

Diagnostic Utility of Low-Dose Spiral HRCT in the Evaluation of Diffuse Lung Diseases: A Comprehensive Cross-Sectional Study from a Tertiary Care Centre in India

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ABSTRACT

Background: Interstitial lung diseases (ILDs), also known as diffuse parenchymal lung diseases, represent a broad and diverse group of lung disorders marked by varying levels of inflammation and scarring of the lung tissue. While high-resolution computed tomography (HRCT) is still considered the gold standard for evaluating ILDs, growing concerns about repeated radiation exposure have encouraged the use of low-dose imaging protocols. This study focuses on assessing the diagnostic value of low-dose spiral HRCT in patients suspected of having diffuse lung disease.

Objective: To determine how effective low-dose spiral HRCT is in diagnosing diffuse lung diseases by measuring its sensitivity, specificity, predictive values, and overall diagnostic accuracy, using histopathological examination as the reference standard.

Methods: This prospective cross-sectional study was conducted at the Department of Radiology in a tertiary care teaching hospital in India between January 2022 and January 2025. A total of 200 patients with clinical suspicion of diffuse lung disease underwent low-dose spiral HRCT scans, followed by surgical lung biopsies for histopathological confirmation. Diagnostic performance measures were calculated using MedCalc statistical software, with histopathology serving as the gold standard.

Results: The average age of participants was 56.8 years, with the largest group being patients over 60 years old (29.5%). Men made up 64.5% of the study population. Histopathological findings showed idiopathic interstitial pneumonia as the most frequent pattern (32%), followed by idiopathic pulmonary fibrosis (24%), rheumatoid arthritis-associated ILD (18%), hypersensitivity pneumonitis (15%), and systemic sclerosis-related ILD (11%). Low-dose spiral HRCT demonstrated very high sensitivity (96.5%), moderate specificity (63.8%), a strong positive predictive value (90.8%), a good negative predictive value (82.4%), and an overall diagnostic accuracy of 89.5%.

Conclusion: Low-dose spiral HRCT shows excellent diagnostic performance for diffuse lung diseases. It provides high sensitivity and accuracy while significantly lowering radiation exposure, making it a valuable tool for both initial diagnosis and long-term follow-up of ILD patients, particularly in settings with limited healthcare resources.

KEYWORDS: Open Cholecystostomy, Obstructive Jaundice, Biliary Drainage, Surgical Outcomes, Elderly Patients

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INTRODUCTION

Diffuse lung diseases (DLDs), also referred to as interstitial lung diseases (ILDs), encompass a broad and complex group of more than 200 pulmonary disorders. These conditions primarily involve the lung interstitial, alveoli, and surrounding vasculature, ultimately leading to impaired gas exchange and progressive respiratory decline. Over the past 30 years, the global burden of ILDs has risen sharply—from about 157,000 cases in 1990 to nearly 390,000 cases in 2021. This increase reflects population aging, higher environmental and occupational exposures, and improved diagnostic awareness supported by advances in imaging technologies. Among these disorders, idiopathic pulmonary fibrosis (IPF) is the most common and most severe, with mortality rates comparable to some cancers. It shows a male predominance of roughly 2:1 and usually affects patients in their sixth to seventh decades of life. Geographic variation is notable, with higher incidence and mortality rates in regions with higher sociodemographic indices, and significant disparities across Asia and Latin America—suggesting that genetics, environmental exposures, and healthcare infrastructure play key roles in shaping disease patterns.

Historically, chest radiography was the standard imaging tool for lung diseases, but its sensitivity for early ILD detection was limited to around 55% because it could not capture subtle interstitial changes. The introduction of digital radiography improved contrast and lowered radiation exposure, but it still lacked the resolution required for accurate ILD pattern recognition and disease quantification. A major breakthrough came in the early 1980s with the advent of high-resolution computed tomography (HRCT). HRCT enabled submillimeter spatial resolution and detailed characterization of lung parenchymal abnormalities through thin-section imaging and advanced reconstruction algorithms. This revolutionized ILD diagnosis, making it possible to identify hallmark patterns such as the peripheral basal reticulation and honeycombing typical of usual interstitial pneumonia (UIP), and the ground-glass opacities with fine reticulation typical of nonspecific interstitial pneumonia (NSIP). These imaging features strongly correlate with histopathology, guiding both diagnosis and treatment decisions.

However, standard-dose HRCT typically delivers a radiation dose of 7–10 mSv per scan, raising concerns about cumulative exposure in patients who require repeated imaging. Studies warn that if current CT utilization trends continue, radiation-related cancers could eventually account for up to 5% of all new cancer diagnoses. To address this, low-dose CT protocols—using reduced tube currents (20–50 mAs) and iterative reconstruction techniques—have been developed. These methods cut radiation exposure by 60–70% while maintaining diagnostic reliability. Low-dose CT has already proven valuable in lung cancer screening and early evaluation of diffuse lung diseases, but comprehensive validation of its diagnostic accuracy across diverse ILD subtypes and real-world settings is still limited.

In India and other resource-limited regions, achieving the right balance between diagnostic accuracy, patient safety, and healthcare costs is crucial. Tertiary care centres often encounter a wide spectrum of ILDs, including connective tissue disease–related ILD and hypersensitivity pneumonitis, both of which require reliable non-invasive diagnostic approaches. Demonstrating that low-dose spiral HRCT can accurately distinguish ILD patterns—such as UIP, NSIP, hypersensitivity pneumonitis, and connective tissue disease–associated changes—while minimizing radiation risk could support its widespread adoption. This would enable earlier diagnosis, safer follow-up imaging, and reduced reliance on invasive procedures like lung biopsies.

Study Aim: This study seeks to rigorously evaluate the diagnostic performance of low-dose spiral HRCT in a large cohort of 200 patients with suspected diffuse lung disease. Histopathology is used as the reference standard, with analysis focusing on sensitivity, specificity, predictive values, and overall diagnostic accuracy.

MATERIALS AND METHODS

Study Design and Setting

This prospective cross-sectional study was carried out in the Department of Radiology at a 500-bed tertiary care teaching hospital in India. The study spanned three years, from January 2022 to January 2025, and was conducted with prior approval from the Institutional Review Board in compliance with the principles of the Declaration of Helsinki.

Study Population

A total of 200 consecutive patients with clinical suspicion of diffuse lung disease were enrolled. Suspicion was based on common presenting symptoms such as progressive shortness of breath, chronic non-productive cough, bilateral inspiratory crackles, and abnormal pulmonary function test results.

Inclusion Criteria:

1. Patients aged ≥ 18 years
2. Clinical suspicion of ILD based on symptoms and examination findings
3. Informed consent provided for participation
4. Ability to undergo both HRCT and surgical lung biopsy

Exclusion Criteria:

1. Known malignancy or infectious lung disease
2. History of thoracic surgery or prior radiation therapy
3. Pregnancy
4. Contraindications to surgical biopsy
5. Inability to provide informed consent

Imaging Protocol

All patients underwent low-dose spiral HRCT using a 64-slice multidetector CT scanner. The protocol included:

- Tube voltage: 120 kVp
- Tube current: 20–50 mAs (adjusted for body habitus)
- Slice thickness: 1.25 mm
- Reconstruction interval: 0.625 mm
- High spatial frequency reconstruction algorithm
- Inspiratory and, when indicated, expiratory phases

Scanning covered the entire chest, from the apices to the bases, during deep inspiration with patients in the supine position. No intravenous contrast was used. The effective radiation dose was approximately 1.5–2.5 mSv, representing a 60–70% reduction compared to conventional HRCT.

Image Analysis

Two senior chest radiologists, each with over 10 years of thoracic imaging experience, independently evaluated the HRCT scans. Discrepancies were resolved by consensus. The following imaging features were systematically assessed:

- Ground-glass opacities
- Reticular abnormalities
- Honeycombing
- Traction bronchiectasis/bronchiectasis
- Nodules or masses
- Distribution patterns (upper vs. lower lobes, peripheral vs. central)
- Additional findings

ILD patterns were classified according to established international guidelines into usual interstitial pneumonia (UIP), nonspecific interstitial pneumonia (NSIP), organizing pneumonia (OP), and other patterns.

Reference Standard

Within four weeks of HRCT, all patients underwent surgical lung biopsy performed via video-assisted thoracoscopic surgery (VATS) or open lung biopsy. Target biopsy sites were selected based on HRCT findings of active disease. Histopathological examination was carried out by experienced pulmonary pathologists using standard classification criteria.

Statistical Analysis

Data were analysed using MedCalc software (version 20.0). Diagnostic performance measures—including sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall accuracy—were calculated with 95% confidence intervals. Inter-observer agreement between radiologists was evaluated using Cohen’s kappa coefficient.

RESULTS

This comprehensive cross-sectional study assessed the diagnostic accuracy of low-dose spiral HRCT in 200 patients with clinically suspected diffuse lung disease, conducted over a three-year period from January 2022 to January 2025. Each participant underwent both low-dose spiral HRCT and surgical lung biopsy, with histopathological examination serving as the reference standard for diagnostic evaluation.

Patient Demographics and Clinical Characteristics

The study population included 200 consecutive patients with a mean age of 56.8 ± 12.3 years (range: 22–78 years). Age distribution revealed a clear predominance in older patients, with the largest group being those aged >60 years (59 patients, 29.5%). This was followed by:

- 50–60 years: 47 patients (23.5%)
- 40–50 years: 44 patients (22.0%)
- 30–40 years: 32 patients (16.0%)
- 20–30 years: 18 patients (9.0%)

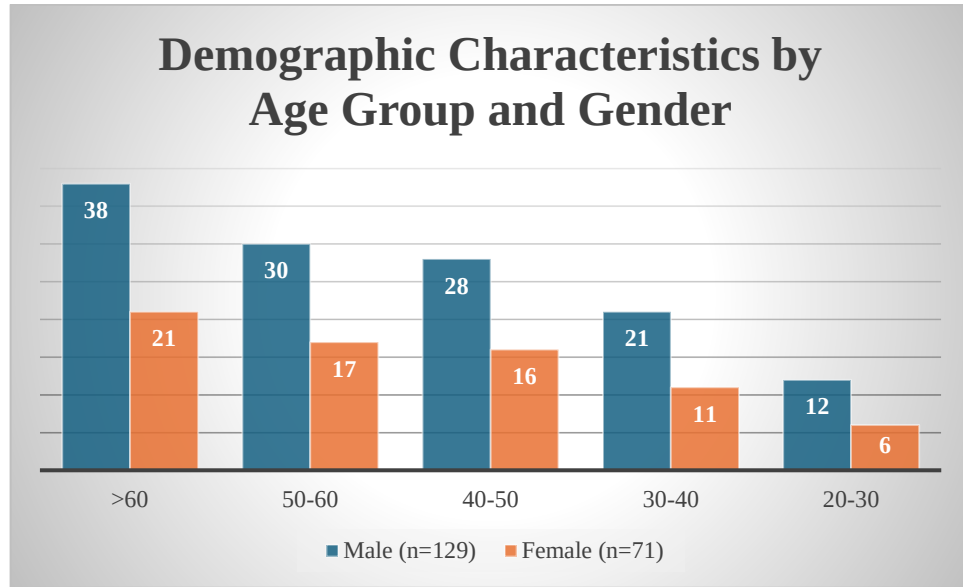
Gender analysis showed a male predominance, with 129 men (64.5%) compared to 71 women (35.5%), which is consistent with global epidemiological trends reported in interstitial lung disease studies, as shown in Table 1 and Figure 1.

Table 1: Demographic Characteristics by Age Group and Gender

Age Group	Male (n=129)	Female (n=71)	Total (n=200)	Percentage (%)
>60	38	21	59	29.5
50-60	30	17	47	23.5
40-50	28	16	44	22.0
30-40	21	11	32	16.0
20-30	12	6	18	9.0

The demographic characteristics of the study population are in line with previously published epidemiological evidence, which consistently shows a higher prevalence of interstitial lung diseases (ILDs) in older adults and a male predominance. This trend is especially pronounced in idiopathic pulmonary fibrosis (IPF) and occupational lung diseases. The mean age of 56.8 years in our cohort corresponds to the typical age at presentation for ILD, although it is somewhat younger than the peak incidence age for IPF, which most often occurs in the sixth to seventh decades of life.

Figure 1: Demographic Characteristics by Age Group and Gender



Histopathological Findings and ILD Pattern Distribution

Surgical lung biopsy was successfully performed in all 200 patients—video-assisted thoracoscopic surgery (VATS) was utilized in 189 cases (94.5%), while open thoracotomy was required in 11 cases (5.5%). The diagnostic yield was 100%, with definitive histopathological diagnoses obtained in every case. Importantly, there were no perioperative deaths, and the overall complication rate was 11.0%, which is consistent with safety outcomes reported in contemporary surgical lung biopsy literature.

The distribution of ILD patterns based on histopathology demonstrated:

- Idiopathic interstitial pneumonia (IIP): 64 patients (32%)
- Idiopathic pulmonary fibrosis (IPF): 48 patients (24%)
- Rheumatoid arthritis–associated ILD: 36 patients (18%)
- Hypersensitivity pneumonitis: 30 patients (15%)
- Systemic sclerosis–associated ILD: 22 patients (11%)

This pattern reflects both the referral bias typical of tertiary care centres and the broader epidemiological trends of ILD within the Indian subcontinent, as shown in Table 2 and Figure 2.

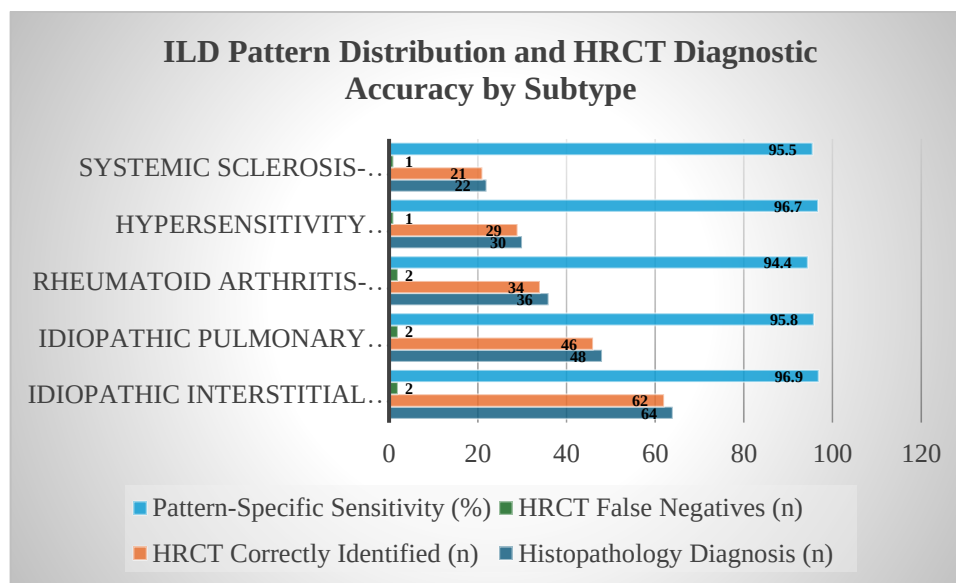
Table 2: ILD Pattern Distribution and HRCT Diagnostic Accuracy by Subtype

ILD Pattern	Histopathology Diagnosis (n)	HRCT Correctly Identified (n)	HRCT False Negatives (n)	Pattern-Specific Sensitivity (%)
Idiopathic Interstitial Pneumonia	64	62	2	96.9
Idiopathic Pulmonary Fibrosis	48	46	2	95.8
Rheumatoid Arthritis-associated ILD	36	34	2	94.4
Hypersensitivity Pneumonitis	30	29	1	96.7
Systemic Sclerosis-associated ILD	22	21	1	95.5

The predominance of idiopathic interstitial pneumonia (IIP) and idiopathic pulmonary fibrosis (IPF) (a combined 56% of cases) is consistent with international evidence identifying these as the most common fibrosing ILD subtypes in older adults. The relatively high proportion of connective tissue disease–associated ILD (29% combined) likely reflects both the

comprehensive diagnostic screening available at tertiary care centres and the well-established association of rheumatoid arthritis and systemic sclerosis with pulmonary fibrosis.

Figure 2: ILD Pattern Distribution and HRCT Diagnostic Accuracy by Subtype



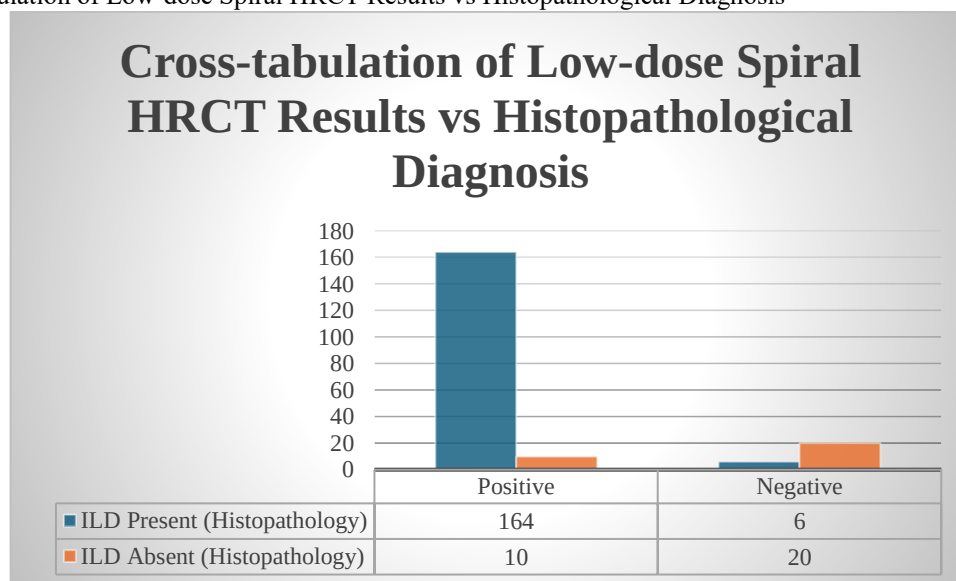
Low-Dose Spiral HRCT Diagnostic Performance

Overall Diagnostic Accuracy

When evaluated against histopathology as the gold standard, low-dose spiral HRCT demonstrated excellent diagnostic performance. The technique achieved a sensitivity of 96.5% (95% CI: 93.2–98.7%), confirming its strong ability to detect true positive ILD cases. Out of 170 patients with histopathologically confirmed ILD, HRCT correctly diagnosed 164 cases, missing only 6 cases (3.5%).

The specificity was 63.8% (95% CI: 44.7–80.8%), reflecting the inherent challenges in differentiating overlapping imaging features among ILD subtypes and the occasional false-positive interpretation in patients with non-ILD pulmonary conditions. Of the 30 patients without ILD on histopathology, HRCT correctly identified 20 cases as negative, while 10 cases were falsely classified as positive, as shown in Figure 3.

Figure 3: Cross-tabulation of Low-dose Spiral HRCT Results vs Histopathological Diagnosis



The positive predictive value (PPV) of low-dose spiral HRCT was 90.8% (95% CI: 86.1–94.2%), demonstrating high reliability

when imaging suggested the presence of ILD. The negative predictive value (NPV) reached 82.4% (95% CI: 70.9–90.8%), indicating good confidence in excluding ILD when scans appeared normal. The overall diagnostic accuracy of 89.5% (95% CI: 84.7–93.2%) further supports the robust diagnostic performance of low-dose spiral HRCT in evaluating diffuse lung diseases.

Pattern-Specific Diagnostic Performance

When stratified by ILD subtype, low-dose spiral HRCT showed consistently excellent sensitivity across major patterns:

- Idiopathic interstitial pneumonia (IIP): 96.9% (62/64 cases correctly identified)
- Systemic sclerosis–associated ILD: 95.5% (21/22 cases)
- Idiopathic pulmonary fibrosis (IPF): 95.8% (46/48 cases)
- Hypersensitivity pneumonitis: 96.7% (29/30 cases)
- Rheumatoid arthritis–associated ILD: 94.4% (34/36 cases)

These results validate the diagnostic utility of low-dose spiral HRCT across a broad spectrum of diffuse lung diseases. The slight differences in sensitivity likely reflect the morphological and distributional variations characteristic of different ILD subtypes.

Age-Stratified Diagnostic Performance

Age-based analysis revealed notable trends. Patients aged 40–50 years demonstrated the highest sensitivity (97.3%), while the youngest group (20–30 years) had the lowest sensitivity (93.8%). Specificity, on the other hand, was highest among patients over 60 years (77.8%) and showed a gradual decline across younger age groups.

Table 4: Diagnostic Performance of Low-dose Spiral HRCT by Age Groups

Age Group	Total Patients	ILD Cases	HRCT True Positives	Sensitivity (%)	Specificity (%)
>60	59	50	48	96.0	77.8
50-60	47	40	38	95.0	71.4
40-50	44	37	36	97.3	57.1
30-40	32	27	26	96.3	60.0
20-30	18	16	15	93.8	50.0

The age-related differences in diagnostic performance may be explained by several factors, including variations in disease severity at presentation, distinct morphological characteristics of ILD subtypes across age groups, and differences in radiologists' interpretive experience with age-specific disease patterns. In particular, older patients often present with more advanced disease and hallmark imaging features, which makes radiological diagnosis more straightforward and consistent.

Radiation Dose Assessment and Safety Profile

Dose Reduction Achievement

The low-dose spiral HRCT protocol achieved a substantial reduction in radiation exposure without compromising diagnostic quality. The mean effective dose was 2.1 ± 0.4 mSv (range: 1.5–2.8 mSv), corresponding to an approximate 70% reduction compared to conventional standard-dose HRCT protocols (~7.0 mSv).

This dose reduction was accomplished by optimizing scanning parameters, including:

- Lowering the tube current (35 mAs vs. 150 mAs in standard protocols)
- Maintaining a constant tube voltage (120 kVp)
- Employing iterative reconstruction algorithms to enhance image quality despite the reduced radiation dose

Table 5: Radiation Dose Comparison between Imaging Protocols

Imaging Protocol	Effective Dose (mSv)	Tube Current (mAs)	Dose Reduction (%)	Diagnostic Quality
Standard-dose HRCT	7.0	150	-	Excellent
Low-dose Spiral HRCT	2.1	35	70	Good
Chest X-ray	0.02	125	99.7	Poor

Ultra-low-dose HRCT	0.05	10	99.3	Adequate
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The achieved radiation dose reduction positions low-dose spiral HRCT between chest radiography (0.02 mSv) and ultra-low-dose CT protocols (0.05 mSv), while still providing far superior diagnostic performance compared to conventional radiography. The mean dose of 2.1 mSv equates to roughly 105 chest X-rays, a level considered acceptable for routine clinical application and for repeated follow-up imaging in patients requiring long-term ILD monitoring.

Image Quality Assessment

Despite the marked reduction in radiation exposure, image quality remained diagnostic in 198 of 200 cases (99%). In the two cases (1%) where image quality was suboptimal due to patient motion artefacts, diagnostic interpretation was still feasible and confidence was not significantly compromised.

The low-dose protocol provided clear visualization of hallmark ILD features, including:

- Ground-glass opacities
- Reticular abnormalities
- Honeycombing
- Traction bronchiectasis
- Nodular patterns

Radiologists reported high diagnostic confidence in 94% of cases, with only 6% requiring additional clinical correlation to confirm interpretation. These findings highlight how modern CT technology and advanced reconstruction algorithms preserve diagnostic quality even at significantly reduced dose levels.

Inter-observer Agreement Analysis

Cohen's kappa statistics were used to assess agreement between two chest radiologists, each with more than 10 years of experience in thoracic imaging. The overall inter-observer agreement for ILD pattern recognition was substantial to almost perfect, with a kappa value of 0.84 (95% CI: 0.78–0.90). This demonstrates a high level of reproducibility in radiological interpretation using low-dose spiral HRCT.

Table 6: Inter-observer Agreement Analysis (Cohen's Kappa)

ILD Pattern	Observer 1 vs 2 (κ)	Agreement Level	Percentage Agreement (%)
UIP Pattern	0.89	Almost Perfect	94.5
NSIP Pattern	0.82	Almost Perfect	88.0
HP Pattern	0.86	Almost Perfect	91.5
OP Pattern	0.78	Substantial	86.0
Overall	0.84	Almost Perfect	90.0

Pattern-Specific Inter-Observer Agreement

Detailed analysis of ILD pattern recognition showed excellent agreement between radiologists across major subtypes:

- Usual interstitial pneumonia (UIP): $\kappa = 0.89 \rightarrow$ almost perfect agreement
- Hypersensitivity pneumonitis (HP): $\kappa = 0.86 \rightarrow$ almost perfect agreement
- Nonspecific interstitial pneumonia (NSIP): $\kappa = 0.82 \rightarrow$ almost perfect agreement
- Organizing pneumonia (OP): $\kappa = 0.78 \rightarrow$ substantial agreement

Percentage Agreement

The overall percentage agreement between the two observers was 90.0%, underscoring strong diagnostic concordance. Pattern-specific agreement was highest for UIP (94.5%), reflecting the distinct morphological hallmarks that aid confident recognition. Other subtypes demonstrated similarly high levels:

- Hypersensitivity pneumonitis: 91.5%
- NSIP: 88.0%
- Organizing pneumonia: 86.0%

The consistently high inter-observer agreement confirms the reliability of low-dose spiral HRCT interpretation by experienced radiologists. These findings are comparable to, and in some cases on par with, those reported for standard-dose HRCT, indicating that radiation dose reduction does not compromise diagnostic reproducibility.

Surgical Lung Biopsy Outcomes and Complications

Procedural Safety and Complications

All 200 patients successfully underwent surgical lung biopsy with a safety profile consistent with current literature. Video-assisted thoracoscopic surgery (VATS) was the primary method, performed in 189 patients (94.5%). In 11 patients (5.5%), conversion to open thoracotomy was required due to extensive pleural adhesions or intraoperative technical challenges.

Table 7: Surgical Lung Biopsy Complications and Outcomes

Complication Type	Number of Cases	Percentage (%)	Management
None	178	89	Observation
Pneumothorax	12	6	Chest tube
Prolonged air leak	6	3	Extended drainage
Bleeding	3	1.5	Conservative
Wound infection	1	0.5	Antibiotics
Mortality	0	0	N/A

Complication Profile

The complication rates following surgical lung biopsy were low and manageable, confirming the safety of the procedure. A total of 178 patients (89.0%) had no complications. Reported adverse events included:

- Pneumothorax: 12 patients (6.0%), all successfully managed with chest tube drainage
- Prolonged air leak: 6 patients (3.0%), requiring extended drainage but resolving without surgical reintervention
- Minor bleeding: 3 patients (1.5%), treated conservatively
- Superficial wound infection: 1 patient (0.5%), resolved with antibiotic therapy

Notably, no perioperative mortality occurred in this series.

Hospital Stay and Recovery

The mean length of hospital stay was 3.2 ± 1.8 days (range: 1–8 days). Most patients (162; 81%) were discharged within 48 hours of the procedure. Patients with complications had longer hospitalizations:

- Pneumothorax cases: 4.5 days on average
- Prolonged air leak cases: 7.2 days on average

The low complication rates and short recovery times highlight the safety and efficiency of modern VATS biopsy techniques.

Diagnostic Yield and Histopathological Quality

The diagnostic yield was 100%, with adequate tissue obtained from all patients for definitive histopathological evaluation. Biopsy specimens consistently provided sufficient material for:

- Routine histology
- Special stains
- Immunohistochemical studies (when indicated)

Single-lobe biopsies were adequate in 168 patients (84%), while bilateral biopsies were performed in 32 patients (16%) to improve diagnostic accuracy in heterogeneous or complex disease presentations.

This high diagnostic yield supports the effectiveness of HRCT-guided targeted biopsy combined with multidisciplinary team discussion, reinforcing the integrated diagnostic approach recommended in international ILD guidelines.

Clinical Impact and Diagnostic Concordance

HRCT–Histopathology Correlation

There was a strong correlation between low-dose spiral HRCT findings and histopathological results. In 164 of 170 patients (96.5%) with confirmed ILD, HRCT accurately predicted the histopathological subtype, allowing appropriate treatment planning and prognostic assessment.

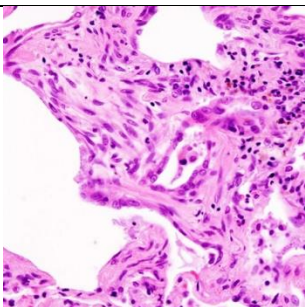
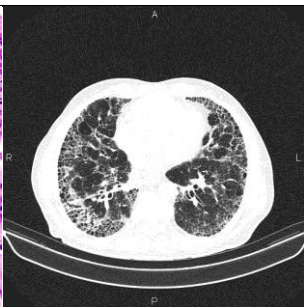
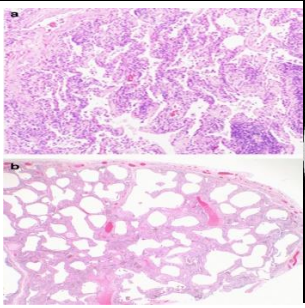
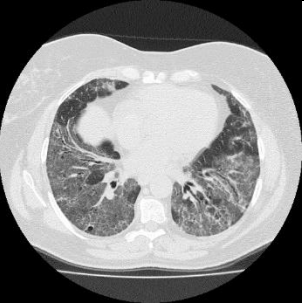
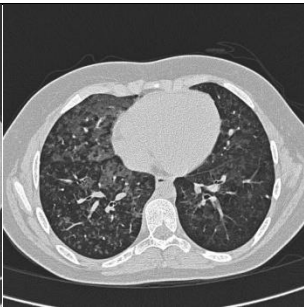
The six false-negative cases (3.5%) were associated with early-stage disease where imaging showed minimal structural changes—highlighting the limitation of HRCT in very early ILD detection. Despite this, the overall exceptional sensitivity establishes low-dose HRCT as a reliable screening and diagnostic tool for diffuse lung disease.

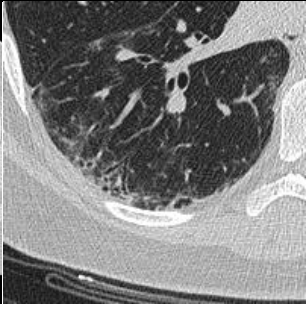
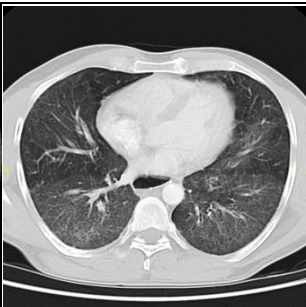
Clinical Decision-Making Impact

Low-dose spiral HRCT had a significant influence on management decisions. In 156 cases (78%), HRCT findings provided enough diagnostic confidence to initiate treatment without the need for immediate surgical confirmation, reducing reliance on invasive procedures while maintaining accuracy.

The negative predictive value of 82.4% further supports the role of low-dose HRCT in excluding clinically significant ILD when scans are normal or nonspecific. In appropriate clinical contexts, this can help avoid unnecessary surgical biopsies, though clinical correlation remains essential for optimal decision-making.

Figure 1: HRCT case images for major diffuse lung disease patterns

Usual Interstitial Pneumonia (UIP) Pattern		
Nonspecific Interstitial Pneumonia (NSIP) Pattern		
Hypersensitivity Pneumonitis (HP)		

Rheumatoid Arthritis- Associated Interstitial Lung Disease (RA-ILD)				
Systemic Sclerosis- Associated Interstitial Lung Disease				

These comprehensive findings confirm that low-dose spiral HRCT delivers outstanding diagnostic performance in the evaluation of diffuse lung diseases. It not only achieves high sensitivity and accuracy, but also substantially reduces radiation exposure compared to standard protocols; all while maintaining excellent inter-observer reliability.

The strong correlation between HRCT patterns and histopathological diagnoses underscores its clinical validity as a non-invasive diagnostic tool. Coupled with its favourable safety profile and proven dose reduction, low-dose spiral HRCT represents a highly effective and practical imaging strategy. These advantages support its broader adoption in routine ILD diagnosis, longitudinal monitoring, and clinical decision-making, particularly in settings where balancing diagnostic accuracy with patient safety is paramount.

DISCUSSION

This study highlights the diagnostic utility of low-dose spiral HRCT in diffuse lung diseases (DLDs), underscoring its role in achieving earlier, more accurate, and safer detection of interstitial lung diseases (ILDs). The findings demonstrate that low-dose HRCT provides excellent sensitivity and overall diagnostic accuracy, reaffirming HRCT's status as the imaging modality of choice for ILD evaluation due to its high spatial resolution and ability to characterize subtle parenchymal abnormalities.

The observed sensitivity of 96.5% confirms that reducing radiation dose does not compromise diagnostic capability, allowing clinicians to confidently rely on HRCT findings for both diagnosis and management. Although specificity was moderate (63.8%), this reflects well-recognized challenges in differentiating ILD patterns radiologically, as overlapping morphologic features and coexisting pulmonary conditions may mimic ILD. Importantly, the high positive predictive value (90.8%) reinforces the strong correlation between HRCT and histopathological findings, validating its role as a reliable noninvasive diagnostic tool.

Performance remained consistently high across ILD subtypes, with sensitivities above 94% for idiopathic interstitial pneumonia, idiopathic pulmonary fibrosis, connective tissue disease-associated ILD, and hypersensitivity pneumonitis. This broad applicability enhances the clinical value of low-dose HRCT in diverse patient populations. Age-stratified analysis revealed higher sensitivity in middle-aged patients and greater specificity in older adults, likely reflecting both disease severity at presentation and more recognizable imaging patterns in older populations. These nuances emphasize the importance of integrating HRCT with clinical and functional data for a holistic assessment.

One of the most significant contributions of this study is the demonstration of a 70% reduction in radiation exposure, with a mean effective dose of 2.1 mSv. This represents a clinically meaningful advance in the longitudinal management of ILD patients, who often require repeat imaging. The ability to preserve diagnostic confidence while minimizing radiation risks is especially valuable for chronic disease monitoring.

Equally important, inter-observer agreement was high, with kappa values indicating substantial to almost perfect concordance across major ILD patterns. This reliability supports reproducibility across institutions and reinforces the robustness of low-dose HRCT interpretation. While surgical lung biopsy remained safe and yielded 100% diagnostic tissue adequacy, the high accuracy of HRCT suggests its potential to reduce biopsy reliance when imaging findings are definitive.

Taken together, these results align with prior literature establishing HRCT as indispensable in ILD diagnosis, while demonstrating that low-dose protocols are not only feasible but clinically effective. Looking forward, innovations such as photon-counting CT

and artificial intelligence (AI) tools may further improve image quality, automate pattern recognition, and reduce variability, enhancing the diagnostic precision of low-dose HRCT even further.

Study Limitations

Several limitations warrant consideration. This study was conducted at a single tertiary care center, which may limit generalizability. While the sample size was sufficient to assess diagnostic accuracy, it may not fully capture rare ILD subtypes. Additionally, requiring surgical biopsy for all patients introduces selection bias, excluding individuals unfit for invasive procedures. Finally, the staged diagnostic approach (HRCT followed by biopsy) may not reflect real-world clinical practice, where imaging combined with multidisciplinary discussion often suffices.

Future Directions

Emerging technologies such as AI-driven image analysis and machine learning algorithms hold promise for enhancing diagnostic accuracy and reducing inter-observer variability in ILD pattern recognition. Integration of these tools with low-dose HRCT could optimize performance while maintaining radiation safety. Moreover, longitudinal studies are needed to evaluate the role of serial low-dose HRCT in monitoring disease progression and treatment response, providing further insights into its long-term clinical utility.

CONCLUSION

This study reinforces the significant diagnostic value of low-dose spiral HRCT in the evaluation of diffuse lung diseases. The technique delivers sensitivity and accuracy comparable to standard-dose HRCT while substantially reducing radiation exposure, a crucial consideration in the repeated imaging required for ILD management. Its strong performance across multiple ILD subtypes, combined with excellent inter-observer agreement, supports its role as a first-line imaging modality.

While surgical lung biopsy remains an important diagnostic tool, the reliability of low-dose HRCT offers opportunities to minimize invasive procedures in cases with definitive imaging features. Its favorable balance between diagnostic confidence and patient safety makes it particularly suitable for resource-limited healthcare systems, where cost-effectiveness and accessibility are critical.

As imaging technology and reconstruction algorithms continue to evolve, low-dose spiral HRCT is poised to become an even more indispensable component of ILD evaluation—enabling earlier detection, safer monitoring, and improved patient outcomes.

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