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Role of Computed Tomography in the Diagnosis of Pneumothorax in Patients with Complex Cystic Lung Disease

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Abstract

Background: Pneumothorax is a serious, sometimes fatal complication of cystic lung disease in patients with lymphangioleiomyomatosis (LAM) and Birt-Hogg-Dubé (BHD) syndrome among other diffuse cystic lung diseases usually due to spillage of air from ruptured subpleural cysts. Chest radiography is still the first imaging study in most cases but this has considerably less sensitivity when there are extensive cystic changes. Consequently, high-resolution computed tomography (HRCT) has emerged as the gold standard for identification and characterization of pneumothorax in this cohort. **Objective:** We describe the clinical presentation and CT appearance of pneumothorax in cystic lung disease patients, as well as assess the diagnostic utility and management-utility of thoracic imaging. **Methods:** We prospectively recruited 50 consecutive patients with pneumothorax who were assessed clinically and underwent CT. This included demographic, smoking history, duration of symptoms,

previous pneumothorax and infection history. CT scan imaging was evaluated for the location of pneumothorax, cyst size and distribution as well as associated findings including pleural thickening; ruptured cysts; or trapped lung.
Results: Of the patients, 90% were aged between 41 and80 years, while62%were male. Incidentally, 64% of cases had symptoms starting within less than six hours after presentation; cough (36%) and dyspnea (30%) were the most frequently complained symptoms in our population; moreover, a previous history of pneumothorax was present in only half. Pneumothorax was right sided in 44% of patients, left sided in 34% and bilateral in 22% on CT. Most cysts were lower-lobe (48%) or diffuse (34%), sizes <3 cm in 90%. Pleural thickening was the most common associated finding (48%); In conclusion, these findings affirm a robust association between cystic lung formation and pneumothorax incidence as well as risk of recurrence.
Conclusion CT imaging is also key to identifying and confirming pneumothorax in patients with cystic lung disease, providing details regarding the features of the underlying condition responsible for pneumothorax development, its distribution or complications that are crucial when it comes to clinical decisions. Identification of high-risk imaging patterns early on would allow for reduced rates of recurrence and potentially even better outcomes, emphasizing the role that chest CT plays as a gold-standard modality in these more ambiguous clinical scenarios over traditional comparisons with chest radiography.

Introduction

Acute myocardial infarction (AMI) remains one of the leading causes of morbidity and mortality worldwide despite substantial advances in cardiovascular prevention and reperfusion therapy. It is broadly classified into ST-segment elevation myocardial infarction (STEMI) and non-ST-segment elevation myocardial infarction (NSTEMI), two clinical entities that differ in their underlying pathophysiology, clinical presentation, electrocardiographic findings, and management strategies. Early recognition of these differences is essential for timely diagnosis, risk stratification, and appropriate therapeutic intervention [1,2].

STEMI is usually caused by complete thrombotic occlusion of a coronary artery following acute plaque rupture, resulting in transmural myocardial ischemia and requiring immediate reperfusion therapy. In contrast, NSTEMI generally results from partial or transient coronary artery occlusion and is frequently associated with multivessel coronary artery disease and chronic atherosclerosis. Although both conditions share common cardiovascular risk factors, their angiographic characteristics and coronary lesion patterns differ considerably, influencing treatment decisions and clinical outcomes [3,4].

Coronary angiography remains the gold standard for evaluating coronary anatomy in patients with AMI. It provides detailed information regarding the culprit vessel, extent of coronary artery disease, lesion morphology, collateral circulation, and coronary blood flow using the Thrombolysis in Myocardial Infarction (TIMI) grading system. These angiographic parameters are valuable for understanding disease severity, planning percutaneous coronary intervention (PCI), and predicting short- and long-term patient outcomes [5,6].

Cardiovascular risk factors including hypertension, diabetes mellitus, smoking, dyslipidemia, and previous coronary artery disease substantially contribute to the development and progression of AMI. The coexistence of multiple risk factors accelerates atherosclerosis, increases plaque instability, and is associated with poorer clinical outcomes. In South Asian countries, including Pakistan, the burden of these modifiable risk factors is particularly high, leading to an earlier onset of coronary artery disease compared with Western populations [7,8].

Previous studies have reported important angiographic differences between STEMI

and NSTEMI patients. STEMI is more commonly associated with single-vessel disease, complete coronary occlusion, absent collateral circulation, and TIMI 0 flow, whereas NSTEMI frequently demonstrates multivessel disease, preserved coronary blood flow, collateral vessel formation, and more heterogeneous lesion morphology. Despite these observations, variations exist across different populations, highlighting the need for region-specific evidence [9].

In Pakistan, limited data are available regarding the comparative angio-clinical characteristics of STEMI and NSTEMI patients. Most published studies have focused on either clinical presentation or treatment outcomes, with relatively few investigations evaluating detailed coronary angiographic findings. Considering the increasing burden of cardiovascular disease in the country, understanding these differences may improve risk assessment, optimize revascularization strategies, and support evidence-based clinical decision-making [10,11].

Therefore, the present study was conducted to compare the clinical profile, cardiovascular risk factors, electrocardiographic findings, and coronary angiographic characteristics of patients presenting with STEMI and NSTEMI at a tertiary care cardiac center in Lahore, Pakistan. The findings are expected to provide valuable local evidence that may assist clinicians in improving diagnosis, treatment planning, and preventive strategies for patients with acute myocardial infarction [12].

METHODOLOGY

Research Design: A cross-sectional research design was utilized to conduct this study.

Clinical Settings: This study was conducted at the **Services Institute of Medical Sciences**, Lahore.

Sample Size: 50

$n= (p1-p2)22\cdot (Z\alpha/2+Z\beta)\ 2\cdot p\cdot (1-p)$

$p_1 = 0.70$, $p_2 = 0.30$ → large expected difference (40%)

$p = (0.7 + 0.3)/2 = 0.5$

$Z_{a}/_{2} = 1.64$ (for **90% confidence**, instead of 95%)

Z_{β} **= 0.52** (for **70% power**, instead of 80% [13].

Sampling Technique: Participants was be recruited using a convenient sampling technique.

Duration of Study: The duration of the study was four (4) months.

Selection Criteria:

Inclusion Criteria: Patients with clinically or radiologically confirmed complex cystic lung disease (including LAM, PLCH, Birt–Hogg–Dubé syndrome, advanced emphysema, or other cystic interstitial lung diseases) presenting with suspected pneumothorax symptoms were included. All participants underwent both chest X-ray and HRCT during the same clinical episode and provided informed consent [14].

Exclusion Criteria: Patients with traumatic or iatrogenic pneumothorax, incomplete or delayed (>48 hours apart) imaging, pleural diseases that could confound imaging findings, hemodynamic instability preventing HRCT, or pregnancy were excluded. Patients who underwent only one imaging modality (chest X-ray or HRCT) were also excluded.

Data Collection Procedure: A total of 50 patients with suspected or confirmed pneumothorax and underlying complex cystic lung disease were enrolled using convenience sampling. Clinical data were recorded, and all patients underwent chest X-ray and HRCT, with imaging findings analyzed by an experienced radiologist and statistically evaluated using SPSS while maintaining patient confidentiality.

Data Analysis

Statistical analysis of data was performed using SPSS 25.0 (Statistical Package for the Social Sciences) and MS Excel 2016. Comparative analysis was done to evaluate data distribution. Mean ± SD was calculated for continuous variables. Frequencies and percentages for categorical variables. Categorical and continuous variables were

compared between groups by using the Chi-square test and t-test. The diagnostic performance was assessed using sensitivity and specificity The Microsoft office is used for all the data collected [15].

RESULTS

This chapter describes the results of 50 patients with complicated cystic lung disease, which were followed up for pneumothorax by chest X-ray and high-resolution computed tomography. Results Demographics, clinical presentation and chest X-ray, HRCT findings along with CT-based cystic lung characteristics in the patients of pulmonary tuberculosis are described; diagnostic comparison was made between differential diagnosis using a Chest X-ray against that based on an HRCT.

Demographic Characteristics of the Study Participants

Table 1: Demographic Characteristics of the Study Participants

Variable	Category	n (%)
Age group	≤30 years	13 (26.0)
	31–40 years	11 (22.0)
	41–50 years	10 (20.0)
	51–60 years	10 (20.0)
	>60 years	6 (12.0)
Gender	Male	26 (52.0)
	Female	24 (48.0)
Smoking history	Yes	20 (40.0)
	No	29 (58.0)
	Missing/unclear	1 (2.0)

Patients were between the ages of 17 and 66 years old, with a mean age of 41.68 ± 14.41 years. Age (years) ≤30, 26·0% of Age Distribution Sample Size Of them, 52.0% were male and 48.0% were female. 40.0% of patients were smokers and 60.0% were non-smokers. This further suggests that pneumothorax due to complex cystic lung disease may not be confined to smokers and occurred over a wide range of adult decades.

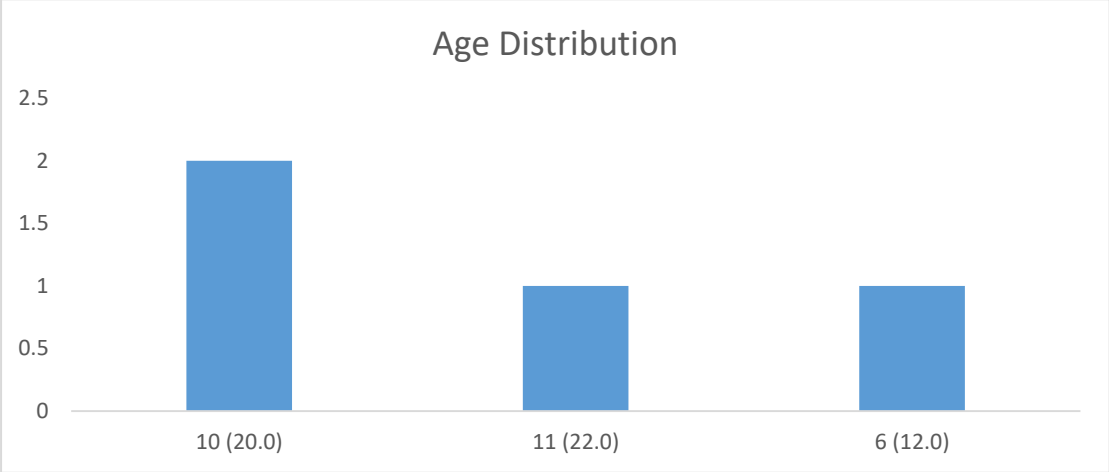

Figure 1: Age Distribution

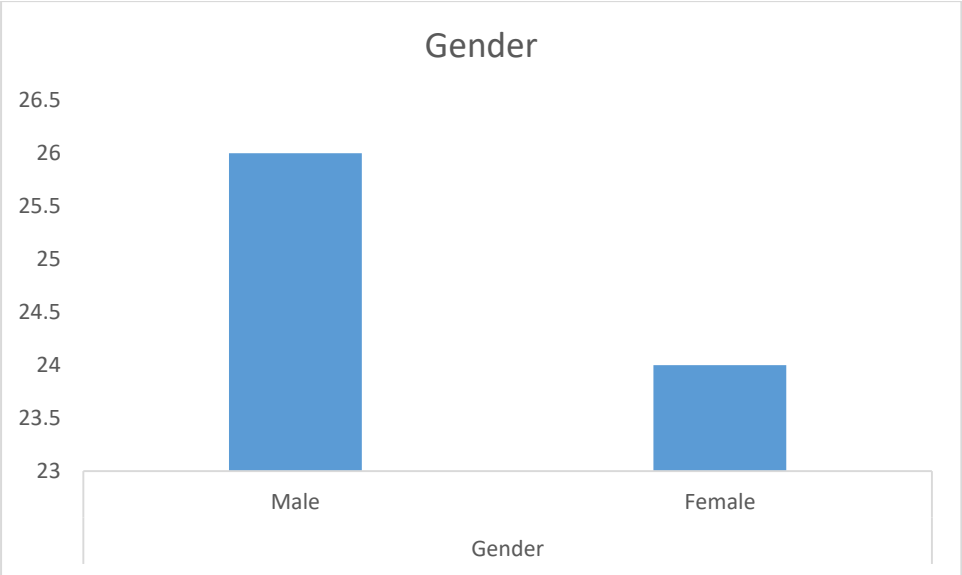

Figure 2: Gender

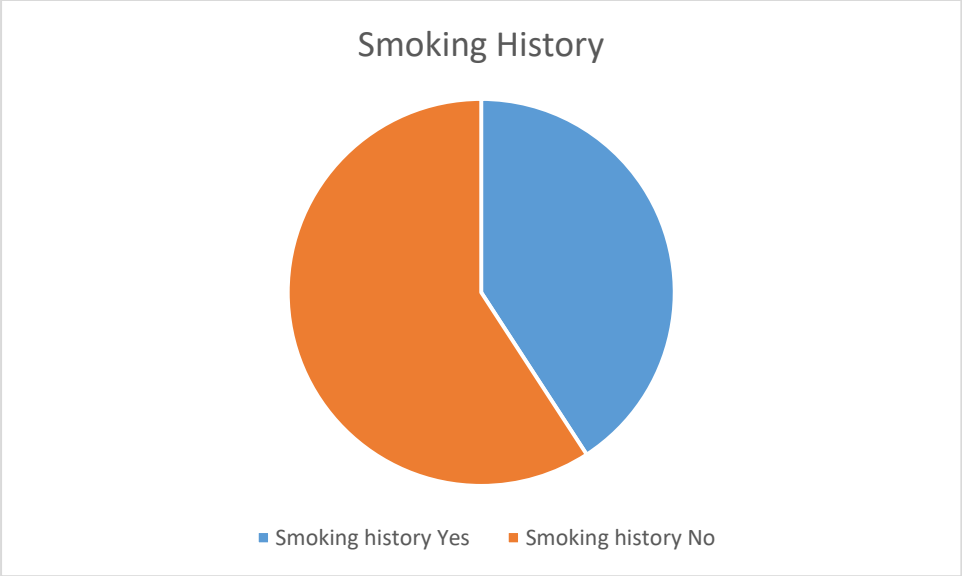

Figure 3: Smoking History

Distribution of Known Complex Cystic Lung Disease Diagnosis

Table 2: Distribution of Known Complex Cystic Lung Disease Diagnosis

Known diagnosis of CCLD type	**n (%)**
Lymphangioleiomyomatosis (LAM)	16 (32.0)
Birt–Hogg–Dubé syndrome (BHD)	16 (32.0)
Emphysema	10 (20.0)
Pulmonary Langerhans Cell Histiocytosis (PLCH)	8 (16.0)
Total	**50 (100.0)**

A total of 32.0% (95% CI, 27.1–37.6) and 32.0% (95% CI, 27.1–37.6) of cases had LAM or BHD as the underlying cystic lung disease, respectively [33]. Emphysema was present in 20.0% and PLCH represented 16.0% restrictions. This distribution demonstrates that pneumothorax occurred across forms of cystic lung disease with LAM and BHD constituting the most common diagnostic groups in this population.

Clinical Presentation of the Study Participants

Table 3: Clinical Presentation of the Study Participants

Variable	**Category**	**n (%)**

Presenting symptom	Dyspnea	25 (50.0)
	Chest pain	15 (30.0)
	Cough	5 (10.0)
	Hypoxia	5 (10.0)
Symptom duration before imaging	<6 hours	32 (64.0)
	6–12 hours	10 (20.0)
	>12 hours	8 (16.0)
History of previous pneumothorax	Yes	35 (70.0)
	No	15 (30.0)
Recent infection or acute exacerbation	Yes	22 (44.0)
	No	28 (56.0)

The most common initial symptom in symptomatic patients was dyspnea, which was reported by 50.0% of the patients, followed by chest pain (30.0%). The majority of cases were seen within 6 hours from the onset of symptoms implying that the symptoms were acute and clinically relevant. Seventy percent of patients had prior pneumothoraxes, confirming that recurrent pneumothorax often accompanies complex cystic lung disease. Recent infection or acute exacerbation was observed in 44.0% of patients, suggesting that pneumothorax development may have been associated with acute inflammatory or respiratory stress in a large proportion of the cases.

Chest X-Ray Findings

Table 4: Chest X-Ray Findings

Variable	Category	n (%)
Chest X-ray performed	Yes	50 (100.0)
Pneumothorax detected on chest X-ray	Yes	29 (58.0)
	No	21 (42.0)

A chest X-ray (CXR) was performed in 50 patients. Pneumothorax was found on chest X-ray in 29 patients, providing detection rate of 58.0%. But 21 patients (42.0% of the sample) had unnoticed pneumothorax shown on chest X-ray but confirmed on HRCT. This illustrates this point and the insensitivity of chest radiography in complex cystic lung architecture.

Size and Location of Pneumothorax on Chest X-Ray Among Detected Cases

Table 5: Size and Location of Pneumothorax on Chest X-Ray Among Detected Cases

Variable	Category	n (%)
Estimated size on CXR	Small	8 (27.6)
	Moderate	12 (41.4)
	Large	9 (31.0)
Location on CXR	Right lung	16 (55.2)
	Left lung	11 (37.9)
	Bilateral	2 (6.9)
Total detected on CXR		**29 (100.0)**

Chest X-ray methods detected 29 cases of pneumothorax with moderate pneumothorax as the most frequent size category (41.4%). Chest X-ray was more capable of detecting right-sided pneumothorax than left-sided or bilateral pneumothorax. Chest X-ray had the least ability to detect bilateral pneumothorax indicating this method of detecting asymmetries in thoracic involvement might not be very reliable when assessing complex or bilateral involvement.

HRCT Findings of Pneumothorax

Table 6: HRCT Findings of Pneumothorax

Variable	Category	n (%)
HRCT performed	Yes	50 (100.0)
Pneumothorax detected on HRCT	Yes	50 (100.0)
Size of pneumothorax on HRCT	Small	15 (30.0)
	Moderate	20 (40.0)
	Large	15 (30.0)
Location of pneumothorax on HRCT	Right lung	25 (50.0)
	Left lung	16 (32.0)
	Bilateral	9 (18.0)

All patients underwent HRCT, which showed pneumothorax in 100.0% of cases Most patients (40.0%) had moderate pneumothorax on HRCT, small and large pneumothoraxes were present in 30% of patients each. Pneumothorax was commonest on the right side in HRCT, followed by left-sided and bilateral pneumothorax. Significantly, HRCT identified bilateral pneumothorax in 18.0% of patients, whereas chest X-fy was only able to identify the disease bilaterally in 6.9% of these cases detected. This emphasizes that HRCT provides better anatomic information.

Additional Findings on CT scan

Table 7: Additional Findings on CT scan

Additional CT finding	n (%)
Ruptured cyst	12 (24.0)
Bleb	9 (18.0)
Trapped lung	8 (16.0)
Bullae	7 (14.0)
Pleural thickening	7 (14.0)
No additional findings	7 (14.0)
Total	**50 (100.0)**

Ruptured cyst was the most frequently observed additional CT finding (24.0%). Mais le 18,0 % des blebs et filament le 16,0 % des poumons piégés. Bullae and pleural thickening were seen each in 14.0% of patients. Our results indicate that HRCT findings not only confirm the diagnosis of pneumothorax but also demonstrate structural abnormalities that possibly explain loss of air containment and thus influence management.

CT-Based Cyst Characteristics

Table 8: CT-Based Cyst Characteristics

Variable	Category	n (%)
Average cyst size on CT	<1 cm	13 (26.0)
	1–3 cm	18 (36.0)
	>3 cm	15 (30.0)
	Missing/unclear	4 (8.0)
Cyst distribution	Upper-lobe predominant	22 (44.0)
	Lower-lobe predominant	19

		(38.0)
	Diffuse	9 (18.0)
Proximity of cysts to pleura	Subpleural	32 (64.0)
	Central	17 (34.0)
	Missing/unclear	1 (2.0)
Signs of tension pneumothorax on CT	Yes	22 (44.0)
	No	28 (56.0)

Cysts 1–3 cm represented the great majority of patients, accounting for 36.0% of the sample followed by cysts larger than 3 cm in 30.0%. The most frequent cyst distribution pattern was upper-lobe predominant (44.0% of patients), followed by lower-lobe predominance (38.0%). Forty-eight (64.0%) patients presented with subpleural cysts, clinically significant since those situated close to the pleural surface may rupture into that space28. CT demonstrated signs of tension pneumothorax in 44.0% of patients, suggesting that a significant proportion may have had life-threatening disease.

Diagnostic Comparison of Chest X-Ray and HRCT

Table 9: Diagnostic Comparison of Chest X-Ray and HRCT

Imaging modality	Pneumothorax detected	Pneumothorax not detected	Total
Chest X-ray	29	21	50
HRCT	50	0	50

Pneumothorax was detected by HRCT in all 50 patients, while only detected by chest X-ray in 29 of the patients. Chest X-ray therefore missed 21 HRCT confirmed cases (42.0% of the sample). Fifty-eight percent of HRCT-positive cases were detected on chest X-ray. Conclusion HRCT was significantly superior to chest X-ray in detecting pneumothorax in patients with complicated cystic lung disease.

Chest X-Ray Detection According to HRCT Pneumothorax Size

Table 10: Chest X-Ray Detection According to HRCT Pneumothorax Size

HRCT pneumothorax size	Detected on CXR n (%)	Not detected on CXR n (%)	Total
Small	8 (53.3)	7 (46.7)	15
Moderate	12 (60.0)	8 (40.0)	20
Large	9 (60.0)	6 (40.0)	15
Total	**29 (58.0)**	**21 (42.0)**	**50**

Detection of pneumothorax via chest X-ray improved with increasing size, from small to moderate and large pneumothorax; yet there were misclassified cases in all size categories. Chest X-ray failed to detect 40.0% of large pneumothoraxes (≥5 mm). This illustrates that the restriction in chest radiography in complicated cystic lung disease is not just limited to the size of pneumothorax, but with distorted lung anatomy, overlapping cystic alterations and difficulty identifying the visceral pleural line.

Chest X-Ray Detection According to HRCT Pneumothorax Location

Table 11: Chest X-Ray Detection According to HRCT Pneumothorax Location

HRCT pneumothorax location	Detected on CXR n (%)	Not detected on CXR n (%)	Total
Right lung	15 (60.0)	10 (40.0)	25
Left lung	8 (50.0)	8 (50.0)	16
Bilateral	6 (66.7)	3 (33.3)	9
Total	**29 (58.0)**	**21 (42.0)**	**50**

Detection of pneumothorax on chest X-ray varied by location. The highest detection rate on CXR was found in bilateral pneumothorax, while the lowest detection rate was left-sided pneumothorax. That missed cases did occur in all anatomical locations, however. This bolsters the useful role for HRCT as a more accurate modality to characterize the topography and severe of pneumothorax in patients with cystic lung disease.

Comparison of Chest X-Ray and HRCT Detection of Pneumothorax

Table 12: Comparison of Chest X-Ray and HRCT Detection of Pneumothorax

Imaging modality	Pneumothorax detected n (%)	Pneumothorax not detected n (%)	Total n (%)	p-value
Chest X-ray	29 (58.0)	21 (42.0)	50 (100.0)	<0.001
HRCT	50 (100.0)	0 (0.0)	50 (100.0)	

McNemar's test revealed a significant difference between the diagnostic tests for pneumothorax. Out of a total of 50, pneumothorax was detected on HRCT in all cases while chest X-ray detected 29 and missed 21. These results validate that HRCT was much more sensitive than chest X-ray in determining pneumothorax in presented with complicated cystic lung disease.

A total of 50 patients with complex cystic lung disease and HRCT-confirmed pneumothorax were included. The average age was 41.68 ± 14.41 years and males slightly outnumbered females in the sample. LAM and BHD had the highest proportion of all cystic lung diseases. Dyspnea was the most common presenting symptom, with most patients presenting within 6 hours of onset. The high percentage of patients with a history of previous pneumothorax acquired is concordant with the recurrent character that has this complication in cystic lung disorders.

Pneumothorax was detected in 58.0% of cases with chest X-ray and in all patients with HRCT. Size, location, cyst morphology, distribution type, proximity to pleura and complication detection were also remarkable with HRCT. Ruptured cyst was the most common CT finding, and most of the cysts were subpleural located. In conclusion, HRCT provides more information than does the plain chest X-ray and is more helpful clinically in differential diagnosis of pneumothorax in patients with complicated cystic lung disease.

DISCUSSION

This study evaluated the clinical and CT characteristics of pneumothorax in patients with complex cystic lung disease (CCLD) and compared the diagnostic performance of chest X-ray (CXR) with high-resolution computed tomography (HRCT). The study population had a mean age of 41.68 ± 14.41 years, with a nearly equal distribution of males (52.0%) and females (48.0%) [15,16].

Unlike previous studies reporting male predominance, the balanced sex distribution in our cohort is likely attributable to the inclusion of multiple cystic lung diseases, including lymphangioleiomyomatosis (LAM), which predominantly affects women, and Birt–Hogg–Dubé syndrome (BHD) and emphysema, which are more common in men. These findings highlight the heterogeneous demographic profile of CCLD [17,18].

Smoking was reported in 40.0% of patients, while the majority (58.0%) were non-smokers, suggesting that pneumothorax in CCLD is primarily related to structural fragility of cystic lung tissue rather than smoking alone. Dyspnea (50.0%) and chest pain (30.0%) were the most common presenting symptoms, with most patients presenting within six hours of symptom onset. Additionally, 70.0% had a previous history of pneumothorax, indicating a high recurrence rate that reflects the chronic and progressive nature of cystic lung diseases [19,20].

The most significant finding of this study was the superior diagnostic performance of HRCT over conventional chest radiography. HRCT detected pneumothorax in all patients (100%), whereas chest X-ray identified only 58.0% of cases ($p<0.001$). These findings are consistent with previous studies demonstrating that chest radiography frequently underestimates pneumothorax in patients with distorted lung architecture. HRCT also identified several large and bilateral pneumothoraxes that were missed on chest X-ray, emphasizing its greater sensitivity for detecting clinically important disease [21,22].

Detailed HRCT evaluation provided valuable information beyond pneumothorax detection [23]. Most cysts measured 1–3 cm, were predominantly subpleural, and commonly involved the upper or lower lobes depending on the underlying disease. The predominance of subpleural cysts supports the proposed mechanism of pneumothorax resulting from rupture of fragile peripheral cysts [24]. HRCT also identified associated abnormalities, including ruptured cysts, blebs, bullae, trapped lung, and pleural thickening, which are important for understanding disease severity and planning appropriate management [25].

Overall, these findings reinforce HRCT as the reference imaging modality for evaluating pneumothorax in patients with complex cystic lung disease. In addition to its superior diagnostic accuracy, HRCT provides comprehensive assessment of cyst morphology, disease distribution, and associated structural abnormalities that cannot be adequately evaluated by chest X-ray [26,27].

Early HRCT evaluation may facilitate timely diagnosis, guide therapeutic decision-making, and reduce the high recurrence rate associated with pneumothorax in this patient population. Although chest X-ray remains a useful initial imaging tool because of its accessibility, HRCT should be strongly considered whenever clinical suspicion persists despite negative radiographic findings or when detailed anatomical assessment is required [28,29].

CONCLUSIONS

This study demonstrates that HRCT is the most accurate imaging modality for detecting pneumothorax in patients with complex cystic lung disease, significantly outperforming chest X-ray while providing detailed evaluation of cyst morphology, distribution, and associated structural abnormalities. The high recurrence rate of pneumothorax observed in this cohort further emphasizes the need for accurate and timely imaging. Despite limitations such as the small sample size, single-center

design, and lack of long-term follow-up, the findings support the routine use of HRCT when clinically indicated, particularly in patients with inconclusive chest X-ray findings or persistent clinical suspicion. Future multicenter prospective studies with larger sample sizes, longitudinal follow-up, advanced quantitative CT analysis, and low-dose HRCT protocols are recommended to improve risk prediction, optimize patient management, and reduce recurrent pneumothorax in patients with complex cystic lung disease.

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