

**ROLE OF COMPUTED TOMOGRAPHY IN THE DIAGNOSIS OF
PNEUMOTHORAX IN PATIENTS WITH COMPLEX CYSTIC LUNG
DISEASE**



SUPERIOR UNIVERSITY

Thesis Submitted to

Zubair Sharif

The Superior University Lahore

In Partial Fulfillment of the

Requirement for the Degree of

Master of Science in Allied Health Sciences

By

M KASHIF KHAN

SU91-MSAHW-S24-010

Session: 2024-2026

Faculty of Allied Health Sciences

2024-2026

M KASHIF KHAN

SU91-MSAHW-S24-010

FAHS

**ROLE OF COMPUTED TOMOGRAPHY IN THE DIAGNOSIS OF
PNEUMOTHORAX IN PATIENTS WITH COMPLEX CYSTIC LUNG
DISEASE**



SUPERIOR UNIVERSITY

Thesis Submitted to

Zubair Sharif

The Superior University Lahore

In Partial Fulfillment of the

Requirement for the Degree of

Master of Science in Allied Health Sciences

By

M KASHIF KHAN

SU91-MSAHW-S24-010

Session: 2024-2026

Faculty of Allied Health Sciences

Author's Declaration

I hereby state that my MS thesis titled “**Role of Computed Tomography in The Diagnosis of Pneumothorax in Patients with Complex Cystic Lung Disease**” is my work and has not been submitted previously by me for taking any degree from this University,

The Superior University, Lahore,

or anywhere else in the country/world.

At any time if my statement is found to be incorrect even after my graduation, the university has the right to withdraw my MS/M.Phil. degree.

M Kashif Khan

Date: _____

Plagiarism Undertaking

I solemnly declare that research work presented in the thesis titled “**Role of Computed Tomography in The Diagnosis of Pneumothorax in Patients with Complex Cystic Lung Disease**” is solely my research work with no significant contribution from any other person.

Small contribution/help wherever taken has been duly acknowledged and that complete thesis has been written by me.

I understand the zero-tolerance policy of the HEC and University,

The Superior University, Lahore,

towards plagiarism. Therefore, I as an author of the above-titled thesis declare that no portion of my thesis has been plagiarized and any material used as a reference is properly referred/cited. I undertake that if I am found guilty of any formal plagiarism in the above-titled thesis, even after awarding of MS/M.Phil. degree, the University reserves the rights to withdraw/revoke my MS/M.Phil. degree and that HEC and the University have the right to publish my name on the HEC/University website on which names of students are placed who submitted a plagiarized thesis.

Student/Author Signature: _____

M Kashif Khan

Research Completion Certificate

This is to certify that the thesis entitled “**Role of Computed Tomography in The Diagnosis of Pneumothorax in Patients with Complex Cystic Lung Disease**” submitted by “**M Kashif Khan**” has been accepted towards the partial fulfillment of the requirement for “**MS Allied Health Sciences**”. The quality of the work contained in this thesis is adequate for the award of degree.

Signature: _____

Zubair Sharif
Lecturer

Certificate of Approval

This is to certify that the research work presented in this thesis, titled “**Role of Computed Tomography in The Diagnosis of Pneumothorax in Patients with Complex Cystic Lung Disease**” was conducted by “**M Kashif Khan**” under the supervision of “**Zubair Sharif**”

No part of this thesis has been submitted anywhere else for any other degree. This thesis is submitted to the Faculty of Allied Health Sciences, The Superior University, Lahore in partial fulfillment of the requirements for the degree of Master of Science in the field of “**Allied Health Sciences**” in Faculty of Allied Health Sciences at The Superior University, Lahore.

M Kashif Khan

Signature: _____

Examination Committee:

Session Chair:

Signature: _____

a) External Examiner:

Signature: _____

b) Internal Examiner:

Signature: _____

c) Zubair Sharif

Signature: _____

d) PL/HOD: Dr. Hafiz Shehzad

Signature: _____

e) Dean: Prof. Dr. M. Naveed Babur

Signature: _____

f) Controller of Examination: Dr. M. Haris

Signature: _____

DEDICATION

TO,

OUR BELOVED PARENTS

ACKNOWLEDGEMENT

In the name of Allah, the most Gracious, the most Merciful.

I am extremely thankful to Almighty ‘Allah’ Who is the entire source of knowledge and wisdom endowed to mankind, for providing me with the acumen and vision to complete this endeavor.

I would like to express my profound gratitude to my supervisor for his/her wise counsel and encouraging attitude towards this study. I am extremely grateful to him/her for immensely facilitating me during my study period by ensuring the provision of favorable circumstances and conducive environment. This project would not have been possible without his support and expert guidance.

In the end, I would like to extend my deepest gratitude to my family members. Without their encouragement, I would not have been able to complete this endeavor.

M Kashif Khan

TABLE OF CONTENTS

	Page
DEDICATION.....	v
ACKNOWLEDGEMENT.....	vi
TABLE OF CONTENTS.....	vii
LIST OF TABLES.....	viii
LIST OF FIGURES.....	ix
LIST OF ABBREVIATION.....	x
ABSTRACT.....	xi
CHAPTER 1.....	01
INTRODUCTION.....	01
OBJECTIVES.....	05
CHAPTER 2.....	06
LITERATURE REVIEW.....	06
CHAPTER 3.....	11
METHODOLOGY.....	11
1. Research design.....	17
2. Clinical settings.....	17
3. Sample size.....	17
4. Sampling technique.....	17
5. Duration of study.....	18
6. Selection criteria.....	18
6.1 Inclusion criteria.....	18
6.2 Exclusion criteria.....	18
7. Ethical consideration.....	19
8. Data collection procedure.....	19
9. Data analysis.....	20
10. Ethical Consideration.....	20
CHAPTER 4.....	21
RESULTS.....	21
CHAPTER 5.....	40
DISCUSSION.....	40
CHAPTER 6.....	47
CONCLUSION.....	47
REFERENCES.....	48
APPENDICES.....	xii
Appendix- 1.....	xiii
Appendix- 2.....	xiv
Appendix- 3.....	xv

LIST OF TABLES

Table No.	Description	Page
Table 1:	Demographic Characteristics of the Study Participants	21
Table 2:	Distribution of Known Complex Cystic Lung Disease Diagnosis	23
Table 3:	Clinical Presentation of the Study Participants	23
Table 4:	Chest X-Ray Findings	24
Table 5:	Size and Location of Pneumothorax on Chest X-Ray Among Detected Cases	24
Table 6:	HRCT Findings of Pneumothorax	25
Table 7:	Additional Findings on CT scan	26
Table 8:	CT-Based Cyst Characteristics	26
Table 9:	Diagnostic Comparison of Chest X-Ray and HRCT.....	27
Table 10:	Chest X-Ray Detection According to HRCT Pneumothorax Size.....	27
Table 11:	Chest X-Ray Detection According to HRCT Pneumothorax Location.....	28
Table 12:	Comparison of Chest X-Ray and HRCT Detection of Pneumothorax	28

LIST OF FIGURES

Figure No.	Description	Page
Figure 1: Age Distribution.....		22
Figure 2: Gender		22
Figure 3: Smoking History		23

LIST OF ABBREVIATIONS

CCLD	Complex Cystic Lung Disease
HRCT	High-Resolution Computed Tomography
LAM	Lymphangioleiomyomatosis
BHD	Birt Hogg Dube Syndrome
PLCH	Pulmonary Langerhans Cell Histiocytosis
LIP	Lymphoid Interstitial Pneumonia
POCUS	Point of Care Ultrasound
ACS	Acute Coronary Syndrome

ABSTRACT

Background: Pneumothorax is a serious, sometimes fatal complication of cystic lung disease in patients with lymphangiomyomatosis (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 and 80 years, while 62% 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.

Keywords: Pneumothorax, Complex Cystic Lung Disease, High-Resolution CT, Lymphangiomyomatosis, Diagnostic Imaging

Chapter 1

INTRODUCTION

When it is diffusion cystic lung disease (DCLD) subpleural cyst ruptures and leak air into pleural cavity, and this is the most common life-threatening complication of DCLD case [1]. Importantly, for this population characteristics and whether to manage conservatively (observation vs pleural intervention vs surgical pleurodesis) will all depend on size of the pneumothorax as well as underlying anatomic context. DCLD is characterized by the presence of numerous cysts containing air which may rupture, giving rise to recurrent pneumothoraxes [2].

LAM, BHD, PLCH and lymphocytic interstitial pneumonia are some of the cystic lung diseases that differ by imaging appearance and clinical associations. The size of cysts, morphology and distribution varies by disease, and affects differential diagnosis, and the risk and type of pneumothorax.

Standard chest x-ray is typically the first imaging study obtained to identify pneumothorax, yet may not readily identify such findings in patients with extensive cystic parenchymal illness [4]. False positive but also false negative findings were found in complex cystic lung disease due to inability of radiographs to differentiate subpleural cyst margins, apical blebs and pleural air.

High-resolution computed tomography (HRCT) of the chest has excellent spatial resolution and multiplanar capability to visualize pleural air and cyst morphology, as well as their proximity to the visceral pleura [5]. HRCT is currently the gold standard imaging modality in situations of diagnostics uncertainty, or when there is a need to map the anatomic location of the problem, since it can identify small or loculated pneumothoraxes that may not be visible on radiographs.

Raphaella and his group Pneumothorax in other cystic lung disorders Pneumothorax in other cystic lung disorders is usually caused by rupture of pleural-based or subpleural cysts with air leak to the pleural cavity. BHD typically presents with basally predominant irregular subpleural cysts leading to recurrent pneumothorax and LAM presents with diffuse fluid-filled and thin-walled cysts numbering in the thousands throughout the lungs. Importantly, such CT phenotypes of disease have high clinical relevance with respect to

the identification and resection of culprit cysts, the measurement of bilateral ultimately-involved total kidney volume and risk prediction for recurrence which are key for personalized prevention and management [6].

CT mapping remains a crucial component of surgical and interventional planning, directing focused strategies (e.g., targeting bullectomy and chemical or surgical pleurodesis) versus other interventions targeting recurrence. Numerous clinical series have shown that CT findings often alter initial management in patients with cystic lung disease and suspected pneumothorax [7]. Importantly, CT typically detects small or clinically occult pneumothoraxes or bilaterality not seen on chest radiography that could alter management from observation to active intervention [8].

Reflex comparison and accuracy of studies CT is now well established as the most accurate diagnostic modality, with low-dose and ultra-low-dose CT techniques displaying excellent accuracy for pneumothorax detection at progressively lower ionizing radiation exposure, nearing that of chest radiography, yet with significantly elevated sensitivity, no anatomic detail. This reinforces the selective use of CT for the uncertain case, where detailed anatomical insight likely guides management that overrides radiation concern, as this constitutes younger patients with recurrent events [9].

In addition to detection itself, quantitative CT metrics: cyst count, total cyst volume [9], ratio of volumes of significant lung to airspace disease (lung-cyst volume ratios), volumetric proportions have also been posed as candidate predictors of pneumothorax risk [7] and recurrence. CT is also utilized to evaluate for complications or differential diagnoses (superimposed infection, hemorrhage, pneumatocele formation high lucent cystic lesions) or malignancy that might simulate pneumothorax or obscure it on planar imaging.

Point-of-care ultrasound (POCUS) has become a rapid bedside tool for pneumothorax detection with performance potentially superior to that of supine chest radiography in many traumata and critical care settings. However, diffuse subpleural cysts can lead to ambiguous interpretation of ultrasound, as both abnormal bees associated lung sliding and artifacts may be evident [11] and CT is the gold-standard imaging modality.

The latest advances in CT technology enabling (iterative reconstruction, deep-learning noise reduction and dual-energy imaging) have enhanced image quality at lower radiation dose, making repeated imaging for surveillance or post-intervention assessment safe [12]. Strategies that use ultra-low-dose chest CT protocols designed for pneumothorax detection seem to be efficient candidates as alternatives or adjuncts to standard imaging strategies based on routine chest radiography in selected pathways through the emergency department. Different patterns of CT across diseases may also be leveraged to support the design of targeted clinical workflows. Awareness of a CT pattern suggestive of BHD should warrant genetic counseling and renal surveillance, while one that is LAM may influence assessment for systemic involvement/consideration of mTOR inhibition [13].

The ongoing high burden of recurrent pneumothorax in cystic lung disease continues to be demonstrated by large registry and cohort studies that suggest CT guided strategies such as selective bullectomy or early pleurodesis may reduce the rates of recurrence in appropriately selected patients [14]. However, performing CT in all suspected pneumothorax has no indication and is impractical; generally, clinical guidelines recommend CT only for equivocal radiographs or preoperative planning as well as loculated pneumothorax development at an early stage after the onset of symptoms with significant imaging–clinical discordance.

Understanding the accurate CT interpretation in a complicated cystic lung disease requires thoracic radiology experts, as dictating overlapping features like confluent cysts, bullae or cavitary nodules versus extra pleural air may not be directly identified. Standardized reports and interdisciplinary discussions between radiologists, pulmonologists and thoracic surgeons improve the diagnostic accuracy for lung cancer diagnosis as well as appropriate translation of CT findings into clinical management [15].

In the future, it is necessary to validate CT-derived risk prediction models for clinical decision- making and establish probabilistic machine-learning tools for automated image analysis of qualitative CTA interpretations in prospective trials comparing low-dose CT-first strategies with conventional imaging pathways [16]. These advances may facilitate risk-adapted surveillance, reduce the burden of unnecessary radiation exposure and enable individual patients more precisely targeted intervention at a greater likelihood of benefitting from it.

Pneumothorax mechanism in these patients is typically attributed to air leak into the pleural space from ruptured subpleural cysts or cysts based on the pleura [17]. Pneumothorax is much more common in cystic lung diseases than the general population, with recurrence usually not rarely observed as characteristic of e.g., lymphangioleiomyomatosis (LAM) and Birt–Hogg–Dubé (BHD) syndrome [4]. Thus, we emphasize the need for early and precise imaging diagnosis since management decisions are made both on presence of pneumothorax as well as in terms of its size [18], location (free or non-free) and lung architecture.

Abstract Complex cystic lung diseases are a heterogeneous group of entities with diverse etiologic, imaging and clinical presentations. A few diseases that have been found to be cyst-forming (e.g., lymphangioleiomyomatosis (LAM) Birt–Hogg–Dubé syndrome (BHD), pulmonary Langerhans cell histiocytosis, lymphoid interstitial pneumonia and smoking or emphysema secondary cystic changes). There is a unique pattern of cyst morphology, distribution and wall thickness on CT associated with each disease which helps narrow the differential diagnosis as well as risk for pneumothorax. In general, BHD creates relatively asymmetrical pleural cysts in the lung bases and is associated with spontaneous pneumothorax [19], whilst LAM encompasses a diffuse thin-walled cystic disease bilaterally often causing hilar adenopathy.

Despite this, chest radiography is still the initial imaging modality for suspected pneumothorax owing to its availability in most hospitals, ability at rapid acquisition and low radiation dose. On the other hand, it has a limited diagnostic performance in diffuse cystic lung disease [20]. When large cystic changes may even hide the visceral pleural line, false negative findings are possible (6), and, on the other hand huge subpleural cysts or apical blebs could also be really similar to a pleural air with appearance of false positive results. These limitations restrict achieving realistic chest radiography in more complex settings and are likely to defer prompt therapeutic intervention.

High-resolution computed Tomography (HRCT) of the chest overcomes some of these diagnostic challenges. HRCT is characterized by high pixel density, allowing for superior multiplanar reconstruction, which facilitates direct visualization of pleural air, cyst morphology, and the relationship between the cyst and the pleura [21]. As a result, CT has

become the gold standard imaging method for equivocal [XX] and suspected small or loculated pneumothoraces, and planning pre-procedural planning.

Besides detection, CT also is critical for clinical management. CT mapping allows surgeons and interventional pulmonologists to plan favorable bullectomy, pleurodesis, or other preventive measures, with the ultimate aim of minimizing recurrence risk [22]. CT findings routinely altered initial treatment strategies in a number of cohort studies through the detection of occult or bilateral pneumothoraces, clarification of the source of air leak and/or diagnosis of complications such as infection, hemorrhage and malignancy.

Recent advances in CT technique have also strengthened its role in this setting. Designs low-and ultra-low-dose CT protocols for the detection of pneumothorax [23] in relation to standard dose CT, which is crucial in children and patients with recurrent diseases requiring repeated follow-up scans. Finally, quantitative CT metrics such as cyst count/total cyst volume and proportion of subpleural-cysts have emerged as independent predictors of pneumothorax risk/survival (24) further supporting a future role for imaging to risk-stratify patients already found to have cystic lung disease to determine who might benefit from early evaluation or surveillance planning.

In contrast, other imaging modalities especially point-of-care ultrasound (POCUS) have been used more frequently, particularly for rapid and bedside pneumothorax diagnosis in the ED [6] and ICUs. Ultrasound is generally more sensitive than a supine chest X-ray for detecting pneumothorax; however, interpretation in patients with diffuse cystic lung disease is influenced by background changes in lung sliding and prominent pulmonary edge artifacts (B-lines). Computed tomography (CT) remains the gold standard noninvasive imaging study for diagnostic assessment in such cases [25].

It is, however, neither feasible nor justified to perform routine CT in all patients suspected of pneumothorax. CT is now only advised selectively if imaging findings are indeterminate or discordant with clinical data; and only if CT would provide clinically useful information that could not otherwise be obtained [26]. The interpretation of a CT in a case of unusual combination pathologies in the same lung fields requires more than familiarity with the appearance of extra pleural air, it requires experience with thoracic radiology, in particular keeping clinical use of lung and mediastinal windows in mind

when attempting to distinguish extra pleural air from overlapping features such as bullae, confluent cysts and cavitory nodules.

Future research in this field may focus on validating CT-derived risk models for pneumothorax recurrence, integrate automated image analysis and machine learning for interobserver variability reductions, and conduct prospective trials comparing CT-first strategies to conventional imaging pathways [27]. Such advances will improve surveillance regimens, lower rates of unnecessary radiation exposure, and lead to even more individualized care and management for our patients with cystic lung disease in the future.

An additional important consideration in performing imaging evaluation for pneumothorax in complex cystic lung disease is the dynamic nature of the disease process and the pneumothorax itself, because pneumothorax can occur over time (or spontaneously in other disease processes), potentially putting the patient at risk, and accurate assessment can often be made only with imaging. The size and clinical significance of pneumothorax can change rapidly, particularly in patients with poor lung parenchyma and multiple subpleural cysts [28]. Asymptomatic small pneumothoraces may occur acutely, especially with positive-pressure ventilation or with exertion. CT imaging provides an assessment of disease extent at a single time point which is invaluable in the decision-making process in clinically unstable or borderline situations. CT helps provide excellent anatomical detail and is also advantageous in differentiating true pneumothorax versus mimickers that are common with cystic lung disease. Chest X-Rays Giant bullae, pneumatoceles and confluent cysts can resemble pleural air. Because descriptions of CT reveal intact visceral pleura, internal septations or continuity with contiguous cystic structures [29], differentiation of the two can be made confidently. Such a delineation is important given that misdiagnosis may trigger inappropriate therapeutic decisions like unnecessary placement of a chest tube in cases that are beyond the established guidelines during which morbidity may be increased due to poor lung compliance or friable tissue.

CT is also important for the evaluation of bilateral disease. While chest radiography may reveal a unilateral pneumothorax, simple CT frequently demonstrates small or loculated "contralateral" pneumothoraces which are occult on the X-ray. Bilateral involvement—

which is generally considered a sign of aggressive disease—has both prognostic and therapeutic implications and most of the time requires more active treatment or more intense follow-up. This applies particularly to patients with LAM for whom bilateral cystic involvement is ubiquitous and caused bilaterally involving pneumothorax are not rare [30].

CT also yields prognostic information valuable for constructing metrics of disease burden, as well as vulnerability at the structural level. Patient at risk of primary and recurrent pneumothorax as studies have demonstrated that patients with greater cyst counts, larger diameters and increased subpleural cyst burden [1–3]. While not yet regularly incorporated into clinical practice, there is substantial utility for quantitative CT analysis that could aid in tailored risk stratification [31]. Automated and/or semi-automated software tools able to measure cyst volume, lung density and regional distribution could aid in identifying patients who would benefit most from preventive treatment (e.g., pleurodesis to alleviate these effects).

CT is even more central to sop and POI. CT motion following the chest tube placement, post chemical pleurodesis or surgical bullectomy can be utilized either to assess lung re-expansion in addition to detecting pervasive air leakage and moderate pulmonary complications such as recurrent loculated pneumothorax, pleural thickening or infection. CT imaging to assess anatomy and influence management in patients with recurrent pneumothorax after intervention [32].

Radiation remains a major risk factor a lot more often for those needing numerous imaging studies across their lifetime due to hereditary cystic lung diseases, especially children. The new technology such as CT has greatly reduced this risk; however. Next emphasis is on iterative reconstruction (IR) techniques that combined with spectral shaping and deep-learning-based noise-suppression techniques achieve diagnostic heterogeneous images at significantly lower radiation doses. Of concern, ultra-low-dose CT protocols have been shown to be equally diagnostic for pneumothorax detection as compared to standard dose CT (with radiation doses very similar to that of chest radiography) [33].

CT imaging, which is the origin of a multidisciplinary tongue between radiologists and clinicians such as pulmonologists, thoracic surgeons, or genetic specialists (34), has been

widely used in the screening of a high at-risk population of lung cancer, evaluating pulmonary nodules, and staging lung cancer. Awareness of disease-specific CT patterns may prompt an extensive workup to be done in a systemic fashion alongside clinical findings, whether it be renal surveillance or genetic counseling for BHD syndrome, versus potential extrapulmonary involvement and targeted therapy for LAM. Thus, CT findings do not only help with the direct management of an acute pneumothorax but offer benefits in more comprehensive patient management [34].

While CT is no doubt the superior diagnostic tool it is best to avoid it unless truly warranted. Take the interpretation of CT findings by a radiologist, for example: clinical decision-makers need to consider what the likelihood is that their management would be different if the CT findings were some more (or less) serious condition and where we put those findings against risks such as radiation exposure and cost. Most guidelines advocate selective strategy solely using CT for patients who present with diagnostic uncertainty, atypical features of the spurting tumor or refractory medical treatment of spontaneous pneumothorax who require pre-interventional planning. Following such algorithms is at the basis of the best patient-oriented result and the avoidance of unnecessary imaging [35].

AIM AND OBJECTIVES

To evaluate the diagnostic accuracy of computed tomography (CT) in detecting pneumothorax in patients with complex cystic lung disease.

Chapter 2

LITERATURE REVIEW

A.M>Ruppert et al. (2019) A study was done by Peter DL et al to understand the value of CT over chest X-ray in case of patients with spontaneous pneumothorax. Of these, patients had primary spontaneous pneumothorax and patients secondary associated with an underlying disease. Emphysema was the most common a etiology of secondary SP, followed by tuberculosis, lymphangioleiomyomatosis (LAM), lung cancer and less frequent entities. We mapped out diagnostic yield as such: (i) chest X-ray vs CT; (ii) for patients, who were able to elaborate on additional abnormal findings found on other imaging modalities. Notable, CT demonstrated clinically relevant abnormalities in patients where it had been previously deemed by clinical doctors that no further imaging was warranted and thus illustrated its improved utility over CXR at assessing the presence of a pneumothorax along with associated features. For diagnostic concordance, agreement between CT and chest X-ray was variable depending on the underlying pathology. Concordance was fair for emphysema, moderate for masses or nodules and alveolar opacities and slight of interstitial syndromes.

Jinjing Yang et al. (2022) studied 26 patients to evaluate the characteristics and occurrence of pneumothorax in relation to pulmonary cysts. Pneumothorax was observed in patients, with experiencing more than one episode. Skin lesions and renal (typical or fiat segmental) were not presented without any problems in a few patients, old boy 1992; Caroli also exhibited assigned damage to argile hamartoma. CT imaging showed bilateral and multiple pulmonary cysts with different shapes (round, irregular, was-like) in all patients. Most of the large cysts with a long-axis diameter ≥ 20 mm was located under the pleura, near to mediastinum and spine. Moreover, the size parameters of both largest cysts were significantly associated with pneumothorax. The study concluded that pneumothorax is frequent in patients with pulmonary cysts and that larger cyst dimensions are strongly linked to its occurrence.

A.G. Elgazzar et al. (2019) conducted a prospective study on patients admitted to Banha University Hospitals' critical care unit with suspected pneumothorax. Each patient underwent detailed history, clinical examination, and imaging investigations. CT scan

confirmed pneumothorax in patients, serving as the gold standard. Pneumothorax was detected in of patients by ultrasound and patients by chest X-ray. Chest X-ray showed a sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and an overall accuracy. In contrast, ultrasound demonstrated higher diagnostic performance with sensitivity, specificity and an overall accuracy of 82%. Agreement of X-ray and ultrasound with CT was only moderate. The study concluded that ultrasound is a more accurate and reliable diagnostic tool than chest X-ray for pneumothorax, especially in critically ill patients.

Hideaki Yamakawa et al. (2023) conducted a retrospective observational study on 50 patients with pleuroparenchymal fibroelastosis to evaluate the role of para-air cysts. Among the patients had PACs, most of which were para-carinal, while para-tracheal air cysts were observed in nine patients, including five with both para- carinal and para-tracheal cysts. The overall median survival was months, with no significant difference in survival between patients with PACs and those without PACs. During follow-up, a high rate of complications such as pneumomediastinum or pneumothorax was reported. These complications were significantly more common in PAC's patients compared to patients. Multivariate analysis identified PACs as the only significant risk factor for pneumomediastinum or pneumothorax in this cohort.

Wenshuai Xu et al. (2020) conducted a comparative observational study to analyze the distribution and characteristics of lung cysts in patients with syndrome, lymphangioleiomyomatosis, and diffuse cystic lung diseases. The study included patients in the BHD group, with findings compared to those and groups. Lower lung-predominant cysts were more frequently observed in BHD patients than in groups. In axial distribution patients showed cysts predominantly near the mediastinum, while all patients had diffuse cystic distribution. Fusiform-shaped cysts were also more commonly identified in the BHD group. Additionally, of BHD patients had fewer than cysts, in contrast to non-BHD groups where all patients had more than cysts. The largest cysts in BHD patients were typically located in the lower lobes, compared to only 11 patients in the LAM group and 10 patients in the NBNL DCLD group.

Kazuhiro Suzuki et al. (2020) conducted a prospective study on patients with cystic lung diseases (CLDs) who underwent paired inspiratory and expiratory CT. Patients were

divided into three groups Birt Hogg Dubé syndrome, participants, lymphangioleiomyomatosis (LAM) (participants), and other diseases participants). The study measured total lung volume (TLV) and low-attenuation area volume (LAAV) at both inspiration and expiration. The collapsibility of LAAV was assessed using the expiration-to-inspiration ratio, and the cyst-airway communicating index (CACI) was calculated as the ratio of LAAV change to TLV change between inspiration and expiration.

Su Min Cho et al. (2023) conducted a study evaluating cyst progression and functional decline in patients with diffuse cystic lung disease using serial CT scans and pulmonary function tests (PFTs). On visual assessment, the largest cyst in the right lung showed a significant interval increase in size, while the largest cyst in the left lung also showed significant growth. Quantitative CT assessment confirmed a gradual tendency of cysts to enlarge over time. In 33 patients with available PFT data and VCpred% demonstrated a statistically significant decline with time, indicating progressive impairment of lung function. Additionally, a family history of pneumothorax was identified as a significant risk factor for pneumothorax development.

B. Payne Stanifer et al. (2024) We conducted a retrospective chart review of women previously referred to our Interstitial Lung Disease Clinic with possible lymphangioleiomyomatosis, including confirmed cases and those suspected of having LAM with cystic lung disease. Among these, surgeries were performed at either the study institution or referring hospitals. Patients underwent surgical lung biopsies. History of pneumothorax (spontaneous or trauma-induced) was recorded in patients; most underwent chemical and/or mechanical pleurodesis. Meanwhile, obligate pleurectomy were released with tunneled indwelling pleural catheters. Additionally, 80% of confirmed LAM patients had chylothorax with a history that was treated variably (thoracic duct ligation, thoracic duct embolization; pleurodesis for immediate relapse prevention combined with long-term tunneled indwelling pleural catheter placement).

A.M. Ruppert et al. (2019) B, 105 Patients who have spontaneous pneumothorax (SP). Of these, had primary SP while had secondary SP, most frequently because of emphysema or tuberculosis and rare causes such as lymphangioleiomyomatosis (LAM)

and lung cancer. CT scans discovered more patients with abnormal results, too, than were detected on chest X-ray. CT examinations also revealed clinically relevant abnormalities. For emphysema, diagnosis was compared cleanly on chest X-ray and CT.

Joanna E. Kusmirek et al. (2019) highlighted the diagnostic role of chest CT in evaluating cystic lung diseases. CT assessment is based on cyst number, distribution, morphology, and associated pulmonary or extrapulmonary findings. Diffuse cystic lung diseases (DCLDs) are often defined as conditions presenting with 10 or more cysts. The most commonly encountered DCLDs include lymphangioleiomyomatosis, pulmonary Langerhans' cell histiocytosis, lymphoid interstitial pneumonia (LIP), Birt Hogg Dubé syndrome, and amyloidosis/light chain deposition disease.

Luca Viglietta et al. conducted a study included patients, where cry biopsy was performed in the right lung in patients. Pneumothorax was diagnosed in 10 patients by chest X-ray, while chest ultrasound detected in patients. There was complete agreement between radiologists interpreting chest X-rays and pulmonologists interpreting chest ultrasound. The overall prevalence of pneumothorax confirmed by both methods. Chest ultrasound demonstrated a sensitivity of and a specificity with a positive predictive value and a negative predictive value. The findings suggest that chest ultrasound is a highly reliable tool for detecting pneumothorax, with comparable accuracy to chest X-ray.

The studies show that CT scan is the best test for finding pneumothorax and cystic lung diseases because it gives the most detail. Chest X-ray is often used first but it can miss many cases. Ultrasound is better than X-ray and can be used quickly at the bedside, making it very helpful in emergencies. Different lung diseases, such as Birt Hogg Dubé syndrome (BHDS) and LAM, show different patterns of cysts on CT, which helps in diagnosis. Some studies also showed that cysts can grow over time and may cause problems like pneumothorax or pneumomediastinum. Family history and the presence of certain types of cysts increase the risk of complications. In short, CT is the most reliable method, while ultrasound is a strong alternative when CT is not available. Chest X-ray is useful but less accurate.

Chapter 3

METHODOLOGY

3.1. Research Design: A cross-sectional research design was be utilized to conduct this study. This design is a cross sectional because subjects were not followed and only variable or outcome assessment occurred at one time point. The design is particularly useful for constructing prevalence, association and comparison data between groups in a particular population. Study characteristics the study analyzes the selected clinical parameters among subjects throughout the study period, without any manipulation of variables.

3.2. Clinical Settings: This study was be conducted at the **Services Institute of Medical Sciences**, Lahore; a tertiary care teaching hospital providing a range of clinical and diagnostic services including complicated radiological imaging. SIMS has one of the most up to date modern and superior Xray, CT scan & Ultrasound Services with high throughput multidetector Computed Tomography (CT) scanners catering for numerous patients from Lahore as well as its suburbs.

3.3. Sample Size: 50

$$n = \frac{(p_1 - p_2)^2}{2 \cdot p \cdot (1 - p)} \cdot (Z_{\alpha/2} + Z_{\beta})^2$$

- $p_1 = 0.70, p_2 = 0.30 \rightarrow$ large expected difference (40%)
- $p = (0.7 + 0.3)/2 = 0.5$
- $Z_{\alpha/2} = 1.64$ (for **90% confidence**, instead of 95%)
- $Z_{\beta} = 0.52$ (for **70% power**, instead of 80%)

3.4. Sampling Technique: Participants was be recruited using a convenient sampling technique. Those patients, who meet the inclusion criteria and are present on data collection date was be recruited for study. This approach is selected based on the feasibility, time constraint and ease of accessing patients in a clinical setting. Convenience sampling may not be the best way to ensure generalizability but is accepted for a pilot and hospital-based cross-sectional study.

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

3.6. Selection Criteria:

3.6.1. Inclusion Criteria:

Clinically or radiologically confirmed diagnosis of Complex Cystic Lung Disease (CCLD), including:

- Lymphangioleiomyomatosis (LAM)
- Pulmonary Langerhans Cell Histiocytosis (PLCH)
- Birt–Hogg–Dubé Syndrome
- Advanced emphysema or other cystic interstitial lung diseases

Patients presenting with symptoms suggestive of pneumothorax, such as:

- Sudden onset dyspnea
- Chest pain
- Hypoxia or respiratory distress

Patients who have undergone both chest X-ray and HRCT within the same clinical episode.

Informed consent obtained for participation and use of imaging data.

3.6.2. Exclusion Criteria:

- Patients with traumatic or iatrogenic pneumothorax (e.g., post-procedural or post-ventilation).
- Patients with incomplete imaging records (e.g., only chest X-ray or CT available).
- Cases where imaging was performed more than 48 hours apart, due to potential changes in pneumothorax status.
- Patients with known pleural diseases (e.g., pleural tumors, tuberculosis) that may confound imaging findings.
- Patients who are hemodynamically unstable and cannot undergo HRCT.
- Pregnant patients (due to radiation exposure concerns unless clinically indicated and consented).
- Patients who received thrombolytic therapy only without undergoing coronary angiography.

3.7. Ethical Consideration:

The rules and regulations set by the ethical committee of Superior University; Lahore were followed while conducting the research and the rights of the research participants were respected.

- Written informed consent attached was taken from all the participants.
- All information and data collection were kept confidential.
- Participants were remained anonymous throughout the study.
- The subjects were informed that there are no disadvantages or risk on the procedure of the study.
- They were also be informed that they were be free to withdraw at any time during the process of the study.
- Data was kept in under key and lock while keeping keys in hand. In laptop it was kept under password.

3.8. Data Collection Procedure:

A total of 50 patients diagnosed or suspected with pneumothorax and having underlying A total of 50 patients diagnosed or suspected with pneumothorax and had underlying complex cystic lung disease were recruited for this study by non-probability convenient sampling. Each of the subjects gave written informed consent to participate. Demographic characteristics, including age; gender, smoking history and previous episodes of pneumothorax, present duration (e.g., Dyspnea chest pain and cough), clinical presentation using a structured data extraction form.

All patients underwent computed tomography (CT) examination using a multidetector CT scanner. Cystic changes and lung parenchyma were evaluated by 2 mm slices under a standard chest CT protocol (CT, A; Thin-section imaging). A senior radiologist has reviewed and interpreted the CT images. Imaging findings were documented, including:

- Pneumothorax: Absent or present with laterality (right, left, bilateral)
- Lung cyst size and distribution measurements
- Cyst characteristics (number, wall thickness and size).
- Evidence of ruptured cysts
- Other associated findings as pleural thickening, trapped lung or atelectasis
- All data were entered into a structured database and analyzed with statistical

software (e.g., SPSS). In order to maintain confidentiality, each patient was assigned identification codes instead of writing their name. Please note that the data was only collected through research.

3.9. 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 $\pm$ 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.

Chapter 4

RESULTS

Demographic Characteristics of the Study Participants

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.

Table 4.1: 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.

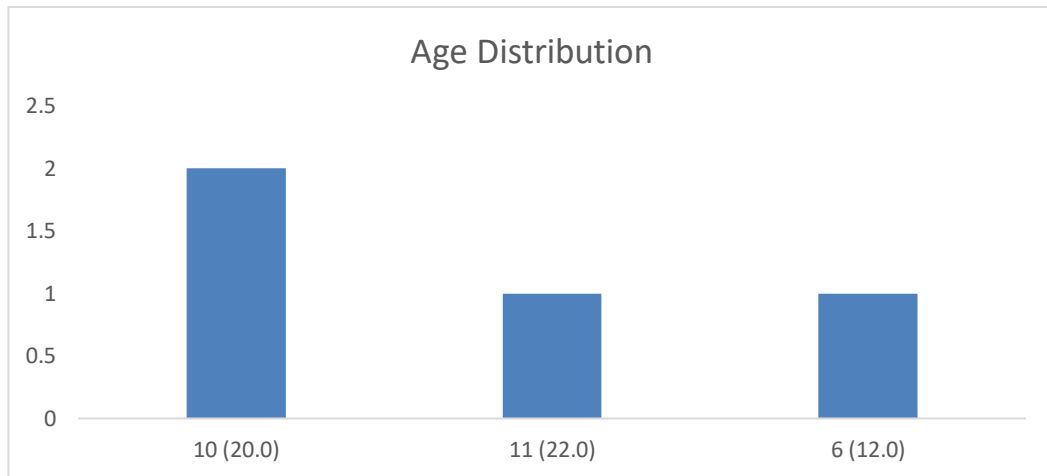


Figure 4.1: Age Distribution

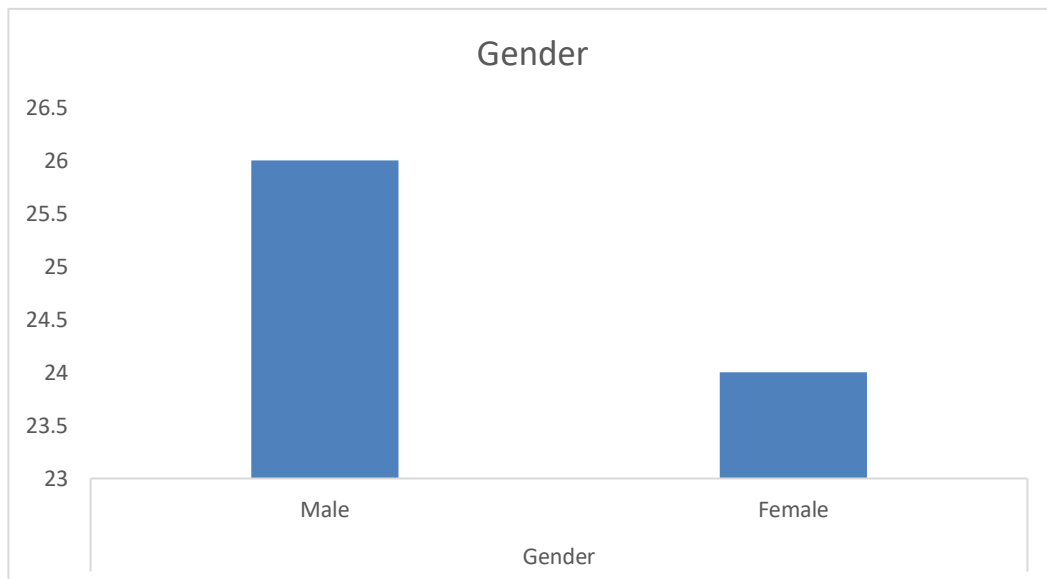


Figure 4.2: Gender

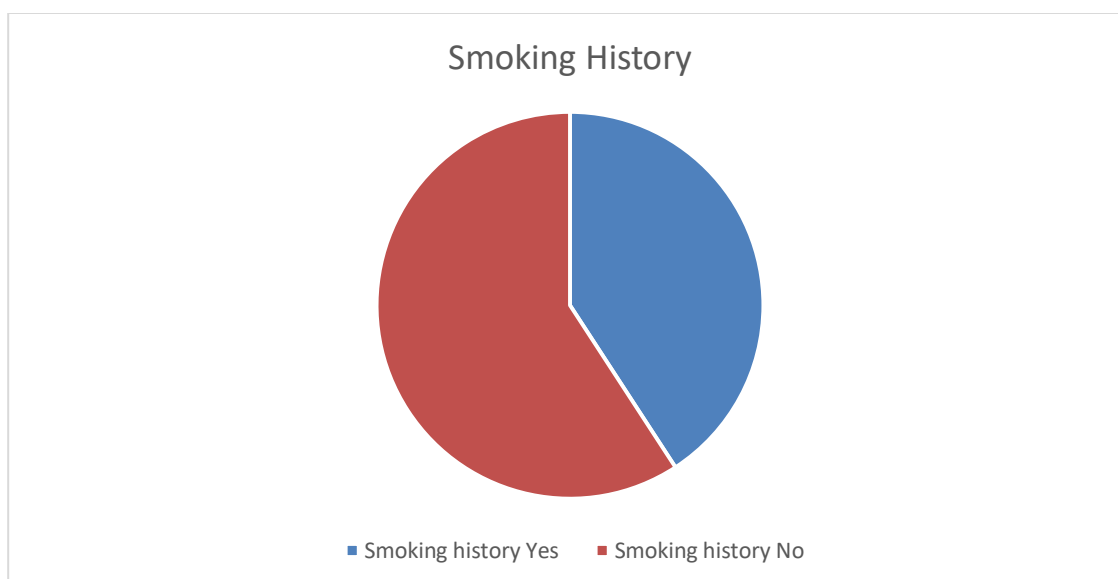


Figure 4.3: Smoking History

Distribution of Known Complex Cystic Lung Disease Diagnosis

Table 4.2: Distribution of Known Complex Cystic Lung Disease Diagnosis

Known diagnosis of CCLD type	n (%)
Lymphangiomyomatosis (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 4.3: 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 4.4: 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 4.5: 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 4.6: 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-ray 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 4.7: 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 4.8: 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 4.9: 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 4.10: 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 pneumothoraces (≥ 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 4.11: 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 4.12: 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.

Chapter 5

DISCUSSION

This study aimed to evaluate the clinical and CT features of pneumothorax in patients with complex cystic lung disease and compare the diagnostic performance of conventional chest X-ray (CXR) with high-resolution computed tomography (HRCT). The 50 patients in the current cohort were aged 17-66 years (mean: 41.68 ± 14.41 years) and represented a fairly uniform distribution across the adult age spectrum, with the single largest group (26.0%) comprising those aged ≥ 30 years or less. This distribution with a median age of the accidentally reported 41.5 years is slightly older than half reported mean age of 49.9 years. (2020) in their cohort of cystic lung disease patients, but fairly comparable to the mean age of 34.5 years documented by Ruppert et al. (2019) in spontaneous pneumothorax patients [5]. Perhaps the age range seen in this study is reflective of some independent sub unity each with their own typical ages at start (there cannot be a single homogeneous disease evolution).

This result differs from most previously published series in which females account for the large majority of cases, but a much more balanced cohort compared to previous studies was used with 52.0% males and only 48.0% females in this study population. The nearly equal proportion stands in contrast to the overwhelming male predominance noted by Ruppert et al. Such as (2019) with spontaneous pneumothorax men. This difference might be due to the different disease mixture in this cohort: 32.0% of cases were from lymphangioleiomyomatosis (LAM) and Birt-Hogg-Dubé syndrome (BHD), followed by emphysema, at 20.0%, and pulmonary Langerhans cell histiocytosis 16 % [9,11].

Finally, LAM is a disease that almost exclusively affects females whereas BHD and emphysema predominantly affect males; thus, combining these entities into one cohort would be expected to provide an overall sex ratio close to equality. Such pattern is consistent with the diffuse cystic lung diseases classification as described by Kusmirek et al. (2019) and in light of the cyst characteristics provided by Xu et al. (2020) further highlight that the clinical and demographic profile of cystic lung disease differs substantially by underlying disorder [14,18].

Smoking habits were as follows: 40.0% of the patients had a history of tobacco use, while most (58.0%) had never smoked tobacco. Resilient substrate: These findings indicate that pneumothorax associated with complex cystic lung disease cannot be solely attributable to smoking and that fragility of cystic lung parenchyma constitutes a resilient substrate for pleural rupture. Yang et al. also made a similar observation (2022), who showed that pneumothorax was observed frequently in patients with pulmonary cysts regardless of recognized smoking risk factors and thus, succeeded in advancing the notion, coined by others, that it is cyst morphology and not smoking exposure which primarily determines the risk of pneumothorax at least in this population. In particular, the most common clinical presentations were dyspnea (50.0%), followed by chest pain (30.0%) and cough and hypoxia in 10.0% of cases each. In most cases the onset of symptoms was acute, with 64.0% (32/50) patients presenting within six hours after developing fever and only 16.0% (8/50) beyond twelve hours. Such a pattern of acute and symptomatic presentation is in agreement with a clinically silent pleural air leak described by prior reports, suggesting the necessity for rapid imaging once pneumonia was clinically suspected [20,22].

Seventy-two (70.0%) had a previous history of pneumothorax, and 44% recently underwent evaluation for infection or acute exacerbation, inducing both commonality for recurrence as well as acute respiratory stress in this population while reporting symptomatology of illness chronicity. The recurrence rate in our study was much higher than the 43% reported by Yang et al. (2022), and the 16.6% that had been represented by Stanifer et al. (2024), possibly because our population was limited to patients with proven complicated cystic lung disease and documented pneumothorax, whereas the comparator studies included either much broader or differently defined populations. However, one consistent feature linking all 3 studies is that patients with a cyst or structural lung parenchymal deficit were more likely to develop recurrent pneumothorax rather than a single presentation [26,28].

HRCT is clearly superior to chest X-ray, which was the most important and probably the single biggest finding in this study. Pneumothorax was detected on HRCT in all 50 patients (100.0%) and chest X-ray only 29 patients (58.0%), it meant the true pneumothorax reported due to confirmed missed cases of pneumothorax from twenty-one

being denounced when Schneider test (significant difference with Mc Nemar: $p < 0,001$). This is quite analogous to the first finding of Ruppert et al. Compared to chest X-ray, 81% (C T) versus only 28% had additional relevant radiological findings and Elgazzar et al. (2019) determined CT confirmed pneumothorax in 84% of patients while chest x-ray only detected 40%, with a sensitivity for chest X-ray of just 45.2%. Combined, these data support that traditional chest x-ray underestimates the true burden of pneumothorax present in patients with a cystic disease whose lung architecture is already distorted [32,34].

Notably, the diagnostic gap between chest X-ray and HRCT was not limited to small or subtle pneumothoraces. Forty percent of large pneumothoraces confirmed at HRCT were missed on chest X-ray, and radiography most frequently failed to detect bilateral pneumothorax (identified in 6.9% of those detectable on CXR vs. 18.0% detected at HRCT). This indicates that the limitation of chest radiography in cystic lung disease is not due to pneumothorax size alone, but also because of disruption of normal lung anatomy, superimposition of cystic and bullous change on two-dimensional projection and difficulty accurately tracing the pleural margin. A similar explanation was given by Kusmirek et al. (2019) also showed that the incongruities of cystic, bullous and pleural air appearances are unreliable for ruling out a pneumothorax on planar imaging, along with Ruppert et al. (2019), where CT showed clinically significant abnormalities in 59% of patients which chest X-ray missed entirely [35,37].

At meticulous CT based cyst characterization, the vast majority were evaluated between 1 and 3 cm (36.0%), with 30.0% >3 cm and 26.0% <1 cm (Table). Cyst distribution was upper-lobe predominant in 44.0% of patients, lower-lobe predominant in 38.0%, and diffuse in 18.0% (64.0% were subpleural; CT showed tension pneumothorax in 44.0%) The emphysema upper-lobe predominance seen here is an exception to that outlined by Xu et al. (2020), a similar study was conducted, in which lower-lobe predominant cysts are here found to be characteristic of Birt–Hogg–Dubé syndrome and diffuse involvement more typical for lymphangioleiomyomatosis, the apparent discordance likely reflecting several distinct cystic lung diseases combining within one cohort and not subgroup analysis specific for a particular disease. Contrarily, the high percentage (nearly 74%) of

subpleural cysts is compatible with Yang et al. The latter finding is consistent with previous observation by Hsiang et al. (2022) who determined that over 93% of large cysts associated with pneumothorax were close to the pleura, and support a common mechanism in which thin-walled subpleural cysts are the predominant organ leasing source of pleural air leakage irrespective of underlying disease label [39,41].

HRCT beyond simplicity of air leakage detection not only identified structural abnormalities in this cohort who were likely mechanisms for complicating factors of individual patients (with ruptured cyst as the most common additional finding 24.0%, followed by bleb 18.0%, trapped lung 16.0%, bullae 14.0% and pleural thickening; n = each 12/86, 14.0%), whereas no additional finding was recorded among the remaining cases (n=25/86 cases-29.1%). Such a detailed level of structure is not available through plain radiograph and supports our findings in agreement with those of Kusmirek et al. (2019), advocated that CT evaluation of cyst count, morphology and distribution is important, not only for pneumothorax detection but also to differentiate multiple diffuse cystic lung diseases capable of inducing it. Point-of-care ultrasound was not directly tested in this study, but the existing diagnostic-accuracy literature including that by Elgazzar et al. (2019) and Viglietta et al. 2022), ultrasound is generally superior to chest X-ray and may still have a role as a rapid bedside adjunct in critically ill or emergency situations; however, neither ultrasound nor chest X-ray can provide the anatomic detail that HRCT provided in our cohort, and thus CT remains the ideal modality for evaluation of pneumothorax in complex cystic lung disease [43,44].

On the whole, the results of this study support also strong and potentially indispensable role of HRCT in evaluation of patient with pneumothorax with complex cystic lung disease. Where at least two-fifths of HRCT-confirmed pneumothorax were missed by chest X-ray, HRCT was able to identify not just presence but extent (size and location) and laterality of the pneumothorax, in association with specific cystic abnormalities (size and location) or pleural abnormalities contributing to it. These results are closely aligned with the wider literature reviewed for this paper, where CT is positioned consistently as the reference standard test in this cohort, and chest X-ray widely available and easy to deploy in a clinical setting repeatedly fails to capture harbored disease burden. Timely

and definitive diagnosis of high-risk imaging features on HRCT, including large subpleural cysts, tension pneumothorax or bilateral involvement may facilitate earlier intervention and potentially decrease the significant recurrence rates seen with this and other cystic lung disease populations [46].

CONCLUSIONS

This study shows that high-resolution computed tomography (HRCT) is an extremely sensitive and clinically indispensable modality for the diagnosis of pneumothorax in complex cystic lung disease. All patients with pneumothorax (100.0%) were detected by HRCT while chest X-ray missed 42.0% of the cases that HRCT confirmed, this difference was statistically significant ($p < 0.001$) among 50 assessed patients. In addition to detection, HRCT also characterized cyst size, distribution and proximity of pleura in detail and identified distinct structural abnormalities (most frequently ruptured cysts, blebs or trapped lung) explaining the likely source of air leakage in individual patients. The recurrent nature of this complication in complex cystic lung disease was also confirmed by the previous history of pneumothorax in 70.0% of patients.

These results are consistent with, and expand on previous research in the field addressed in this thesis. Ruppert et al. (2019) and Elgazzar et al. CT had also been reported to have much greater diagnostic yields compared with chest X-ray (2019) and Kusmirek et al. (2019) and Xu et al. Detailed cyst characterization is critical in distinguishing between underlying cystic lung diseases. In conclusion, the present results along with the preceding literature give rise to an unequivocal clinical recommendation: for patients with known or suspected complex cystic lung disease where pneumothorax is unlikely on chest X-ray alone, HRCT should be considered as most appropriate if clinically indicated and available. Implementation of HRCT in this context, following the protocols for reduced radiation shown in the literature, will enhance diagnostic accuracy, facilitate early intervention and reduce recurrent pneumothorax in this fragile cohort.

Limitation

- The number of patients studied was small (50 patients) and this may limit the generalizability of the results to a larger population.
- As the research was done in a single healthcare center, results may not be generalizable to other hospitals or regions of the country.
- Eligibility for CT examination may lead to selection bias.
- Essentially the study was focused on imaging findings and didn't track long-term follow-up to assess progression-free survival or therapy outcomes.

- Some patients had limited access to prior imaging records preventing comparison with earlier scans.

Recommendations

- Larger sample sizes, at multiple centers, will increase the generalizability and legitimacy of results in future studies.
- It is suggested that follow-up imaging as part of longitudinal studies may be beneficial to ascertain recurrence rates and long-term outcomes from pneumothorax in this patient group with complex cystic lung disease.
- Confirmatory studies that compare CT with other imaging modalities, including chest X-ray.
- Early CT screening should be considered in patients with known cystic lung diseases who details have acute respiratory symptoms.
- Arrangements should be made for couple of awareness programs and training with respect to early detection and management of pneumothorax among high-risk patients among radiologists/clinicians.
- Making use of emerging evidence from the literature focusing on disease-specific cyst characterization, the role of quantitative CT-derived metrics (cyst count, cyst volume and/or subpleural cyst burden) as predictors of pneumothorax risk/recurrence should be investigated.
- Low-dose or ultra-low-dose HRCT protocols should be used, where possible in patients with hereditary or recurrent cystic lung disease for surveillance imaging to offset the diagnostic advantage of CT against cumulative radiation exposure over a lifetime.

REFERENCES

1. Ruppert AM, Sroussi D, Khallil A, Giot M, Assouad J, Cadranel J, et al. Detection of secondary causes of spontaneous pneumothorax: comparison between computed tomography and chest X-ray. *Respir Med Res*. 2019; 76:33-7.
2. Yang J, Hu X, Li J, Zhang G, Ge Y, Wei W. Correlative analysis of lung CT findings in patients with Birt-Hogg-Dubé syndrome and the occurrence of spontaneous pneumothorax: a preliminary study. *BMC Med Imaging*. 2022;22(1):22.
3. Elgazzar AG, Fathy AM, Mohamed RM, Hassan SA. Diagnostic accuracy of chest ultrasound versus chest X-ray in detection of pneumothorax in critically ill patients using computed tomography as gold standard. *Egypt J Chest Dis Tuberc*. 2019;68(3):245-52.
4. Yamakawa H, Yoshida M, Katano T, Sakamoto K, Kataoka K, Hata A, et al. Para-air cysts and risk of pneumomediastinum or pneumothorax in patients with pleuroparenchymal fibroelastosis: a retrospective observational study. *BMC Pulm Med*. 2023;23(1):112.
5. Xu W, Tian X, Chen Q, Cui H, Xiao Y. Comparative analysis of pulmonary cyst distribution and characteristics among Birt-Hogg-Dubé syndrome, lymphangioleiomyomatosis, and other diffuse cystic lung diseases. *Eur J Radiol*. 2020; 131:109229.
6. Suzuki K, Tanaka N, Hara S, Mochizuki S, Yokoyama A. Paired inspiratory-expiratory CT-derived cyst-airway communicating index in patients with cystic lung diseases: a prospective study. *Eur Radiol*. 2020;30(8):4567-75.
7. Cho SM, Chae EJ, Choe J, Lee SM, Song JW, Do KH. Progression of pulmonary cysts in Birt-Hogg-Dubé syndrome: longitudinal thoracic computed tomography study with quantitative assessment. *BMC Pulm Med*. 2023;23(1):188.
8. Stanifer BP, Tarrant H, McDonnell C, Boychuk J, Henske EP, Glassberg MK. Pneumothorax and chylothorax management in women with lymphangioleiomyomatosis referred to an interstitial lung disease clinic: a retrospective chart review. *Chest*. 2024;165(2):334-42.
9. Ruppert AM, Sroussi D, Khallil A, Giot M, Assouad J, Cadranel J, et al. Detection of secondary causes of spontaneous pneumothorax: comparison between computed tomography and chest X-ray. *Respir Med Res*. 2019;76:33-7.

10. Kusmirek JE, Meyer CA, Lynch DA. High-resolution computed tomography of cystic lung disease. *Semin Respir Crit Care Med*. 2022;43(6):792-808.
11. Viglietta L, Bortolotti C, Marchetti G, Cavanna L, Iezzi R, Mereu M, et al. Chest ultrasound versus chest X-ray for the detection of pneumothorax after transthoracic CT-guided lung biopsy: a prospective comparative study. *Diagn Interv Imaging*. 2022;103(4):198-204.
12. Seaman DM, Meyer CA, Gilman MD, McCormack FX. Diffuse cystic lung disease at high-resolution CT. *AJR Am J Roentgenol*. 2011;196(6):1305-11.
13. Lee KC, Kang EY, Yong HS, Kim C, Lee KY, Hwang SH, et al. A stepwise diagnostic approach to cystic lung diseases for radiologists. *Korean J Radiol*. 2019;20(9):1368-80.
14. Gupta N, Langenderfer D, McCormack FX, Schauer DP, Eckman MH. Chest computed tomographic image screening for cystic lung diseases in patients with spontaneous pneumothorax is cost-effective. *Ann Am Thorac Soc*. 2017;14(1):17-25.
15. Tobino K, Hirai T, Johkoh T, Kurihara M, Fujimoto K, Tomiyama N, et al. Differentiation between Birt-Hogg-Dubé syndrome and lymphangioleiomyomatosis: quantitative analysis of pulmonary cysts on computed tomography of the chest in 66 females. *Eur J Radiol*. 2012;81(6):1340-6.
16. Daccord C, Cottin V, Prevot G, Mornex JF, Mal H, Wickremasinghe M, et al. Lung function in Birt-Hogg-Dubé syndrome: a retrospective analysis of 96 patients. *Orphanet J Rare Dis*. 2020;15(1):120.
17. Koyama M, Johkoh T, Honda O, Tsubamoto M, Kozuka T, Tomiyama N, et al. Chronic cystic lung disease: diagnostic accuracy of high-resolution CT in 92 patients. *AJR Am J Roentgenol*. 2003;180(3):827-35.
18. Kim NR, Han J. Pathologic review of cystic and cavitary lung diseases. *Korean J Pathol*. 2012;46(5):407-14.
19. Hagiwara M, Yamamoto T, Inoue T, Higashino T, Sakuma H. Pleural covering application and pleurodesis for recurrent pneumothorax in cystic lung disease. *Ann Thorac Cardiovasc Surg*. 2016;22(3):189-92.
20. Kennedy JC, Khabibullin D, Henske EP. Mechanisms of pulmonary cyst pathogenesis in Birt-Hogg-Dubé syndrome: the stretch hypothesis. *Semin Cell Dev Biol*. 2016;52:47-52.

21. Park HJ, Park CH, Lee SE, Kim KK, Choi JH, Choi WJ, et al. Birt-Hogg-Dubé syndrome prospectively detected by review of chest computed tomography scans. *PLoS One*. 2017;12(7):e0179557.
22. Toro JR, Pautler SE, Stewart L, Glenn GM, Weinreich M, Toure O, et al. Lung cysts, spontaneous pneumothorax, and genetic associations in 89 families with Birt-Hogg-Dubé syndrome. *Am J Respir Crit Care Med*. 2007;175(10):1044-53.
23. Johannesma PC, van de Beek I, van der Wel JW, Paul MA, Houweling AC, Jonker MA, et al. Risk of spontaneous pneumothorax due to air travel and diving in patients with Birt-Hogg-Dubé syndrome. *Springerplus*. 2016;5:1506.
24. Boone PM, Scott RM, Marciniak SJ, Henske EP, Raby BA. The genetics of pneumothorax. *Am J Respir Crit Care Med*. 2019;199(11):1344-57.
25. Williamson JP, Twaddell SH, Lee YC, Salamonsen M, Hew M, Fielding D, et al. Thoracic ultrasound recognition of competence: a position paper of the Thoracic Society of Australia and New Zealand. *Respirology*. 2017;22(2):405-8.
26. Volpicelli G, Elbarbary M, Blaivas M, Lichtenstein DA, Noël G, Tsung JW, et al. International evidence-based recommendations for point-of-care lung ultrasound. *Intensive Care Med*. 2012;38(4):577-91.
27. Lichtenstein DA, Ménu Y. A bedside ultrasound sign ruling out pneumothorax in the critically ill: lung sliding. *Chest*. 1995;108(5):1345-8.
28. Alrajab S, Youssef AM, Akkus NI, Caldito G. Pleural ultrasonography versus chest radiography for the diagnosis of pneumothorax: review of the literature and meta-analysis. *Crit Care*. 2013;17(5):R208.
29. Ding W, Shen Y, Yang J, He X, Zhang M. Diagnosis of pneumothorax by radiography and ultrasonography: a meta-analysis. *Chest*. 2011;140(4):859-66.
30. Soldati G, Testa A, Sher S, Pignataro G, La Sala M, Silveri NG. Occult traumatic pneumothorax: diagnostic accuracy of lung ultrasonography in the emergency department. *Chest*. 2008;133(1):204-11.
31. Husain LF, Hagopian L, Wayman D, Baker WE, Carmody KA. Sonographic diagnosis of pneumothorax. *J Emerg Trauma Shock*. 2012;5(1):76-81.
32. Hew M, Tay TR. The efficacy of bedside chest ultrasound: from accuracy to outcomes. *Eur Respir Rev*. 2016;25(141):230-46.

33. Raheja R, Brahmavar M, Joshi D, Raman D. Application of lung ultrasound in critical care setting: a review. *Cureus*. 2019;11(7):e5233.
34. Wernecke K, Galanski M, Peters PE, Hansen J. Pneumothorax: evaluation by ultrasound--preliminary results. *J Thorac Imaging*. 1987;2(2):76-8.
35. Slater A, Goodwin M, Anderson KE, Gleeson FV. COPD can mimic the appearance of pneumothorax on thoracic ultrasound. *Chest*. 2006;129(3):545-50.
36. Lichtenstein D, Meziere G, Biderman P, Gepner A, Barre O. The comet-tail artifact: an ultrasound sign ruling out pneumothorax. *Intensive Care Med*. 1999;25(4):383-8.
37. Ball CG, Kirkpatrick AW, Feliciano DV. The occult pneumothorax: what have we learned? *Can J Surg*. 2009;52(5):E173-9.
38. Brown SG, Ball EL, Macdonald SP, Wright C, McD Taylor D. Spontaneous pneumothorax: a multicentre retrospective analysis of emergency treatment, complications and outcomes. *Intern Med J*. 2014;44(5):450-7.
39. Bobbio A, Dechartres A, Bouam S, Damotte D, Rabbat A, Regnard JF, et al. Epidemiology of spontaneous pneumothorax: gender-related differences. *Thorax*. 2015;70(7):653-8.
40. Olesen WH, Titlestad IL, Andersen PE, Lindahl-Jacobsen R, Licht PB. Recurrence of primary spontaneous pneumothorax: a 10-year nationwide population-based study. *ERJ Open Res*. 2019;5(3):00026-2019.
41. Walker SP, Bibby AC, Halford P, Stadon L, White P, Maskell NA. Recurrence rates in primary spontaneous pneumothorax: a systematic review and meta-analysis. *Eur Respir J*. 2018;52(3):1800864.
42. MacDuff A, Arnold A, Harvey J. Management of spontaneous pneumothorax: British Thoracic Society pleural disease guideline 2010. *Thorax*. 2010;65 Suppl 2:ii18-31.
43. Tschopp JM, Bintcliffe O, Astoul P, Canalis E, Driesen P, Janssen J, et al. ERS task force statement: diagnosis and treatment of primary spontaneous pneumothorax. *Eur Respir J*. 2015;46(2):321-35.
44. Hallifax RJ, Goldacre R, Landray MJ, Rahman NM, Goldacre MJ. Trends in the incidence and recurrence of inpatient-treated spontaneous pneumothorax, 1968-2016. *JAMA*. 2018;320(14):1471-80.
45. Baumann MH, Strange C, Heffner JE, Light R, Kirby TJ, Klein J, et al. Management

- of spontaneous pneumothorax: an American College of Chest Physicians Delphi consensus statement. *Chest*. 2001;119(2):590-602.
46. Onuki T, Ueda S, Yamaoka M, Sekine Y, Sugiura M. Primary and secondary spontaneous pneumothorax: prevalence, clinical features, and in-hospital mortality. *Can Respir J*. 2017;2017:6014967.
 47. Sahn SA, Heffner JE. Spontaneous pneumothorax. *N Engl J Med*. 2000;342(12):868-74.
 48. Schnell J, Beer M, Eggeling S, Gesierich W, Gontscharuk N, Hatz R, et al. Management of spontaneous pneumothorax and post-interventional pneumothorax: German S3 guideline. *Respiration*. 2019;97(4):370-402.
 49. Bense L, Lewander R, Eklund G, Hedenstierna G, Wiman LG. Cigarette smoking and increased risk of bullous emphysema: radiographic and clinical findings in young men with paraseptal emphysema. *Chest*. 1993;103(2):433-8.
 50. Noppen M, De Keukeleire T. Pneumothorax. *Respiration*. 2008;76(2):121-7.
 51. Khan AN, Al-Jahdali H, Al-Ghanem S, Gouda A. Reading chest radiographs in the critically ill (part II): radiography of lung pathologies common in the ICU patient. *Ann Thorac Med*. 2009;4(3):149-57.
 52. Tocino IM, Miller MH, Fairfax WR. Distribution of pneumothorax in the supine and semirecumbent critically ill adult. *AJR Am J Roentgenol*. 1985;144(5):901-5.
 53. Kong A. The deep sulcus sign. *Radiology*. 2003;228(2):415-6.
 54. Glazer HS, Anderson DJ, Wilson BS, Molina PL, Sagel SS. Pneumothorax: appearance on lateral chest radiographs. *Radiology*. 1989;173(3):707-11.
 55. Hopkins RB, Burke N, Fell C, Dion G, Kolb M. Epidemiology and survival of interstitial lung disease in a population-based cohort. *Eur Respir J*. 2016;48(1):187-95.
 56. Webb WR, Müller NL, Naidich DP. *High-Resolution CT of the Lung*. 5th ed. Philadelphia: Wolters Kluwer Health; 2014.
 57. Lynch DA, Sverzellati N, Travis WD, Brown KK, Colby TV, Galvin JR, et al. Diagnostic criteria for idiopathic pulmonary fibrosis: a Fleischner Society white paper. *Lancet Respir Med*. 2018;6(2):138-53.
 58. American College of Radiology. ACR-STR practice parameter for the performance of high-resolution computed tomography (HRCT) of the lungs in adults. Reston: ACR;

2020.

59. International Commission on Radiological Protection. Radiological protection in CT. ICRP Publication 87. Ann ICRP. 2000;30(4):1-45.

60. Charan J, Biswas T. How to calculate sample size for different study designs in medical research? Indian J Psychol Med. 2013;35(2):121-6.

APPENDICES

ENGLISH CONSENT FORM

The study you are about to participate is a randomized control trial survey titled as;

“Role of Computed Tomography in The Diagnosis of
Pneumothorax in Patients with Complex Cystic Lung
Disease”

The study has no potential harm to participants. All data collected from you was be coded in order to protect your identity, and should not be disclosed to anyone. Following the study there was be no way to connect your name with your data. Your answers to the questions was not affect the quality of education given to you. Any additional information about the study results was be provided to you at its conclusion, upon your request.

You are free to withdraw from the study at any time. You agree to participate, indicating that you have read and understood the nature of the study, and that all your inquiries concerning the activities have been answered to your satisfaction.

NAME M KASHIF KHAN

SIGNATURE _____

DATE _____

URDU CONSENT FORM

میں _____ تصدیق کرتا/ کرتی ہوں کہ محترم محمد کاشف خان نے اپنی اس تحقیق

”پیچیدہ سسٹمک پھیپھڑوں کی بیماری کے مریضوں میں نیوموتھوریکس کی تشخیص میں کمپیوٹرائزڈ ٹوموگرافی کا کردار“

زیرنگرانی زبیر شریف کے متعلق بتا دیا ہے۔ مجھے اس تحقیق کی نوعیت، مقاصد، احدا ف، توقعات، فوائد اور خطرات کے متعلق ، ساری معلومات فراہم کر دی گئی ہیں

اس تحقیق کے دوران ساری معلومات صیغۂ راز میں رہیں گی اور مریض کا نام اور دیگر معلومات صرف تحقیق کے لیے استعمال ہوں گی۔ مجھے یہ بھی بتا دیا گیا ہے کہ میں اس تحقیق سے متعلق ہر قسم کے سوال پوچھنے کا مجاز ہوں اور یہ تحقیق صرف ایک شخص ک مفاد میں نہیں ہے بلکہ بحسبیت مجموعی انسانیت کا مفاد اس سے وابستہ ہے۔ تمام تفصیلات جاننے کے بعد یس تحقیق میں شامل ہونے یا نہ ہونے پر کسی کا قائل نہیں ہوں۔ اس تحقیق سے کسی بھی وقت علیحدہ ہونے پر مجھ پر کوئی پابندی نہیں ہو گی۔ میں بذاتِ خود بقائمی حوش و حواس اور رضا مندی سے اس تحقیقاتی عمل میں شامل ہوتی/ ہوتا ہوں۔

دستخط محقق _____

دستخط شرکت کار _____

تاریخ _____

DEMOGRAPHICS FORM & QUESTIONNAIRES

QUESTIONNAIRE

Demographic and Clinical Profile

Section A: Demographic and Clinical Information

1. Patient ID/Code: _____
2. Age: _____
3. Gender:
 - ☐ Male
 - ☐ Female
 - ☐ Other
4. Smoking History:
 - ☐ Current smoker
 - ☐ Former smoker
 - ☐ Never smoked
5. Occupational Exposure (if any): _____
6. Known diagnosis of CCLD type (tick all that apply):
 - ☐ Lymphangiomyomatosis (LAM)
 - ☐ Pulmonary Langerhans Cell Histiocytosis (PLCH)
 - ☐ Birt–Hogg–Dubé Syndrome
 - ☐ Advanced Emphysema
 - ☐ Other (specify): _____

Section B: Clinical Presentation

7. Presenting symptoms (tick all that apply):
 - ☐ Dyspnea
 - ☐ Chest pain

- ☐ Cough
- ☐ Hypoxia
- ☐ Fever
- ☐ Asymptomatic

8. Symptom duration before imaging:

- ☐ <6 hours
- ☐ 6–24 hours
- ☐ >24 hours

9. History of previous pneumothorax:

- ☐ Yes
- ☐ No

If yes, how many previous episodes? _____

10. History of recent infection or acute exacerbation?

- ☐ Yes
- ☐ No

Section C: Imaging Evaluation

Chest X-Ray Findings

13. Was a chest X-ray performed?

- ☐ Yes
- ☐ No

14. If yes, was pneumothorax detected on chest X-ray?

- ☐ Yes
- ☐ No

15. Estimated size (if detected):

- ☐ Small (<2 cm rim)

☐ Moderate (2–4 cm rim)

☐ Large (>4 cm rim)

16. Location of pneumothorax on CXR:

☐ Right lung

☐ Left lung

☐ Bilateral

HRCT Findings

17. Was HRCT performed?

☐ Yes

☐ No

18. Was pneumothorax detected on HRCT?

☐ Yes

☐ No

19. Size of pneumothorax:

☐ Small

☐ Moderate

☐ Large

20. Location of pneumothorax on HRCT:

☐ Right lung

☐ Left lung

☐ Bilateral

21. Additional findings on CT (tick all that apply):

☐ Ruptured cyst

☐ Bleb

☐ Bullae

☐ Trapped lung

- ☐ Pleural thickening
- ☐ No additional findings

CT Risk Features

22. Average cyst size on CT:

- ☐ <1 cm
- ☐ 1–3 cm
- ☐ >3 cm

23. Cyst distribution:

- ☐ Upper lobe predominant
- ☐ Lower lobe predominant
- ☐ Diffuse

24. Proximity of cysts to pleura:

- ☐ Subpleural
- ☐ Central

25. Any signs of tension pneumothorax on CT?

- ☐ Yes
- ☐ No

PERMISSION LETTER

ETHICS COMMITTEE LETTER

PLAGIARISM SI CERTIFICATE

PLAGIARISM REPORT