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Diagnostic Accuracy of Chest Ultrasonography for Post-traumatic Pneumothorax Taking CT scan as Gold Standard

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ABSTRACT

Objective: To determine the diagnostic accuracy of chest ultrasonography for detecting post-traumatic pneumothorax, using high-resolution CT scan as gold standard. **Study design:** Cross-sectional validation. **Place and duration of study:** Department of Diagnostic Radiology, CMH Multan from Nov, 2024 to Apr, 2025. **Methodology:** A total of 150 patients aged ≥18 to ≤65 years, referred to the department with clinical signs of pneumothorax were included in the study. Patients underwent chest ultrasonography for detecting post-traumatic pneumothorax based on key sonographic signs. A high-resolution CT scan of the thorax was then performed within three hours of ultrasonography. Diagnostic accuracy was then calculated by determining sensitivity, specificity, positive predictive value, negative predictive value, and overall accuracy and a 2×2 contingency table was constructed keeping CT scan as gold standard. **Results:** Mean age of patients was 36.85±9.61 with age range of 23 to 64 years. Number of male patients was higher (76%) in overall study population compared to females (24%). The diagnostic accuracy parameters for detecting pneumothorax demonstrated high sensitivity (87.27%), specificity (96.84%), positive predictive value (94.12%), negative predictive value (92.93%), and overall diagnostic accuracy (93.33%) of chest ultrasonography keeping CT scan as gold standard. **Conclusion:** Chest ultrasonography provides high sensitivity, specificity, and predictive values offering a reliable alternative where immediate CT access is difficult or not feasible.

INTRODUCTION

Trauma caused by external factors exert a critical impact on global mortality and morbidity across all age groups.[1] WHO reports that trauma is the cause of over 6 million annual deaths worldwide making it a major global health burden, especially affecting the young population.[2] Among these traumas, chest trauma presents serious clinical challenges, with pneumothorax being one of the most critical and life-threatening complication. Pneumothorax occurs when air enters the pleural space and causes potential lung and cardiovascular (CV) compromise, leading to death if not promptly treated. Data show that approximately 5-7% of all trauma patients are affected by pneumothorax making it a leading cause of mortality in such cases.[3]

Early diagnosis of pneumothorax is crucial and life-saving as delay can lead to respiratory compromise, tension pneumothorax, and death. Despite this need for timely identification, relying solely on clinical signs and symptoms may result in misdiagnosis or delayed detection as decreased breath sounds, chest pain, and dyspnea may be masked by pain medications, altered mental status, or concurrent injuries. Use of imaging modalities therefore plays a central role in this life-threatening condition. The imaging techniques traditionally used to evaluate suspected pneumothorax include chest X-rays and computed tomography (CT) scans.[4]

Chest X-ray (CXR) has been traditionally the initial imaging modality for pneumothorax detection. However, it has the disadvantages of limited sensitivity, particularly for small or occult pneumothoraces.[5] CT scan is taken as gold standard in these cases due to its high sensitivity and specificity, as it has the ability to detect even small amounts of pleural air. Despite these clear benefits, the cost and accessibility of CT scan in rural and resource-limited setting are the major limitations of its wide use. Moreover, CT scan may not be feasible due to the challenges of transportation and positioning in critically ill patients. Additionally, breath-holding required during CT imaging for optimal results may be difficult for patients suffering from trauma, which causes suboptimal quality of images.[6] All these factors can result delays in the diagnosis and treatment of critically injured patients requiring immediate intervention.

Chest ultrasonography (USG), a rapid, non-invasive, and bedside diagnostic tool has gained increasingly preference in emergency and trauma settings for pneumothorax detection in recent years. Chest USG offers

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significant advantages over chest X-ray and CT, including portability, cost-effectiveness, real-time imaging, and no radiation exposure. Trained clinicians use key sonographic signs, such as absence of lung sliding, loss of B-lines (comet-tail artifacts), and lung point sign, for quick identification, early diagnosis and treatment. Its accuracy, affordability, and efficiency have made it a preferred technique in critical care settings.[7,8]

Chest USG in emergency and trauma settings can help to enhance the outcomes by allowing rapid bedside diagnosis, minimizing transport needs, and enabling timely treatment. This can especially fulfill the need where CT access is limited or unavailable due health budget constraints and at small health care settings. However, despite the promising evidence mentioned in some studies, most research on USG has been conducted in medical or ICU settings, and data in trauma cases is limited.[9] Moreover, the diagnostic accuracy of chest USG is dependent on operator expertise and the instrument used. This underscores the need for validation of the diagnostic accuracy of chest USG in our local trauma population.[10]

This study was therefore planned to determine the diagnostic accuracy of chest USG for detecting post-traumatic pneumothorax, using high-resolution CT chest as the gold standard. The findings of this study will add to the evidence supporting the reliability of USG in the diagnosis of post-traumatic pneumothorax, promoting its use in areas where CT scan can't be performed, potentially reducing mortality and improving outcomes in emergency settings.

METHODOLOGY

This cross-sectional validation study was conducted at the Department of Diagnostic Radiology, CMH Multan from Nov, 2024 to Apr, 2025 over a period of six months after approval by the institutional ethics review board.

The sample size was calculated using a one-sample sensitivity and specificity formula. With sensitivity of chest USG 83.6%, specificity of 97.9%, prevalence of 36.2% , confidence interval 95% and desired precision 10%, the minimum sample size required (n) was 147.[11] We however took a sample of 150 patients.

A total of 150 patients aged ≥18 to ≤65 years, of either gender, referred to the diagnostic radiology department with clinical signs of pneumothorax such as difficulty in breathing, dullness on percussion, or decreased air entry were included in this study through consecutive sampling.

The exclusion criteria was set as patients who had undergone needle thoracostomy prior to imaging, patients with unstable hemodynamics, patient who can't safely undergo both USG and CT imaging, patients with subcutaneous emphysema, patients with a history of chest surgery or trauma on the same side were also excluded. Inadequate or non-interpretable imaging results and pregnant patients were also excluded.

Informed consent was taken from patient/guardian prior to their enrolment in the study.

Demographic details were recorded for each patient. Patients then underwent chest USG performed by a consultant radiologist with a minimum five years of post-fellowship experience. The USG was performed with patients in a supine position using a B-mode machine (with a high-frequency linear probe of 5–10 MHz). The probe was placed perpendicular to the anterior chest wall in the midclavicular line at the 2nd–3rd intercostal spaces.

Pneumothorax was diagnosed based on the use of key sonographic signs, such as absence of lung sliding (barcode sign), loss of B-lines (comet-tail artifacts arising from pleural line), and lung point sign.

A high-resolution CT scan (64-slice multidetector) of the thorax was performed within three hours of USG. To enhance the structural details, thin-slice (1–2 mm collimation) and high spatial frequency reconstruction algorithms were employed. All the findings were documented in a predesigned proforma.

Data was analyzed using SPSS version 26. Continuous variables (such as age) were presented as mean ± standard deviation, while categorical variables (such as gender and findings of the imaging techniques) were reported as frequencies and percentages. Diagnostic accuracy of USG was calculated by determining sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall accuracy and a 2×2 contingency table was constructed while keeping CT scan as gold standard. A p-value <0.05 was taken as statistically significant for the analyses.

RESULTS

Mean age of patients was 36.85±9.61 years with age range 23 to 64 years. Proportion of male patients was higher (76%) in overall study population compared to females (24%). The details of demographics are given in Table-I.

Table I

Demographics and clinical presentation (n= 150)

Demographics and clinical presentation		
Age (Mean± SD) years		36.85±9.61
Gender	**Male n (%)**	114 (76)
	Female n (%)	36 (24)

The presence of sonographic sings of pneumothorax among the patients diagnosed thorough USG are shown in Table-II.

Table II

Sonographic Signs in Patients diagnosed with pneumothorax (n= 55)

Sonographic Signs	n (%)
Absent Lung Sliding	53 (96.4)
Presence of Lung Point	32 (58.2)
Barcode Sign (M-mode)	52 (94.5)
Presence of A-lines	33 (60)
Presence of Seashore Sign (M-mode)	2 (3.6)
Presence of Lung Sliding	2 (3.6)

USG detected 51 (34%) while CT scan confirmed 55 (36.67%) cases of pneumothorax. The diagnostic accuracy parameters of USG compared to CT for detecting pneumothorax demonstrated high sensitivity (87.27%) and specificity (96.84%) thereby indicating a strong agreement with CT findings. The high PPV (94.12%), NPV (92.93%), and overall diagnostic accuracy (93.33%), suggested that USG is reliable in both confirming and ruling out pneumothorax. A statistically significant association with p < 0.000 further supported the diagnostic utility of USG. The details of diagnostic accuracy parameters are shown in Table-III.

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Table III
Diagnostic Accuracy of USG Compared CT Scan (n= 150)

CT Scan (Gold Standard)	USG (Yes/Positive)	USG (No/Negative)
(Yes/Positive)	48 (True Positive)	7 (False Negative)
(No/Negative)	3 (False Positive)	92 (True Negative)

Sensitivity = TP / (TP + FN) = 48 / (48 + 7) = 87.27%
Specificity = TN / (TN + FP) = 92 / (92+ 3) = 96.84%
Positive Predictive Value (PPV) = TP / (TP + FP) = 48 / (48 + 3) = 94.12%
Negative Predictive Value (NPV) = TN / (TN + FN) = 92/ (92 + 7) = 92.93 %
Diagnostic Accuracy = (TP + TN) / Total = (48 + 92) / 150 = 93.33%

DISCUSSION

The findings of our study revealed that chest USG has high sensitivity and specificity, thereby indicating strong agreement with CT findings. The high PPV and NPV suggested that USG is reliable in both confirming and ruling out pneumothorax. A statistically significant association with $p < 0.0001$ further supported the diagnostic utility of USG. These results indicated that the technique serves as a reliable, affordable and readily available assessment tool in patients presented with clinical symptoms of post-traumatic pneumothorax.

The diagnostic accuracy of chest USG in cases of post-traumatic pneumothorax has been the topic of interest among radiologists, especially in regions with limited health care facilities and budget constraints. It is important that the results of our study are aligned with growing international evidence that supports chest USG in trauma care settings.

Staub LJ et al. in their systematic review assessed the chest USG for its accuracy in emergency diagnosis of traumatic pneumothorax. The review of 19 studies demonstrated high diagnostic accuracy with AUC 0.979 for pneumothorax. Absence of lung sliding showed sensitivity 0.81 (95%CI 0.71-0.88), specificity 0.98 (95%CI 0.97-0.99), and positive likelihood ratio 67.9. Chest USG was therefore proved accurate for diagnosing both traumatic pneumothorax and haemothorax. The researchers however emphasized on more research work to strengthen the evidence.[12]

Following this systematic evidence, individual studies have further validated similar results across diverse clinical settings especially with compromised health facilities. Ahmad S et al. in a study in Iraq aimed to evaluate the accuracy of bedside chest USG in diagnosing traumatic pneumothorax in comparison to chest CT. USG detected pneumothorax in 31.2% cases versus 33.1% cases by CT ($p = 0.719$). Chest USG proved to be a rapid bedside diagnostic tool with a high sensitivity (92.45%), specificity (99.07%), and accuracy (96.88%).[13]

In a recent study conducted in India by Sirajudeen SA et al. lung USG was compared with CT in diagnosing pneumothorax in cases of blunt chest trauma. With a sensitivity and specificity of 100%, USG was proven to be a reliable, radiation-free, and accurate tool for detecting pneumothorax and associated thoracic injuries.[14] With these results and advantages of the technique in ICU setting, Elgazzar AG et al. evaluated the effectiveness of chest USG for pneumothorax diagnosis in Egypt. USG showed 80% sensitivity, 87.5% specificity, 97.1% PPV, 46.7% NPV, and 82% overall accuracy, and outperformed the chest X-ray (45.2% sensitivity, 52% accuracy) in this regard.[15] There are however other studies demonstrating different outcomes regarding parameters of diagnostic accuracy. In a health care set up in Turkey, Temel A et al. assessed the sensitivity and specificity of bedside thoracic USG in the diagnosis of pneumothorax in trauma patients. USG detected pneumothorax in 14.4% cases and showed a sensitivity of 56.2% and specificity of 99%. Sensitivity was however observed to be increased with the severity of pneumothorax (70% for grade 2, 100% for grade 3). Hence USG proved to be highly specific but less sensitive especially for small pneumothoraces.[16]

The utility of chest USG has also been investigated within the Pakistani healthcare context, with consistent results for pneumothorax detection. An initial work on the diagnostic accuracy of USG in traumatic pneumothorax in comparison to other radiographic techniques done in Pakistan was by Mumtaz U et al. who compared the diagnostic accuracy of bedside USG with chest radiography. Among trauma patients, USG showed higher sensitivity (83.33%) than radiography (54.76%), with both having 100% specificity. The study concluded that ultrasound is a reliable, non-invasive, bedside tool and a suitable adjunct to CT in trauma settings.[17] These findings supporting the use of USG have been confirmed by subsequent studies conducted in our local settings. Naseem A et al. determined the diagnostic accuracy of chest USG for pneumothorax in trauma patients in Pakistan. Pneumothorax occurred in 36.2% cases with high sensitivity (83.6%), specificity (97.9%), PPV (95.8%), and NPV (91.3%) shown by USG when CT was kept as gold standard.[11] Kamboh MN also evaluated the diagnostic accuracy of chest USG in suspected cases of pneumothorax and showed a sensitivity of 78.26%, specificity of 96.83%, and overall accuracy of 95.27% [18] In a recently published study by Nazir MH et al. in Pakistan, diagnostic accuracy of chest USG for detecting pneumothorax in emergency care showed sensitivity of 92.8%, specificity of 91.7%, PPV of 94.5%, NPV of 88.5%, and overall accuracy of 92.2%.[19] Hence these studies conducted in Pakistan also support effectiveness and usefulness of this tool in our local health care settings as a rapid, reliable, and radiation-free modality. The collective evidence demonstrates that chest ultrasonography serves as a highly accurate, cost-effective, and radiation-free diagnostic tool for post-traumatic pneumothorax detection, making it an invaluable bedside modality for emergency and resource-limited settings, though standardized training protocols remain essential to optimize its operator-dependent diagnostic performance.

In short, the accumulated evidence from international systematic reviews as well as local studies consistently demonstrates that chest USG represents a valuable diagnostic tool for post-traumatic pneumothorax detection where portability and cost-effectiveness make it particularly suitable for resource-limited settings and emergency scenarios.

The limitations of this study include its single-center design which may limit generalizability. Moreover, the

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interpretation of USG is operator dependent and may produce diagnostic variability in different settings. Future multicenter studies including larger and diverse populations will be helpful in validating these findings on a larger scale.

CONCLUSION

This study demonstrated that chest USG is an easily accessible, highly accurate, non-invasive, diagnostic tool that provides rapid detection of post-traumatic pneumothorax. With a bedside applicability, USG offers high sensitivity, specificity, and predictive values offering a reliable alternative, especially in emergency and resource-limited settings where immediate CT access is difficult or not feasible.

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