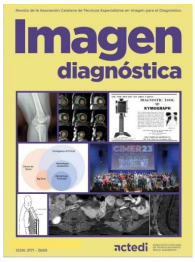

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Evaluation of Interstitial Lung Disease by High Resolution Computed Tomography

Rowa Aljondi[1], Abdulrahman Tajaldeen[2*], Salem Alghamdi[3], Afnan Sindi[4], Taif Salhabi[5], Manar AlJehani[6] and Manar AlZahrani[7]

[1-7]Department of Applied Radiologic Technology, College of Applied Medical Sciences, University of Jeddah, 23218 Jeddah, Saudi Arabia

Author Designation:
[1,2]Associate Professor, [3]Professor, [4-7]Students

*Corresponding author:
Dr. Abdulrahman Tajaldeen
aatajaldeen@uj.edu.sa

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Abstract: Background and Objective: Interstitial Lung Diseases (ILDs) comprise a heterogeneous group of lower respiratory tract disorders affecting the pulmonary parenchyma and interstitial. High-Resolution Computed Tomography (HRCT) plays a pivotal role in visualizing fine parenchymal structures. This study aimed to perform a radiological evaluation of HRCT manifestations, severity distribution and anatomical patterns in patients with ILD in Jeddah, Saudi Arabia. **Methods:** A retrospective observational study was conducted on 100 adult patients (53 males, 47 females; mean age 60.4±17.1 years) with clinically documented ILD who underwent HRCT at two major tertiary hospitals in Jeddah between 2022 and 2023. Imaging parameters and clinical data were retrieved from electronic medical records. Data was analyzed using descriptive statistics (frequencies and percentages) in SPSS. **Results:** The majority of patients (57%) were aged 60 years or older. Bilateral lung involvement was predominant (77%). Disease extent on HRCT was classified as mild/extensive in 78% and moderate in 22% of cases. The most frequent radiological features observed were ground-glass opacity (GGO) (43%), interstitial septal thickening (25%), volume loss (20%), consolidation (20%), traction bronchiectasis (18%) and honeycombing (14%). Overlapping clinical chest CT categories included documented ILD entities (39%), chronic lung conditions (29%) and post-infectious/COVID-19 changes (23%). **Conclusion:** HRCT is an essential non-invasive imaging modality for characterizing parenchymal patterns, disease extent and anatomical distribution in ILD. HRCT findings provide important radiological guidance and should be integrated with clinical, laboratory and multidisciplinary evaluations.

Key Words: High Resolution Computed Tomography, Interstitial Lung Disease, Radiographic Patterns, Radiological Evaluation, Saudi Arabia

INTRODUCTION

Interstitial Lung Diseases (ILDs) are a diverse category of lower respiratory tract disorders marked by interstitial inflammation and dysregulation as well as the loss of functioning alveolar units [1]. The disease also affects epithelial, endothelial and mesenchymal cells, acini and bronchioles. As a result, the entire pulmonary parenchyma was affected [2]. The chest radiograph might help to identify further beneficial features that could support a differential diagnosis as well as in evaluating overall patterns of disease distribution. However, conventional chest radiography has been replaced by High Resolution Computed Tomography (HRCT) scanning as the recommended imaging method for the ILDs due to its improved capacity to see fine detail within the lung [3,4]. In HRCT of the chest, thin- slice chest images are post-processed using a high-spatial-frequency reconstruction algorithm [5]. This technique generates lung images with exceptional lung detail that are useful for assessing diffuse interstitial lung diseases [6,7].

Several research studies have been assessed the accuracy and effectiveness of HRCT in diagnosing Interstitial lung diseases [8-13]. According to the majority of published studies, an HRCT scan is recognized as the most accurate technique to diagnose and treat Interstitial lung diseases [8,12]. The main advantages of HRCT were provided detailed visualization and characterization of diffuse parenchymal lung abnormalities compared to conventional chest radiography [14,15]. HRCT provided a detailed assessment of suspected diffuse lung disease, including characterization of the pattern, distribution and extent of parenchymal opacities and associated findings such as bronchiectasis and lymphadenopathy [15]. Its high spatial resolution supports refinement of the radiological differential diagnosis when interpreted together with clinical information [14,16]. One of the

most common radiological features of ILDs are Bronchiectasis then Reticulation, Ground Glass and Honeycombing, while only a few patients on the sample from Saudi Arabian cohort had Consolidation [17-19]. However, there was scarcity of published HRCT observational data specifically on the evaluation of interstitial lung disease in a cohort from Saudi Arabia.

Researchers found that Idiopathic Pulmonary Fibrosis (IPF) and Connective Tissue Diseases (CTD) were the most common disease entities [20-22]. Sarcoidosis is the next most frequent, followed by Nonspecific Interstitial Pneumonia (NSIP), Cryptogenic Organizing Pneumonia (COP) and Respiratory Bronchiolitis-associated Interstitial Lung Disease (RB-ILD) [23,24]. Lymphocytic Interstitial Pneumonia (LIP) and Acute Interstitial Pneumonia (AIP) are rare [25]. Differences in population characteristics and environmental exposures may influence the spectrum and presentation of ILDs across different populations. Therefore, characterizing ILDs within a Saudi Arabian cohort is essential to improve disease recognition and provide context-specific evidence that may support earlier diagnosis and guide future clinical practice and research.

Although international guidelines underscore the importance of HRCT in characterization [26], local epidemiological and radiological data regarding ILD pattern distributions in Saudi Arabia specifically in the Western Region (Jeddah) remain limited. Therefore, this retrospective study was undertaken to characterize the HRCT findings, radiological patterns, severity and distribution of pulmonary abnormalities among patients with confirmed interstitial lung disease in Jeddah, Saudi Arabia.

METHODS

Study Design and Data Collection

This retrospective observational study included a total of 100 adult patients (53 males and 47 females) with confirmed Interstitial Lung Disease (ILD) who underwent High-Resolution Computed Tomography (HRCT) of the chest at the Radiology Departments of King Abdullah Medical Complex and King Abdulaziz Hospital in Jeddah, Saudi Arabia. Formal prospective sample size estimation was not performed due to the retrospective observational study design; all available eligible records within the inclusion period (2022-2023) were analyzed.

The inclusion criteria comprised adult patients aged ≥18 years with a confirmed clinical diagnosis of ILD and complete high-quality HRCT examinations available for review. Pediatric patients (<18 years), HRCT examinations with severe motion artifacts or inadequate image quality and cases with incomplete clinical or imaging records were excluded from the study. The HRCT images and corresponding clinical and radiology reports were retrospectively reviewed by expert radiologists on the field to identify and characterize the imaging patterns and radiological signs associated with ILD.

All HRCT examinations were performed using a standardized imaging protocol and were evaluated by radiologists for the presence and characterization of radiological findings associated with ILD. Chest HRCT examinations were performed using either a 128-slice GE Discovery CT 750 HD scanner or a 64-slice Siemens SOMATOM CT scanner. Images were acquired using standardized scanning parameters, including a tube voltage of 120 kVp, tube current of 150-300 mAs, rotation time of 0.8 s, pitch of 1.375 and reconstructed slice thickness of 0.6 mm. Scanning was performed in the axial plane, extending from above the lung apices to below the costophrenic angles, with an individually optimized Display Field of View (DFOV). Anteroposterior (AP) and lateral scout images were obtained before image acquisition. Patients were instructed to suspend respiration at full inspiration during scanning to minimize respiratory motion artifacts. Images were evaluated using lung window settings with a Window Width (WW) of 1500 HU and Window Level (WL) of -700 HU). These HRCT examinations were retrospectively assessed for radiological features of interstitial lung disease, with particular attention to the imaging pattern, distribution and extent of pulmonary involvement and severity of the observed abnormalities. Scans were interpreted during routine clinical service by staff radiologists who had access to clinical histories; re-interpretation or blinded review was not performed. The documented ILD diagnosis was retrieved from finalized electronic medical records and clinical radiology reports. Histopathological correlation and formal multidisciplinary team consensus were not available as a reference standard; consequently, the study describes HRCT manifestations and radiological characterization rather than diagnostic sensitivity, specificity or accuracy.

Statistical Analysis

Data was analyzed using IBM SPSS Statistics (Version 26.0). Categorical variables (sex, anatomical distribution, presence of specific HRCT features, clinical diagnostic categories) are presented as frequencies and percentages. Continuous variables (age) are presented as Mean±Standard deviation (SD). Due to the descriptive focus of the study, inferential comparative statistics and multivariable modeling were not conducted.

RESULTS

Demographic Characteristics

The study included 100 patients (53% male, 47% female; mean age 60.4±17.1 years). The majority of patients (57%) were aged 60 years or older, whereas only 1% were under 20 years old as shown in Table 1.

Disease Severity and Anatomical Distribution

Bilateral lung involvement was present in 77% of patients, while 23% demonstrated unilateral involvement. Figure 1 illustrates the distribution of

Table 1: Sample Demographic Characteristics (N = 100)

Variable	Categories	Frequency (n)	Percentage
Age Group (Years) (Mean = 60.4, SD = 17.1)	<20	1	1.0
	20-29	2	2.0
	30-39	14	14.0
	40-49	6	6.0
	50-59	20	20.0
	≥60	57	57.0
Gender	Male	53	53.0
	Female	47	47.0

Table 2: Spectrum of Clinical Diagnoses

Category	Specific Clinical Diagnosis	Frequency n (%)
Interstitial Lung Diseases (39%)	Pneumonia UIP	11 (11%)
	Idiopathic Pulmonary Fibrosis (IPF)	8 (8%)
	Nonspecific Interstitial Pneumonia (NSIP)	7 (7%)
	Pneumocystis Jirovecii Pneumonia	3 (3%)
	Idiopathic Interstitial Pneumonias (IIP)	3 (3%)
	Cryptogenic Organizing Pneumonia (COP)	2 (2%)
	Cystic Bronchiectasis/Granulomatous/Other ILD	5 (5%)
Chronic Lung Diseases (29%)	Atelectasis/Nodules/Asthma/Post-COVID Fibrosis	29 (29%)
Infectious/COVID-19 & Chest Findings	COVID-19 related features	23 (23%)
	Pleural Effusion	12 (12%)
	Emphysema/Obstructive disease	11 (11%)

Table 3: Frequency of HRCT Features

Radiological Feature	Frequency n (%)
Ground-glass opacity (GGO)	43 (43%)
Interstitial septal thickening	25 (25%)
Volume loss	20 (20%)
Consolidation	20 (20%)
Traction bronchiectasis	18 (18%)
Bronchiectasis	14 (14%)
Honeycombing	14 (14%)
Air bronchogram	10 (10%)
Pleural fluid	9 (9%)
Enlarged mediastinal lymph nodes	5 (5%)
Architectural distortion/Mosaic attenuation	4 (4%)

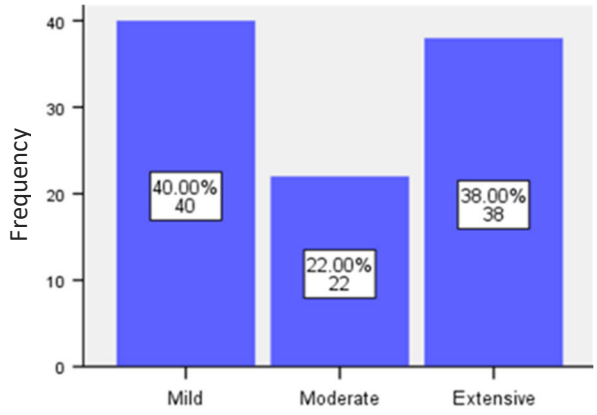

Figure 1: The Distribution of Disease Severity Among the Study Population
Mild/Extensive: 78%, Moderate: 22%

disease extent/severity in the study population. Most patients (78%) were classified in the recorded mild/ extensive category, while 22% were classified as moderate.

The anatomical distribution of lung involvement in the study sample was shown in Figure 2. A large majority

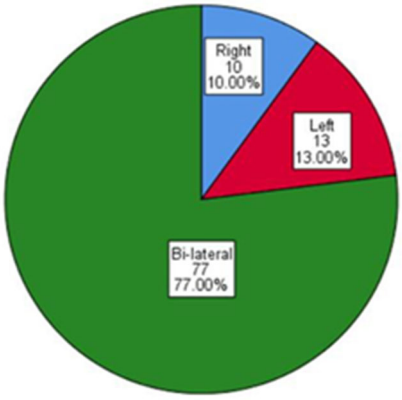

Figure 2: The Anatomical Distribution of Lung Involvement in the Study Sample
Bilateral: 77%, Unilateral: 23%

(77%) demonstrated bilateral lung involvement, confirming that ILD typically affects both lungs rather than being confined to one side. Bilateral patterns are commonly associated with diffuse parenchymal processes, including fibrotic and inflammatory lung diseases. Unilateral cases (23%) likely represent early-stage disease or localized pathology.

Spectrum of Clinical Diagnoses

Table 2 presents the documented clinical diagnostic categories and associated chest CT findings in the study records. ILD accounted for 39%, chronic lung disease categories for 29%, acute lung disease categories for 8% and vascular disease categories for 6%. COVID-19-related findings were documented in 23% of records. Because some categories and findings overlap, these percentages should be interpreted descriptively rather than as mutually exclusive diagnostic groups.

HRCT Radiological Features

The most prevalent radiological feature was Ground-Glass Opacity (GGO), observed in 43% of patients. Interstitial septal thickening was identified in 25%, volume loss in 20%, consolidation in 20%, traction bronchiectasis in 18% and honeycombing in 14% (Table 3).

DISCUSSION

The present study characterized the HRCT manifestations, anatomical distribution and disease extent among patients with Interstitial Lung Disease (ILD). The principal findings were the predominance of older patients, frequent bilateral pulmonary involvement and a heterogeneous spectrum of HRCT abnormalities. Ground-Glass Opacity (GGO) was the most common radiological finding (43%), followed by interstitial septal thickening (25%), volume loss (20%), consolidation (20%), traction bronchiectasis (18%) and honeycombing (14%). Collectively, these findings demonstrate the coexistence of inflammatory and fibrotic imaging manifestations within this Saudi ILD cohort and reinforce the value of HRCT for characterizing the morphological spectrum and extent of interstitial pulmonary abnormalities.

The age distribution was one of the notable characteristics of the cohort. The mean age was 60.4±17.1 years and 57% of patients were aged 60 years or older. The sex distribution was relatively balanced, with 53% males and 47% females. This demographic profile is broadly consistent with previous ILD studies. Man et al. [27] reported a mean age of 58.97±15.59 years and a slight male predominance (58.6%) and Cömert *et al*. [28] reported a mean age of 59.2±14.2 years. The similarity across these studies indicates that clinically recognized ILD frequently occurs in older adults. However, the nearly equal distribution of males and females in the current study should be regarded as a characteristic of this cohort rather than evidence that ILD risk is equivalent between sexes, as individual ILD subtypes may have different demographic profiles.

A second important finding was the predominance of bilateral lung involvement, which was identified in 77% of patients, compared with unilateral involvement in 23%. This distribution is compatible with the diffuse nature of many interstitial pulmonary disorders and demonstrates the usefulness of HRCT in defining the anatomical extent of parenchymal involvement. Regarding radiological extent/severity, 78% of patients were recorded within the mild/extensive categories and 22% as moderate. Comparison with previous studies be made cautiously because different methods have been used to quantify ILD severity. Previous study by Mohamed *et al*. [29], used the Warrick score, reported mild disease in 46%, moderate disease in 44% and severe disease in 10% of patients. Sarac *et al*. [30] also applied Warrick-based assessment, whereas Hasan *et al*. categorized HRCT scores according to mild and severe fibrosis. Thus, differences between the present results and previous studies may reflect not only differences in disease burden and patient populations but also variation in the methods used to classify radiological severity. A standardized semiquantitative scoring system would facilitate more meaningful comparisons in future Saudi ILD studies.

The most important radiological finding in the present study was the predominance of GGO, observed in 43% of patients. This finding is remarkably similar to that of Mohamed *et al*. [29], who reported GGO in 44% of patients. These observations support GGO as a common, although nonspecific, manifestation of interstitial pulmonary disease. GGO may occur in inflammatory, cellular or fibrotic processes and therefore should not be interpreted as an isolated disease-specific sign. Its diagnostic significance depends on its distribution and its relationship to other HRCT abnormalities, such as reticulation, traction bronchiectasis, consolidation and honeycombing.

Interstitial septal thickening was the second most frequent abnormality in the present cohort, affecting 25% of patients, while volume loss was present in 20%. More established fibrotic features were also identified, particularly traction bronchiectasis in 18% and honeycombing in 14%. The simultaneous occurrence of GGO, septal thickening, traction bronchiectasis and honeycombing illustrates the broad spectrum of non-fibrotic and fibrotic abnormalities encountered in ILD. This is consistent with established HRCT descriptions of major ILD patterns [26]. UIP and IPF are commonly characterized by reticular abnormalities, traction bronchiectasis and honeycombing, whereas NSIP more frequently demonstrates GGO accompanied by reticulation and traction bronchiectasis [11,31]. The relatively lower frequency of honeycombing compared with GGO in the present study may therefore reflect the heterogeneous disease spectrum of the cohort rather than a predominance of advanced fibrotic disease.

The presence of honeycombing in 14% of patients is particularly relevant because honeycombing is an important HRCT feature in the characterization of fibrotic ILD and the UIP pattern. Nevertheless, honeycombing alone cannot establish a specific ILD diagnosis; its distribution and accompanying findings must be considered. Similarly, traction bronchiectasis, identified in 18% of the cohort, may indicate fibrotic architectural distortion when occurring within areas of reticulation or fibrosis. These observations emphasize that interpretation of ILD should be based on the overall HRCT pattern rather than the presence of individual radiological signs. This is particularly relevant given the variability that may occur in image interpretation. Delaney *et al*. [19] in a meta-analysis of interobserver agreement for HRCT assessment of ILD, reported only modest pooled agreement for common imaging features, including GGO and honeycombing.

The clinical records also demonstrated substantial heterogeneity. Specific documented ILD entities included UIP (11%), IPF (8%), NSIP (7%), Pneumocystis jirovecii

pneumonia (3%), idiopathic interstitial pneumonias (3%) and COP (2%), among other diagnoses. In addition, chronic lung disease categories and COVID-19-related findings were recorded in 29 and 23%, respectively. These categories were overlapping rather than mutually exclusive. This distinction is particularly important because post-infectious and COVID-19-related abnormalities can produce GGO, consolidation, reticulation and fibrotic changes that overlap radiologically with ILD. Therefore, the high frequency of GGO in this cohort cannot be attributed to a single ILD subtype and should instead be interpreted within the complete clinical and radiological context.

The present findings are also relevant within the Saudi Arabian context, where published observational data describing the radiological spectrum of ILD remain relatively limited. Alhamad [17] previously reported ILD characteristics in a Saudi single-center cohort in Riyadh, providing important national evidence. The current study extends this literature by providing descriptive HRCT data from the Western Region of Saudi Arabia in Jeddah. Differences between the current findings and other Saudi and international cohorts may reflect variations in referral patterns, environmental exposures, underlying disease distribution, clinical documentation and imaging interpretation. Consequently, future studies should be viewed as regional descriptive data rather than estimates of the prevalence of ILD or individual ILD subtypes in the wider Saudi population.

An important consideration when interpreting these findings is that the study relied on finalized routine clinical radiology reports rather than a standardized, blinded reinterpretation of all HRCT examinations. Furthermore, histopathological confirmation and formal multidisciplinary consensus were not available as reference standards. Consequently, the study does not establish the sensitivity, specificity or diagnostic accuracy of HRCT for ILD. Instead, its contribution lies in describing the spectrum, frequency, anatomical distribution and extent of HRCT abnormalities encountered among patients with documented ILD in routine clinical practice in Jeddah.

Overall, the predominance of bilateral involvement and GGO, together with the presence of interstitial septal thickening, traction bronchiectasis, volume loss, consolidation and honeycombing, demonstrates the heterogeneous HRCT appearance of ILD in this Saudi cohort. The findings are broadly consistent with previous studies showing that HRCT can demonstrate both inflammatory and fibrotic components of ILD, while also illustrating that individual CT signs lack sufficient specificity to be interpreted independently. HRCT should therefore be considered an essential component of ILD characterization but interpreted alongside clinical history, pulmonary function testing, laboratory findings and multidisciplinary assessment when available [14,31,32].

CONCLUSIONS

This study provides a descriptive characterization of HRCT findings among patients with documented interstitial lung disease evaluated in Jeddah, Saudi Arabia. Bilateral lung involvement was common and ground-glass opacity was the predominant feature, followed by interstitial septal thickening, volume loss, consolidation, traction bronchiectasis and honeycombing. These findings demonstrate the heterogeneous radiological spectrum of ILD and highlight the importance of evaluating the overall HRCT pattern, distribution and extent of pulmonary abnormalities rather than relying on individual imaging signs.

HRCT remains an important non-invasive imaging modality for the characterization of interstitial lung abnormalities and can provide valuable information regarding both inflammatory and fibrotic disease manifestations. However, because histopathological confirmation or formal multidisciplinary consensus was not available as a reference standard in this study, the findings should be interpreted as descriptive radiological observations rather than evidence of diagnostic accuracy. Integration of HRCT findings with clinical history, laboratory investigations, pulmonary function testing and multidisciplinary assessment remains important for comprehensive evaluation of patients with ILD. Larger prospective multicenter studies using standardized HRCT interpretation and severity scoring are warranted to further characterize ILD patterns and their clinical significance across the Saudi population.

Limitations

This study has several limitations that should be considered when interpreting the findings. First, its retrospective design and inclusion of patients from only two tertiary hospitals in Jeddah may introduce selection and referral bias and may limit the generalizability of the results to the wider Saudi population. Second, the relatively small sample size may not fully represent the clinical and radiological heterogeneity of ILD. In addition, the study relied on finalized routine clinical radiology reports rather than a standardized, blinded reinterpretation of all HRCT examinations and interobserver agreement between radiologists was not assessed. Histopathological confirmation and formal multidisciplinary team consensus were also not available as reference standards; therefore, the findings should be interpreted as descriptive radiological observations rather than measures of diagnostic accuracy. Furthermore, disease severity was not assessed using a single validated semiquantitative scoring system, which limits direct comparison with studies using standardized tools such as the Warrick score. Finally, the descriptive statistical design did not allow assessment of significant associations between HRCT findings, demographic characteristics, ILD subtypes or disease severity.

Future Directions

Future studies should address these limitations through larger prospective multicenter investigations involving different geographical regions of Saudi Arabia to improve representativeness and external validity. Standardized HRCT acquisition protocols, reporting terminology and validated semiquantitative scoring systems should be adopted to facilitate comparison across institutions and over time. Prospective studies should also incorporate independent blinded image review and assessment of interobserver agreement for key HRCT features such as ground-glass opacity, reticulation, traction bronchiectasis and honeycombing. Integration of radiological findings with pulmonary function tests, laboratory findings, clinical characteristics, histopathology where appropriate and multidisciplinary team assessment would allow more comprehensive characterization of ILD subtypes and disease progression. In addition, longitudinal studies could evaluate temporal changes in HRCT patterns and their relationship with treatment response and clinical outcomes. Emerging quantitative CT and artificial intelligence approaches may also have a future role in automated detection, fibrosis quantification and standardized assessment of ILD, although these methods should be validated against expert radiological and multidisciplinary evaluation before routine clinical implementation.

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Ethical Considerations

The Bioethics Committee of the University of Jeddah approved this research (Registration Number: HAP-02-J-094, Application Number: UJ-REC-111; Approval Date: February 27, 2023). A waiver of informed consent was granted due to the retrospective nature of the study using anonymized electronic medical records, in full compliance with the Declaration of Helsinki.

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