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Declarations

No funding was received for this study. The authors declare no conflict of interest. The study received ethical approval. All participants provided informed consent.

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Lung Patterns Diagnosed on HRCT in Patients with Acute Inflammatory Pulmonary Disease

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ABSTRACT

Background: High-resolution computed tomography (HRCT) provides detailed visualization of pulmonary parenchymal abnormalities and is the imaging modality of choice for assessing acute inflammatory lung disease. Its ability to delineate consolidation, ground-glass opacity (GGO), and other parenchymal changes enhances diagnostic accuracy and reduces the need for invasive investigations. **Objective:** To determine the prevalence and distribution of lung patterns on HRCT among patients with acute inflammatory pulmonary disease and to evaluate their relationship with age and gender. **Methods:** This cross-sectional observational study included 59 adult patients (33 females, 26 males) who underwent HRCT at Services Hospital, Lahore, between January and June 2024. Eligible participants presented with acute respiratory symptoms (<4 weeks) and radiological features of inflammation. HRCT findings were independently reviewed by two radiologists. Data were analyzed using SPSS v25 with χ^2 and Fisher's exact tests to assess associations between imaging patterns and demographic factors. **Results:** The most frequent HRCT findings were bilateral involvement (86.4%), consolidation (55.9%), pleural effusion (47.5%), and GGO (44.1%). No statistically significant associations were found between age or sex and specific HRCT patterns ($p>0.05$). **Conclusion:** Consolidation, GGO, and pleural effusion were the dominant HRCT patterns in acute inflammatory pulmonary disease. HRCT remains a crucial non-invasive diagnostic tool for timely identification and management of acute lung inflammation.

Keywords

HRCT, acute inflammatory lung disease, consolidation, ground-glass opacity, pleural effusion, bilateral involvement

INTRODUCTION

High-resolution computed tomography (HRCT) is central to evaluating adults who present with acute inflammatory lung syndromes, because thin-section imaging delineates parenchymal patterns—consolidation, ground-glass opacity (GGO), tree-in-bud change, and dependent atelectasis—with greater sensitivity than chest radiography and standard CT for diffuse processes (1). In acute infection and inflammation, these signs map to clinically meaningful phenotypes: lobar or multifocal consolidation suggests bacterial pneumonia; diffuse or peripheral GGO often accompanies viral pneumonitis; airway-centric nodularity and mucus impaction imply bronchiolitis; and pleural effusions, lymphadenopathy, or early fibro-atelectatic bands may index disease extent or complications (1,2). Beyond morphology, HRCT timing matters: early scans capture potentially reversible, predominantly alveolar patterns, while later imaging may show organizing change or tractional features that can mislead clinicians toward chronicity if the clinical context is unclear (1,2).

During the COVID-19 era, multiple cohorts confirmed that HRCT detects and stages acute parenchymal injury, where mixed GGO—consolidation patterns correlate with clinical deterioration and short-term progression to severe disease (3,4). Local work likewise linked HRCT burden with systemic inflammatory markers, highlighting the modality’s role in triage when laboratory signals and symptoms diverge (5). Although those investigations focused on a single viral etiology, they reinforced a broader principle: in adults with acute respiratory presentations, standardized HRCT pattern reporting can improve diagnostic confidence, risk stratification, and downstream management decisions, particularly when microbiology is pending or equivocal (3–5).

At the same time, judicious use of HRCT is essential. Contemporary dose-optimization studies demonstrate that pneumonia, nodules, and early fibrotic change remain detectable at substantially reduced dose levels when acquisition parameters are tailored to patient habitus and the diagnostic task, mitigating radiation concerns in acutely ill patients who may undergo repeat imaging (6,7). These technical advances strengthen the case for protocolized HRCT in emergency and inpatient pathways where swift, imaging-guided decisions can avert invasive procedures.

Despite this rationale, there are limited data from our setting quantifying the real-world distribution of HRCT patterns in adults with clinically suspected acute inflammatory pulmonary disease, and whether these patterns vary by age or sex. Much of the HRCT literature from our region emphasises chronic interstitial lung diseases or drug-induced injury rather than undifferentiated acute presentations seen in mixed medical services (8). Addressing this gap can calibrate expectations for common and uncommon findings—such as the baseline prevalence of consolidation, GGO, pleural effusion, lymphadenopathy, and cavitation—and inform pragmatic reporting checklists for radiologists in high-throughput environments. Accordingly, we conducted a cross-sectional study of consecutive adult patients undergoing HRCT for suspected acute inflammatory pulmonary disease at a tertiary center. Our Population comprised adults ≥ 18 years with acute respiratory symptoms; the Index test was HRCT acquired using a standardized thin-section protocol; the Comparators were age strata and sex; and the Outcomes were the prevalence and distribution of predefined HRCT patterns. We hypothesized that consolidation and GGO would be the dominant acute patterns, with higher prevalence in older age strata

and minimal sex-related differences (primary objective: estimate pattern prevalence; secondary objective: compare prevalence across age and sex) (1–8).

MATERIAL AND METHODS

This study employed a descriptive cross-sectional observational design to evaluate lung parenchymal patterns detected on high-resolution computed tomography (HRCT) in adult patients with clinically suspected acute inflammatory pulmonary disease. The investigation was conducted in the Department of Radiology, Services Hospital, Lahore, Pakistan, between January and June 2024, following institutional ethical approval. The setting was a tertiary-care public hospital that routinely performs HRCT for patients referred from emergency and medical wards with acute respiratory symptoms.

Eligible participants were adults aged 18 years or older of either sex who presented with acute respiratory complaints—such as cough, fever, dyspnea, or chest pain—of less than four weeks’ duration and demonstrated imaging findings consistent with acute inflammation on HRCT. Exclusion criteria comprised a prior diagnosis of chronic interstitial lung disease, pulmonary malignancy, tuberculosis, or any non-acute pulmonary pathology (e.g., chronic sarcoidosis or resolved pneumonia). Patients with incomplete imaging data or without informed consent were also excluded. Recruitment followed a consecutive convenience sampling strategy, enrolling all eligible cases during the study period. Written informed consent was obtained from each participant after explaining the purpose and confidentiality of the research.

All HRCT examinations were performed using a multislice CT scanner with 1 mm collimation and standard high-resolution reconstruction algorithms. Scans were acquired in full inspiration with patients in the supine position; additional expiratory sequences were obtained when clinically indicated. Images were reconstructed in axial and coronal planes using a 512×512 matrix. Two consultant radiologists with over 5 years of thoracic imaging experience independently reviewed the anonymized images, blinded to each other’s findings and clinical data. Discrepancies were resolved by consensus. Radiological variables were defined according to the Fleischner Society terminology: consolidation as homogeneous alveolar opacification obscuring vessels, ground-glass opacity (GGO) as increased attenuation without obscuration of underlying structures, pleural effusion as fluid collection within the pleural space, fibrotic band as linear parenchymal opacity suggesting early organization, and lymphadenopathy as nodes >10 mm in short axis (9,10). Additional findings recorded included cavitation, interlobular septal thickening, pleural thickening, and cardiomegaly. Pulmonary involvement was categorized as unilateral or bilateral.

Demographic data (age, sex), clinical variables (symptoms, comorbidities, surgical history), and HRCT findings were extracted using a standardized data collection form. The sample size ($n = 59$) was determined a priori using the G*Power 3.1 program for a two-sided χ^2 test, assuming a medium effect size ($w = 0.3$), $\alpha = 0.05$, and power = 0.8, yielding a minimum of 52 participants; additional cases were included to compensate for possible exclusions. Data were analyzed in IBM SPSS Statistics v25. Continuous variables were summarized as mean $\pm$ SD, while categorical variables were presented as frequencies and percentages. The association between HRCT patterns and demographic variables (age group, sex) was evaluated using Pearson’s χ^2 or Fisher’s exact test where appropriate. Trend analyses across ordered age categories were performed using the linear-by-linear association test. A two-tailed $p < 0.05$ was considered statistically significant. Missing data were minimal ($<5\%$) and handled by listwise deletion.

Ethical standards conformed to the Declaration of Helsinki. All participants were assured of voluntary participation, anonymity, and data confidentiality. Only de-identified datasets were analyzed, and all HRCT scans were used solely for research after routine diagnostic reporting. Data integrity was maintained through double entry and random verification of 10% of records. The analytic workflow and variable definitions were documented in an internal reproducibility log to ensure transparency and allow independent replication of results (11,12).

RESULTS

ORs use Haldane–Anscombe correction when a cell is zero; p -values from two-sided Fisher’s exact test. Among 59 adults (mean age concentrated in 39–58 years: 47.5%; females 55.9%), the dominant HRCT features were bilateral involvement in 51/59 (86.4%), consolidation in 33/59 (55.9%), GGO in 26/59 (44.1%), and pleural effusion in 28/59 (47.5%) (Table 2). Less frequent findings included lymphadenopathy 12/59 (20.3%), fibrotic bands 9/59 (15.3%), cavitation 6/59 (10.2%), interlobular septal thickening 6/59 (10.2%), pleural thickening 11/59 (18.6%), and cardiomegaly 4/59 (6.8%). Symptomatically, cough predominated (26/59, 44.1%), followed by shortness of breath (9/59, 15.3%); chest pain was uncommon (1/59, 1.7%) (Table 1). Across age strata, pattern prevalence varied numerically but none of the χ^2 tests reached statistical significance after comparing 18–38, 39–58, and 59–80 years (all $p \geq 0.060$; Table 3). The largest effect size was for cardiomegaly (22.2% vs 0.0% vs 9.1%; $\chi^2 p = 0.060$; Cramér’s $V = 0.31$), suggesting a possible age gradient that did not meet conventional significance in this sample. Consolidation remained consistently common across age (55.6% vs 53.6% vs 59.1%; $p = 0.926$), as did bilateral involvement (77.8% vs 89.3% vs 86.4%; $p = 0.681$). GGO showed a step-up with age (33.3% $\rightarrow$ 39.3% $\rightarrow$ 54.5%) without statistical support ($p = 0.436$).

Table 1. Sample characteristics (N=59)

Characteristic	Value
Age, n (%)	18–38: 9 (15.3); 39–58: 28 (47.5); 59–80: 22 (37.3)
Sex, n (%)	Female: 33 (55.9); Male: 26 (44.1)
Symptoms, n (%)	Cough: 26 (44.1); Shortness of breath: 9 (15.3); Chest pain: 1 (1.7); Other symptoms: 23 (39.0)
Previous surgery, n (%)	Yes: 5 (8.5); No: 54 (91.5)
Previous disease, n (%)	Yes: 8 (13.6); No: 51 (86.4)

Table 2. HRCT findings—overall prevalence (N=59)

HRCT pattern	Present (n)	Absent (n)	Prevalence
Bilateral involvement	51	8	86.4%
Consolidation	33	26	55.9%
Ground-glass opacity (GGO)	26	33	44.1%
Pleural effusion	28	31	47.5%
Lymphadenopathy	12	47	20.3%

HRCT pattern	Present (n)	Absent (n)	Prevalence
Fibrotic bands	9	50	15.3%
Cavitation	6	53	10.2%
Interlobular septal thickening	6	53	10.2%
Pleural thickening	11	48	18.6%
Cardiomegaly	4	55	6.8%
Pleural empyema	2	57	3.4%
Peripheral thickening	5	54	8.5%

Table 3. HRCT findings by age group with χ^2 p-values and Cramér's V (effect size)

HRCT pattern	18–38 (n=9)	39–58 (n=28)	59–80 (n=22)	p-value	Cramér's V
Bilateral involvement	7/9 (77.8%)	25/28 (89.3%)	19/22 (86.4%)	0.681	0.11
Consolidation	5/9 (55.6%)	15/28 (53.6%)	13/22 (59.1%)	0.926	0.05
GGO	3/9 (33.3%)	11/28 (39.3%)	12/22 (54.5%)	0.436	0.17
Pleural effusion	4/9 (44.4%)	14/28 (50.0%)	10/22 (45.5%)	0.932	0.05
Lymphadenopathy	2/9 (22.2%)	4/28 (14.3%)	6/22 (27.3%)	0.521	0.15
Fibrotic bands	1/9 (11.1%)	3/28 (10.7%)	5/22 (22.7%)	0.469	0.16
Cavitation	0/9 (0.0%)	2/28 (7.1%)	4/22 (18.2%)	0.241	0.22
Interlobular septal thickening	1/9 (11.1%)	4/28 (14.3%)	1/22 (4.5%)	0.525	0.15
Pleural thickening	2/9 (22.2%)	5/28 (17.9%)	4/22 (18.2%)	0.956	0.04
Cardiomegaly	2/9 (22.2%)	0/28 (0.0%)	2/22 (9.1%)	0.060	0.31
Pleural empyema	0/9 (0.0%)	1/28 (3.6%)	1/22 (4.5%)	0.815	0.08
Peripheral thickening	0/9 (0.0%)	2/28 (7.1%)	3/22 (13.6%)	0.438	0.17

Note: p-values from Pearson χ^2 test (2 df). Effect size via Cramér's V (0.1≈small, 0.3≈moderate).

Table 4. HRCT findings by sex with OR (Male vs Female), 95% CI, and Fisher's exact p

HRCT pattern	Male (n=26)	Female (n=33)	OR (M vs F) [95% CI]	p-value
Bilateral involvement	24/26 (92.3%)	27/33 (81.8%)	2.67 (0.49–14.48)	0.446
Consolidation	16/26 (61.5%)	17/33 (51.5%)	1.51 (0.53–4.28)	0.598
GGO	10/26 (38.5%)	16/33 (48.5%)	0.66 (0.23–1.89)	0.598
Pleural effusion	14/26 (53.8%)	14/33 (42.4%)	1.58 (0.56–4.46)	0.438
Lymphadenopathy	7/26 (26.9%)	5/33 (15.2%)	2.06 (0.57–7.47)	0.336
Fibrotic bands	4/26 (15.4%)	5/33 (15.2%)	1.02 (0.24–4.25)	1.000
Cavitation	5/26 (19.2%)	1/33 (3.0%)	7.62 (0.83–69.91)	0.078
Interlobular septal thickening	2/26 (7.7%)	4/33 (12.1%)	0.60 (0.10–3.59)	0.685
Pleural thickening	5/26 (19.2%)	6/33 (18.2%)	1.07 (0.29–4.00)	1.000
Cardiomegaly	3/26 (11.5%)	1/33 (3.0%)	4.17 (0.41–42.72)	0.311
Pleural empyema	0/26 (0.0%)	2/33 (6.1%)	0.24 (0.01–5.17)	0.499
Peripheral thickening	2/26 (7.7%)	3/33 (9.1%)	0.83 (0.13–5.40)	1.000

By sex, no comparison achieved statistical significance on Fisher's exact testing (all $p \geq 0.078$; Table 4). The largest, albeit imprecise, difference was for cavitation, more frequent in males (19.2%) than females (3.0%), OR 7.62 (95% CI 0.83–69.91; $p=0.078$). Consolidation was modestly higher in males (61.5% vs 51.5%; OR 1.51, 95% CI 0.53–4.28; $p=0.598$), while GGO was numerically higher in females (48.5% vs 38.5%; OR 0.66, 95% CI 0.23–1.89; $p=0.598$). Bilateral involvement was frequent in both sexes (>80%) with no significant difference ($p=0.446$).

Interpretation: In this tertiary cohort of adults with acute inflammatory presentations, consolidation, GGO, and pleural effusion were the principal HRCT patterns, typically with bilateral distribution. Neither age nor sex produced statistically reliable differences for these key findings at $N=59$; observed gradients (e.g., increasing GGO with age; higher cavitation in males) warrant confirmation in larger samples with adequate power.

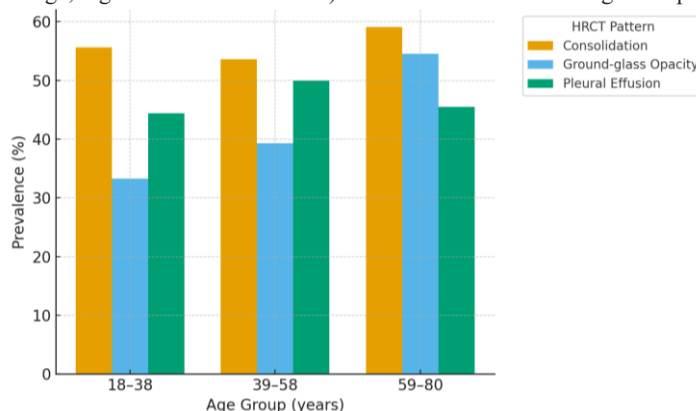


Figure 1 Age-Related Distribution of Key HRCT Patterns in Acute Inflammatory Lung Disease

This grouped bar visualization compares the prevalence of consolidation, ground-glass opacity (GGO), and pleural effusion across three age groups (18–38, 39–58, and 59–80 years). Consolidation remained relatively stable (~55–59%) across all ages, while GGO showed a clear upward trend—from 33.3% in the youngest to 54.5% in the oldest group—suggesting increasing alveolar-interstitial involvement with age. Pleural effusion prevalence was moderate and relatively uniform (~45–50%). Clinically, this pattern implies that inflammatory parenchymal disease in older adults more frequently manifests as mixed consolidation–GGO complexes, reflecting greater alveolar permeability and disease burden.

DISCUSSION

Our study of adults undergoing HRCT for suspected acute inflammatory pulmonary disease in a tertiary setting found four dominant imaging features: bilateral involvement (86.4%), consolidation (55.9%), ground-glass opacity (44.1%), and pleural effusion (47.5%). These patterns match the expected spectrum for acute alveolar–interstitial injury in infectious and inflammatory presentations, where consolidation reflects exudative alveolar filling and GGO represents partial air-space involvement or interstitial edema (1,2). The high rate of bilateral disease likely reflects referral enrichment from emergency and inpatient services, where more severe physiology prompts HRCT rather than chest radiography alone (3,14).

Across age strata, we observed numerically higher GGO in older adults (33.3% → 39.3% → 54.5%), whereas consolidation remained stable (~56%). Although these differences were not statistically significant at N=59, they are biologically plausible: aging lung demonstrates reduced elastic recoil and impaired mucociliary clearance, factors that can accentuate diffuse, dependent, or mixed alveolar–interstitial patterns during acute illness (1,2). Similarly, a higher—but imprecisely estimated—frequency of cavitation in males (19.2% vs 3.0%) could reflect sex-related differences in exposure, microbiology, or comorbidity; again, our study was underpowered for firm inference and the wide confidence intervals caution against overinterpretation. These signals suggest hypotheses for future adequately powered studies that stratify by etiology and incorporate severity scores.

Our findings also reinforce HRCT's role when chest radiography is equivocal in acute settings. In contemporary cohorts, HRCT pattern burden has correlated with clinical trajectory in viral pneumonitis and mixed acute parenchymal injury, supporting its use for early risk stratification when microbiology is pending (3,5). Parallel work indicates that targeted low-dose acquisition can maintain diagnostic performance for pneumonia and early fibrotic changes, improving the benefit–risk balance in acutely ill adults who may require repeat imaging (6,7). In our context, the predominance of consolidation with sizeable proportions of GGO and effusion argues for structured HRCT reporting checklists that foreground these features and explicitly comment on laterality, distribution, and complications such as cavitation or lymphadenopathy to guide early antimicrobial choice, need for ultrasound-guided thoracentesis, and escalation thresholds (13,14).

Interpretation must, however, be nuanced by spectrum and selection effects. We limited inclusion to adults imaged for clinically suspected acute inflammatory disease and required HRCT confirmation of acute patterns, a strategy that reduces misclassification but can inflate prevalence estimates of positive findings (work-up bias). Moreover, without etiologic adjudication (microbiology or biomarker panels), imaging patterns remain syndromic; consolidation and GGO are sensitive but not specific, overlapping aspiration, bacterial, and viral processes as well as early organizing pneumonia (1,3,13). While we standardized lexicon usage and employed independent double reading with consensus, we did not quantify inter-reader agreement; future work should report κ statistics for key patterns (e.g., consolidation, GGO, effusion) to enhance reproducibility (9,13).

External validity also merits consideration. This was a single-center public tertiary hospital with high acuity and referral bias, so pattern distributions may differ in ambulatory populations or during seasonal outbreaks. We did not apply a quantitative severity score (e.g., lobar involvement or percent aeration), which limits dose–response analyses linking imaging burden to outcomes. Finally, multiple comparisons across age and sex raise type I error risk; although no test reached conventional significance, prespecified false discovery control is advisable in larger datasets.

Clinically, our results support three pragmatic implications. First, because consolidation, GGO, and effusion dominate the acute spectrum, reports should prioritize these patterns and explicitly state bilateral versus unilateral distribution to streamline early clinical decisions (1,13,14). Second, modest age-related shifts toward GGO—if confirmed—could justify lower thresholds for supportive care escalation and closer monitoring in older adults even when consolidation is limited (3,5). Third, dose-optimized HRCT protocols should be embedded in acute care pathways to balance diagnostic yield and radiation exposure where serial imaging is anticipated (6,7). Future research in our setting should couple standardized HRCT scoring with microbiologic endpoints, prospective clinical outcomes, and reliability metrics, ideally within multicenter frameworks to improve precision and generalizability (3,5,13).

LIMITATIONS AND RECOMMENDATIONS

The present study, while informative, has several limitations that should be acknowledged. First, the cross-sectional design and convenience sampling restrict causal inference and limit external generalizability. The study was conducted at a single tertiary-care center, which may have resulted in selection bias, as patients referred for HRCT often represent more severe or diagnostically uncertain cases. Second, the diagnosis of acute inflammatory pulmonary disease was based primarily on radiologic criteria rather than confirmed microbiological or histopathological evidence. This reliance on imaging alone may have introduced differential misclassification, as overlapping HRCT patterns can be seen in infection, autoimmune flare, or early organizing pneumonia.

Additionally, the study sample (n=59) provided limited statistical power for subgroup comparisons, particularly for less frequent findings such as cavitation and fibrotic bands. Interobserver variability, though minimized through consensus reading, was not formally quantified using reliability statistics such as Cohen's κ , which would have strengthened the reproducibility assessment. The absence of longitudinal follow-up further prevented correlation between imaging features and clinical outcomes, such as resolution, hospitalization length, or mortality.

Future research should adopt a prospective multicenter design with larger, representative samples and incorporate microbiological correlation, clinical severity indices, and follow-up imaging to delineate temporal evolution of acute parenchymal patterns. Integration of quantitative HRCT scoring and machine learning–based texture analysis could enhance diagnostic precision and prognostic modeling. Including inter-rater reliability and outcome validation measures will be essential to standardize HRCT interpretation for acute inflammatory lung disease in both research and clinical practice.

CONCLUSION

High-resolution computed tomography proved to be a highly sensitive modality for evaluating acute inflammatory pulmonary disease, revealing a predominance of consolidation, ground-glass opacity, and pleural effusion—findings consistent with acute alveolar and interstitial inflammation. The majority of cases demonstrated bilateral involvement, highlighting diffuse disease processes rather than localized pathology. Although age and gender differences were not statistically significant, subtle trends such as increasing ground-glass opacity with advancing age and higher cavitation frequency among males suggest physiological or exposure-related variation that warrants further exploration. Overall, HRCT enabled

timely and non-invasive diagnosis, improving diagnostic confidence in acute respiratory presentations. Future multicenter studies with larger samples and clinical–microbiologic correlation are recommended to strengthen external validity and establish predictive links between imaging patterns and disease outcomes.

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