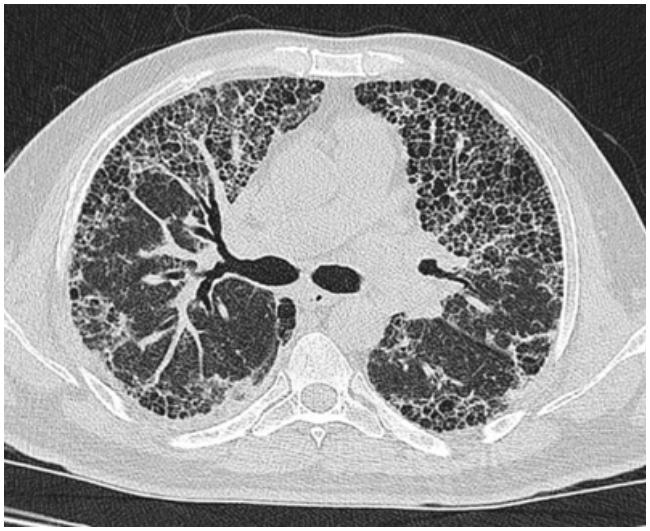

Figure 7: Basal and Peripheral Reticular Opacities with Honeycombing and Traction Bronchiectasis

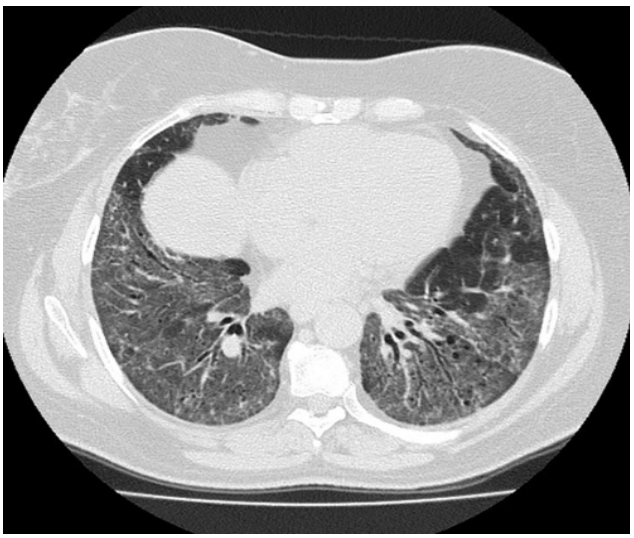

Figure 8: Bibasilar Symmetric Ground Glass Opacities with Reticulation and Traction Bronchiectasis/Bronchiolectasis

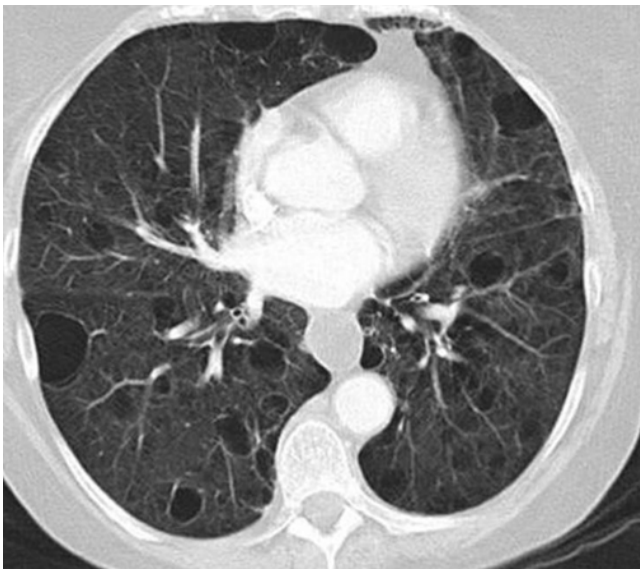

Figure 9: Bilateral, Variable Sized, Pulmonary Air Cysts

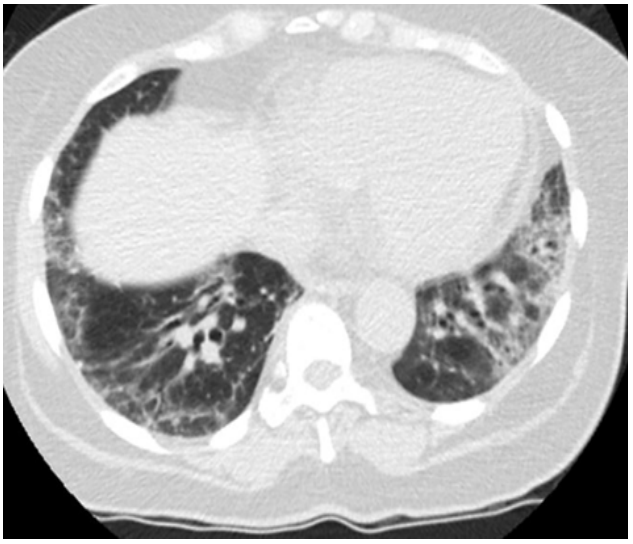

Figure 10: Bi-Basilar and Dependent Ground Glass Opacities, Interlobular Septal Thickening and Mild Traction Bronchiectasis

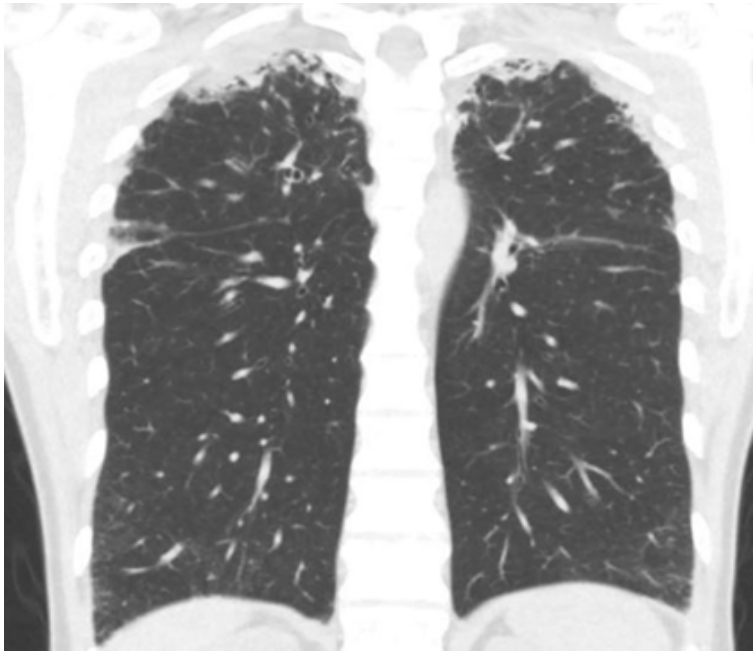

Figure 11: Apical Pleural Thickening, Traction Bronchiectasis and Reticular Thickening. Hilar Retraction

DISCUSSION

High-resolution computed tomography (HRCT) is crucial for diagnosing interstitial lung disease (ILD) due to its detailed imaging capabilities. It surpasses conventional methods by offering superior resolution and sensitivity, allowing for the detection of subtle lung abnormalities. HRCT aids in distinguishing ILD from other pulmonary conditions, supporting early and accurate diagnosis. It also helps monitor disease progression and assess treatment responses, leading to better patient outcomes. Numerous studies emphasize the importance of HRCT in managing ILD [11][12].

The study by Almeida RF et al. (2020) analyzed HRCT patterns in 244 ILD patients, categorizing diagnoses into typical, probable, and indeterminate usual interstitial pneumonia (UIP) patterns. It found that idiopathic pulmonary fibrosis (IPF) was most common among those with a typical UIP pattern, while chronic hypersensitivity pneumonitis (CHP) and connective tissue disease-related ILD (CTD-ILD) followed. Probable UIP was often linked to CTD-ILD, and indeterminate UIP frequently involved CTD-ILD and desquamative interstitial pneumonia. Patients with a typical UIP pattern faced higher mortality risks or needed lung transplants. This highlights HRCT's crucial role in ILD diagnosis and prognosis. In contrast, our study focused on ILD patient age distribution, showing a bell-shaped curve around a mean age of 52, revealing common demographic trends. Both studies stress the importance of HRCT in ILD research, with Almeida RF et al.'s work emphasizing diagnostic patterns and prognosis, while our study adds valuable demographic insights [13][14].

The 2017 study by Afzal F et al. compared chest x-rays and HRCT for diagnosing ILD in 137 patients aged 20-50 years. It found chest x-rays identified ILD in 58.39% of cases with 81% accuracy, but HRCT was more precise. Our study, analyzed gender distribution and smoking habits, revealing a significant gender disparity in smoking, with 44.90% of males and 12.24% of females smoking where the x-rays of these patients were not very precise and informative. The HRCT of the coreponding patients showed early changes of ILD which played a crucial role for us to diagnose at an early stage of the disease.This data highlights how the impact of HRCT can influence ILD prevalence. Both studies emphasize the importance of HRCT for accurate diagnosis and the role of demographic factors in understanding ILD, illustrating the need for advanced imaging and demographic context in managing the disease[15].

The study by Hanna MM et al. (2017) assessed 45 patients with collagen diseases (rheumatoid arthritis, systemic lupus erythematosus, and scleroderma) using high-resolution computed tomography (HRCT) to identify lung interstitial abnormalities. They found 66.6% of patients had parenchymal involvement, while 33.4% had normal HRCT results. This underscores HRCT's crucial role in diagnosing ILDs by detecting patterns, distribution, and severity of lung abnormalities, aiding in prognosis and management. Our study analyzed the prevalence and symptomatology of various ILDs, including idiopathic pulmonary fibrosis (IPF) and desquamative interstitial pneumonia (DIP). It highlighted smoking as prevalent in IPF (64.3%) and noted a significant environmental factor in lymphocytic interstitial pneumonia (LIP) with 87.5% of patients exposed to organic dust. This also implies HRCT with good clinical history amplifies the accuracy of the HRCT in diagnosing ILD better. Together, these studies emphasize HRCT's importance in accurate ILD diagnosis and the value of integrating symptom and risk factor analysis to enhance patient care[16][17].

The 2018 study by Ayush M et al. examined 50 ILD

.patients using both conventional radiography and HRCT. HRCT revealed diverse patterns, with honeycombing being the most common (18%), followed by crazy paving, mosaic attenuation, and miliary mottling. The study highlighted HRCT's crucial role in diagnosing ILDs and often eliminating the need for lung biopsies when characteristic patterns are evident. Our study too identified distinct HRCT features for different ILDs, such as nodules and reticular patterns in idiopathic pulmonary fibrosis (IPF) and traction bronchiectasis in acute interstitial pneumonia (AIP) [18][19].

Additionally, Fujii M et al. assessed systemic sclerosis progression over 1.5 years using HRCT and pulmonary function tests, finding that while forced vital capacity changes were minimal, specific airway resistance decreased significantly. Our study on age distribution found a higher prevalence of ILD among older adults, suggesting age as a key factor in the condition's incidence. Both studies emphasize the importance of advanced imaging and demographic analysis in improving ILD diagnosis and management [20][21].

The studies by Hanna MM et al. and our research both explore interstitial lung diseases (ILDs) in patients with collagen disorders using distinct approaches to enhance diagnostic accuracy. Hanna MM et al. used HRCT to analyze patients with rheumatoid arthritis, systemic lupus erythematosus, and scleroderma, discovering that 66.6% had significant parenchymal abnormalities. This underscores HRCT's vital role in identifying and assessing ILD severity. Conversely, our study examined symptom distribution among ILD patients, finding dyspnea and cough as prevalent complaints, aligning with Hanna MM et al.'s emphasis on these symptoms for diagnostic evaluation. Both studies highlight HRCT's essential role in diagnosing ILDs and advocate for early symptom recognition and imaging to ensure effective management. Together, they provide critical insights into improving care strategies and outcomes for patients with ILDs associated with collagen disorders [16][22][23].

CONCLUSION

This study evaluates the effectiveness of High Resolution Computed Tomography (HRCT) in diagnosing various Interstitial Lung Diseases (ILDs), which are marked by lung scarring and fibrosis that impair respiratory function. Conducted over a 24-month period at Sri Siddhartha Medical College & Hospital, the study included 98 patients with suspected ILD, excluding those with Chronic Obstructive Pulmonary Disease (COPD), Congestive Cardiac Failure (CCF), or lobar consolidation.

HRCT was utilized to identify distinct radiological patterns such as ground-glass opacities, reticular patterns, and honeycombing. The patient cohort exhibited a broad age range, with the majority falling between 41-50 years (28.57%) and over 60 years (27.55%). Gender distribution was nearly balanced, with 55.10% males and 44.90% female-s.In terms of smoking habits, 60.20% of patients were non-smokers and 39.79% were smokers, with a notable prevalence of smoking among those with idiopathic pulmonary fibrosis (64.3%).

Common symptoms included dyspnea and cough, whereas weight loss and fever were less prevalent. HRCT findings revealed ground-glass opacities in 72.45% of cases and traction bronchiectasis in 56.12% of cases.

The study underscores the pivotal role of HRCT in the diagnosis and differentiation of ILDs, highlighting the significant impact of symptoms, smoking status, and age on patient outcomes.

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