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Diagnostic Accuracy of Chest Ultrasonography in Diagnosing Pneumothorax Taking CT Chest as A Gold Standard

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ABSTRACT

Ultrasound of the lung is an emerging diagnostic technique for diagnosing pneumothorax in patients with traumatic injury which is faster, safer, or more accessible than a conventional computed tomography scan. **Objectives:** To assess the diagnostic accuracy of chest ultrasonography in diagnosing pneumothorax using computed tomography chest as a gold standard. **Methods:** A cross-sectional validation study was conducted at the Radiology Department of Holy Family Hospital, from Nov 2022 to May 2023. Adult patients of either gender, with clinical suspicion of pneumothorax either traumatic or spontaneous, were included. Patients undergone chest ultrasound and pneumothorax were confirmed by the presence of sonographic features. Plain computed tomography chest imaging was done to confirm the diagnosis and compare it with ultrasound results. **Results:** There were ninety patients included. The ultrasound technique was found to have 92.8% sensitivity and 91.7% specificity to correctly diagnose pneumothorax as compared to chest computed tomography. The positive and negative predictive values were found to be 94.5% and 88.5% respectively, and overall diagnostic power was 92.2%. **Conclusions:** It was concluded that the diagnostic accuracy of chest ultrasonography in detecting pneumothorax is comparable to computed tomography Chest gold standard and this technique can be utilized in emergency care settings.

INTRODUCTION

Pneumothorax is a medical term used to describe a serious condition where there is air trapped inside the pleural cavity [1]. The most common reason resulting in pneumothorax is trauma which can occur due to any external factor or accident with a direct forceful hit to the chest, followed by other iatrogenic causes. As a result of injury, the parietal or visceral pleura ruptures allowing air entry into the pleural space [2, 3]. Other than post-traumatic pneumothorax, pneumothorax can occur in intensive care unit patients, post-intervention pneumothorax, pneumothorax due to lung disease, residual pneumothorax associated with intercostal chest tube drainage, and spontaneous pneumothorax in adults and paediatric population [4, 5]. Due to entrapment of air in the pleural cavity, there is a drop in negative pressure which is necessary to keep the lung inflated and assist in proper breathing. A drop in negative pressure leads to improper breathing, severe pain and even collapsing of the lung can occur in severe situations [6]. An early diagnosis can play an important role in the timely management of pneumothorax which can be life-saving. Clinically pneumothorax is presented with severe dyspnoea, extreme air hunger, and chest pain. All trauma patients are recommended to be examined for pneumothorax during initial clinical examination [7]. In routine, patients who are clinically suspicious of pneumothorax undergo chest X-rays for evidence of trapped air and/or collapsed lungs. For critically ill patients who cannot stand, undergo a supine

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chest x-ray which can cause pneumothorax, or sometimes undergo a chest Computed Tomography (CT) [8, 9]. It is reported in the literature that at times supine chest X-ray might not be enough to diagnose pneumothorax which can pose the patients at risk of developing complications; whereas, chest CT is an established gold standard test for diagnosing pneumothorax [10]. CT scan is an expensive and time-consuming procedure, which exposes the patients to high doses of ionizing radiation and sometimes is not feasible for unstable patients. In addition to that CT scans might not be available at every accident and trauma center in resource-constrained developing countries like Pakistan. Ultrasound of the lung is an emerging diagnostic technique for diagnosing pneumothorax in patients with traumatic injury or other causes with fairly decent sensitivity and specificity. Literature showed that it has the advantage of being simple, is portable, can provide real-time imaging, and is more easily accepted by patients [11]. A systematic review reported 91% specificity and 99% sensitivity of chest ultrasound to diagnose pneumothorax [12]. Some major advantages of chest ultrasound over chest CT scan include; less time-consuming, less expensive, no exposure to harmful radiations, handy, portable, available at most healthcare facilities, and suitable for repeated examinations [13]. Despite of literature supporting the efficiency of chest ultrasound in establishing the diagnosis of pneumothorax, very few studies are reported from Pakistan in this context. In a developing country like Pakistan with constrained resources, chest ultrasound can prove to be cost-effective in the diagnosis of pneumothorax.

This study aims to assess the performance of chest ultrasonography in diagnosing patients with pneumothorax against the CT Chest images as the reference standard.

METHODS

A cross-sectional diagnostic validation study was conducted in the Department of Radiology of Holy Family Hospital, Rawalpindi, for a period of six months from Dec 2022 to May 2023. Before executing the research, ethical approval was taken from the College of Physicians and Surgeons Pakistan (Ref no. CPSP/REU/RAD-2021-126-3489). A sample of 90 patients was calculated by the WHO sample size calculator considering 89.6% sensitivity [14]. 95.6% specificity [14]. 40.6% prevalence of pneumothorax in accident and trauma patients 95% confidence, 80% power and 6% precision. Patients presenting to the emergency department with traumatic chest injury and complaining of sudden shortness of breath were considered for enrolment using a consecutive sampling method. Those fulfilling the inclusion criteria of any age group, either gender, clinical suspicion of pneumothorax, whether traumatic or spontaneous, willing to participate in the study were included. Patients who were critically ill, required urgent surgery, had tension pneumothorax, experienced hemodynamic instability, or were pregnant were excluded. Before data collection the study objectives and procedures were explained to the participants and consent for participation was taken. Socio-demographic and clinical data were recorded for each patient. All included patients were undergone chest ultrasound using Honda HS-2600 ultrasound machine having 5-10 MHz frequency. A single operator performed all the ultrasound tests. The patients were scanned in a supine position by an ultrasound machine with a high-frequency linear probe (5-10 MHZ) placed perpendicular to two rib spaces in the anterior chest region in the midclavicular line in the second and third intercostal spaces. The ribs were characterized as hyperechoic and their acoustic shadows visible as hypoechoic rays were considered stationary structures. This was defined as interspace which is the location of the pleural line that appears as an echogenic line obtained at the inferior border of the space between two ribs. Pneumothorax was diagnosed from the sonographic signs, such as the lack of a seashore sign, absent lung sliding sign, lung point sign, and presence of a barcode sign at that particular site. The presence or absence of A-lines was also noted. All of the included patients were then followed up with plain CT chest imaging modality to confirm the diagnosis. The results were reported by a radiologist who was unaware of the ultrasound findings. Data were extracted from a data collection tool, and data management software IBM SPSS version 23.0 was used for data analysis. The ultrasound findings of pneumothorax were reported as present or absent in percentage and confirmed with gold standard chest CT scan findings. Diagnostic accuracy was measured. A p-value of ≤0.05 was considered statistically significant.

RESULTS

The mean age of the study population was 33.37 ± 14.90 years. The majority of the patients, accounting for 59 individuals (65.56%), were above 40 years of age. Among the 90 patients that were included in the study, the total male patients were 52 (57.78%), while the total female patients were 38 (42.22%), resulting in a male-to-female ratio of 1.4:1. Demographic characteristics are shown in Table 1.

Table 1: Socio-Demographics of Study Participants (n=90)

Characteristics	Frequency (%)
Age	33.37 ± 14.90
Age Categories	
≤40 Years	59 (65.6%)
>40 Years	31 (34.4%)

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Sex Distribution	
Female	38 (42.2%)
Male	52 (57.8%)

All patients underwent chest ultrasonography followed by computed tomography (CT) for confirmation of the diagnosis. The frequency and percentage of ultrasound signs observed among study participants are given in table 2.

Table 2: Distribution of Ultrasound Signs (n=90)

Pneumothorax Positive (n=55)	n (%)
Absent Lung Sliding Sign	53 (96.0%)
Lung Point Sign	11 (29.1%)
Barcode Sign (M-Mode)	52 (94.5%)
A-Lines	23 (44.0%)
Pneumothorax Absent (n=35)	
Present Lung Sliding Sign	33 (94.2%)
Seashore Sign (M-Mode)	32 (91.0%)
A-Lines	26 (74.2%)

Present lung sliding and seashore sign (M-mode), Pneumothorax absent. The specific ultrasound signs are shown in figure 1.

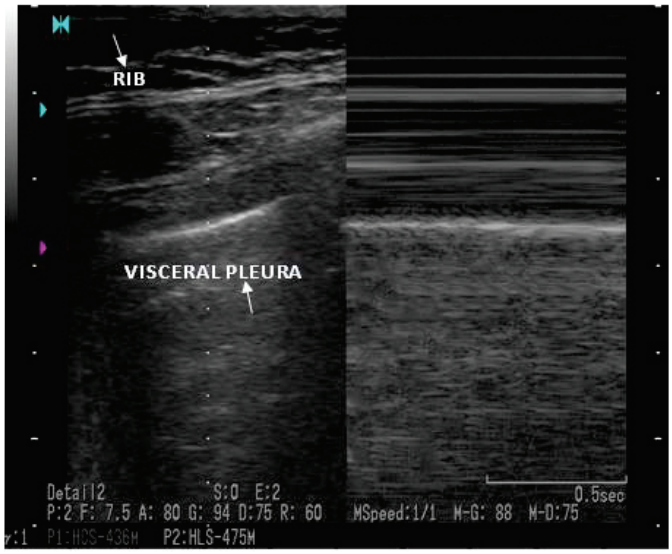

Figure 1: Present Lung Sliding and Seashore Sign (M-Mode), Pneumothorax Absent

Absent lung sliding sign and barcode sign (M-Mode), Pneumothorax present are shown in figure 2.

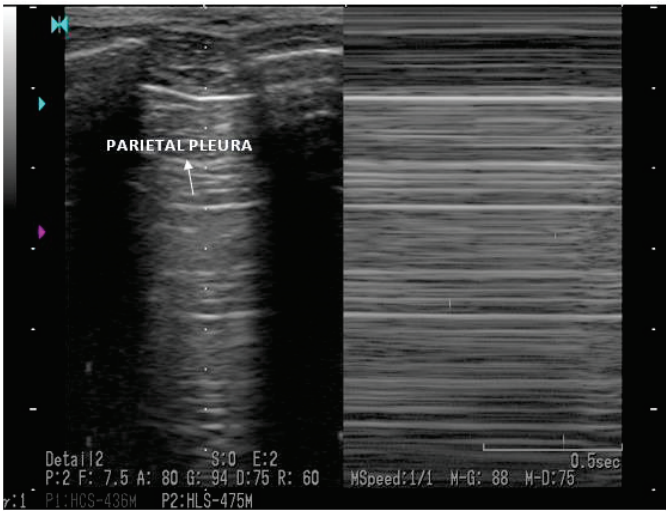

Figure 2: Absent Lung Sliding Sign and Barcode Sign (M-Mode), Pneumothorax Present

Results show lung point sign (right image, arrow) and absent point sign (left image, star) in figure 3.

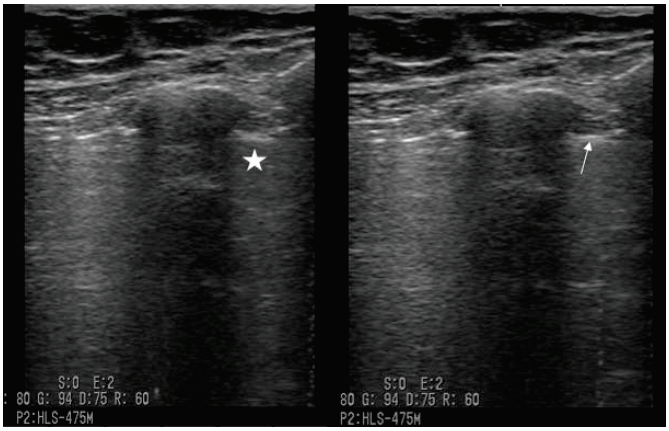

Figure 3: Showing Lung Point Sign (Right Image, Arrow) and Absent Point Sign (Left Image, Star)

A line, Pneumothorax absent is shown in figure 4.

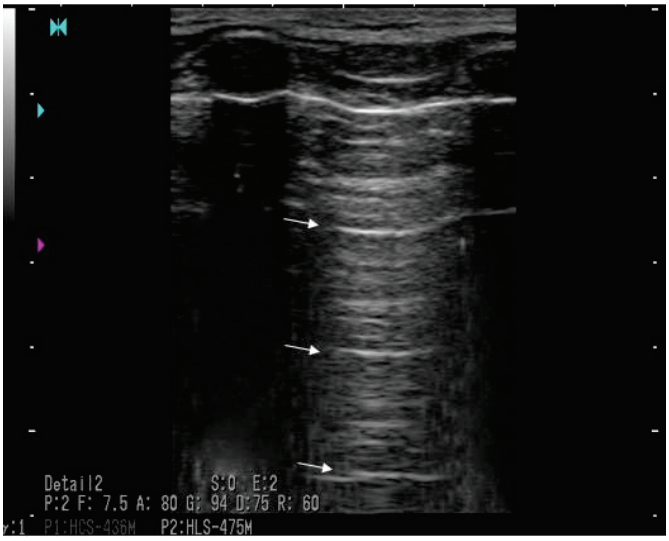

Figure 4: A-Line, Pneumothorax Absent

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CT left-sided pneumothorax is shown in figure 5.

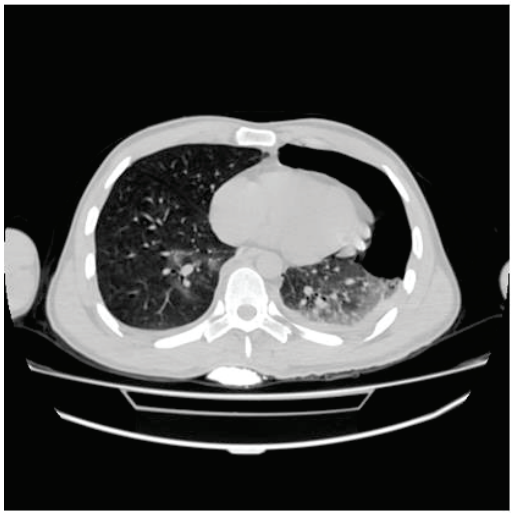

Figure 5: CT, Left-Sided Pneumothorax

Among the cases that tested positive via ultrasonography, 52 were confirmed as true positives, while 3 were identified as false positives. In the ultrasonography-negative group, 31 were confirmed as true negatives, and 4 were classified as false negatives as shown in Table 3.

Table 3: Distribution of Patients as Per Test and Confirmed Diagnosis

Variables	Pneumothorax Present On CT	Pneumothorax Absent On CT	p-value
Pneumothorax Present On USG Scan	52 (TP)*	03 (FP)***	0.0001
Pneumothorax Absent On USG Scan	04 (FN)**	31 (TN)****	

*-TP=True Positive, **-FP=False Positive, ***-FN=False Negative, ****-TN=True Negative

The diagnostic performance of chest ultrasonography in detecting pneumothorax, using CT chest imaging as the gold standard, revealed a sensitivity of 92.85%, specificity of 91.17%, positive predictive value of 94.54%, negative predictive value of 88.57%, and an overall diagnostic accuracy of 92.22% as given in Table 4.

Table 4: Diagnostic Parameters for Ultrasound Technique to Diagnose Pneumothorax

Parameters	Value
Sensitivity	92.8%
Specificity	91.7%
Positive Predictive Value	94.5%
Negative Predictive Value	88.5%
Diagnostic Accuracy	92.2%

DISCUSSION

Ultrasound of the lung is an emerging diagnostic technique for diagnosing pneumothorax in patients with traumatic injury or other causes with fairly decent sensitivity and specificity. It has many advantages over chest radiography and CT scanning it does not use ionizing radiations, is movable, is capable of real-time imaging, and is ideal for repeated tests. Also, it is easily accessible, and the cost is relatively low.Despite of literature supporting the efficiency of chest ultrasound in establishing the diagnosis of pneumothorax, very few studies are reported from Pakistan in this context. The goal of this research work is to establish the diagnostic efficacy of chest ultrasonography in diagnosing pneumothorax using a CT chest as the reference. Ninety patients were included in this study and the ultrasound technique was found to have 92.8% sensitivity and 91.7% specificity to diagnose pneumothorax as compared to chest CT correctly. The positive and negative predictive values were found to be 94.5% and 88.5% respectively, and overall diagnostic power was 92.2%.Several studies done in different countries have demonstrated that the ultrasound method has comparatively high sensitivity and specificity in diagnosing pneumothorax in trauma patients [14]. Similar results were demonstrated in the current study where we reported fairly high sensitivity and specificity of the same method compared with CT as the gold standard. According to Bhoil et al., the sensitivity of the ultrasound method was 89.6% as compared to gold standard chest CT, with higher reported predictive values as well [14]. The results of the current study match with those reported by Staub *et al.*, in a systematic review, identified the role of the ultrasound method in chest trauma including both haemothorax and pneumothorax [15].The author reported sensitivity and specificity of 81% and 98% respectively and overall accuracy of 97.9%.The results reported were slightly different than the current study, a slightly lower value of sensitivity was reported by the authors and the reason can be that they included patients with both pneumothorax and haemothorax in their study whereas we included patients with pneumothorax only.Another systematic review by Netherton et al., reported the pooled estimate specificity and sensitivity of ultrasound to be 69% and 99% respectively for pneumothorax [16]. The sensitivity found in the current study is comparatively higher may be due to the characteristics of the study population and sample size. The study by Abdalla *et al.*, in Egypt, revealed that ultrasound was also found to be more sensitive as compared to chest X-ray with a sensitivity of 86.1% and sensitivity of 52.7% respectively [17]. These results align with the findings and results of our current study. It was concluded by Undziakiewicz *et al.*, that there is a high utility potential of chest ultrasound to diagnose pneumothorax among trauma patients presenting in emergency settings, and the author reported a specificity of 91% and sensitivity of 99% [18]. The results are very similar to what was reported in the current study. A local study conducted in Lahore by Naseem *et al.*, reported that ultrasound can be used to diagnose pneumothorax with specificity of 97.9% and sensitivity of 83.6% as compared to a chest CT scan [19]. These local results are somewhat similar to what we reported because the population dynamics are almost the same within the country. Another local study reported by Imran *et al.*, included 275 cases of tension pneumothorax presenting to the emergency department before cardiac

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arrest. The authors explored the utility of the ultrasound technique to diagnose tension pneumothorax in such patients and reported a sensitivity of 78.2% and specificity of 96.8% [20]. The results might vary from the current study because the authors considered specific cases retrospectively who later on developed cardiac arrest. The current study highlighted the importance of using ultrasound techniques in diagnosing pneumothorax in comparison with a CT scan. Being a non-invasive and cost-effective imaging modality, ultrasonography eliminates the need for ionizing radiation exposure, making it a safer alternative to traditional methods like chest radiography and computed tomography. Similarly, given its wide availability, affordability, and capacity for bedside application, chest ultrasonography proves to be of high importance in emergency settings and in areas with limited access to advanced imaging techniques.This can contribute toward enabling clinicians to make timely and accurate diagnoses and thus improve patient outcomes.

CONCLUSIONS

It was concluded that the diagnostic accuracy of ultrasonography is comparable with the CT scan gold standard. Therefore, it can be utilized to detect pneumothorax in trauma patients presenting in emergency care settings, or in other resource-constraint settings where the availability of CT scans is limited.

Authors Contribution

Conceptualization: NK
Methodology: MHN, NK
Formal analysis: AZ
Writing review and editing: MHN, SBK, RR, BN

All authors have read and agreed to the published version of the manuscript

Conflicts of Interest

All the authors declare no conflict of interest.

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