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Diagnostic Accuracy of Chest Ultrasound in Diagnosing Rib Fractures, Keeping CT Chest as Gold Standard

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ABSTRACT

Blunt chest trauma is a frequent cause of emergency visits with a high risk of rib fractures, timely identification of which is crucial for effective patient management. **Objectives:** To assess the accuracy of chest ultrasound in diagnosing rib fractures, keeping CT chest as a gold standard. **Methods:** A cross-sectional validation study was conducted at the Radiology Department, Holy Family Hospital, Rawalpindi, for six months (Jun-Nov 2023). Adult patients presenting with blunt chest trauma in the Emergency Department who fulfilled eligibility criteria were included. The presence of rib fractures was assessed in each patient by chest ultrasound and verified by CT chest. The diagnostic power of the ultrasound method was assessed and reported as sensitivity, specificity and predictive values by comparison with the gold standard. **Results:** The mean age reported was 35.3 ± 5.93 years; there were 61(57.5%) male and 45(42.4%) female. The accuracy of chest ultrasound in detecting rib fracture, with CT-chest as the reference standard, demonstrated 92.1% sensitivity, 95.2% specificity, 96.7% and 88.8% positive and negative predictive values, and an accuracy of 93.3%. **Conclusions:** It was concluded that chest ultrasound has good diagnostic power (93.3%) to establish the diagnosis of broken ribs in patients with trauma in emergency settings compared with CT-chest scan.

INTRODUCTION

The third most frequent injury in trauma patients is blunt chest trauma (BCT), which affects 15% of emergency visits [1]. The most frequent causes include falls, car accidents, and direct strikes. The prevalence of fractured ribs in blunt trauma is quite high and is reported to be 39.0% [2]. When rib fractures are swiftly and accurately diagnosed, early management can be initiated in the emergency department, relieving patient symptoms [3]. The lungs can suffer catastrophic consequences, including tearing of the lung or chest wall, causing pneumothorax due to rib fractures. To avoid these life-threatening complications, early diagnosis is crucial [4]. Radiological evaluation is almost always considered in such individuals; as physical examination rarely reveals any distinguishing indicators for fractured rib diagnosis [5]. The early diagnosis of fractured ribs has historically been a chest x-ray scan, ideally in the standard postero-anterior position. The detection of major diseases like pneumothorax, hemothorax, or contusion has made the chest x-ray study beneficial in some instances, although studies have regularly and continuously indicated low sensitivities for the diagnosis of rib fracture [6, 7]. The most reliable imaging method for identifying rib fractures and ruling out other concurrent diseases is computed tomography (CT). The CT was ranked

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first for blunt trauma chest by the American College of Radiology. However, the traditional drawbacks, such as exposure to radiation, higher expenses, and the requirement of leaving the emergency department, continue to exist [8, 9]. Another effective screening method for quickly evaluating trauma patients in the emergency department is ultrasonography [10]. To diagnose rib fractures, chest ultrasound can potentially be as good as a CT scan and can also offer some distinct advantages over chest CT as well for example, being quicker, more convenient, and less exposure to harmful radiation [11]. Contrarily, some studies highlighted drawbacks of chest ultrasound as well, including prolonged examination times, discomfort due to the pressure of the ultrasound probe and missed diagnosis [8, 12]. However, literature supports the utility and diagnostic value of chest ultrasound compared with CT chest [13, 14], but data from lower and middle-income countries like Pakistan are deficient. In the context of low-income countries, health system constraints exist, and in low-resource settings availability of chest CT might be questionable. In such circumstances, ultrasonography can serve the purpose of quickly diagnosing the patients for rib fracture, timely management of which is crucial for better patient outcomes. In a poor country like Pakistan with limited resources, chest ultrasonography can be demonstrated to be cost-effective in the identification of rib fractures in patients visiting the emergency room owing to traumatic chest trauma. The goal is to inspect the practicality and benefit of utilizing chest ultrasonography to detect rib fractures in acute chest trauma using CT chest as the gold standard.

This study aims to compare the accuracy of ultrasound and computed tomography in detecting fractured ribs in the Emergency Department.

METHODS

This study employed an analytical cross-sectional validity study, conducted in the Radiology Department of Holy Family Hospital, Rawalpindi, over six months (Jun-Nov 2023) following synopsis approval by the CPSP (RAD-2027-726-3677). The sample size was determined by an online sample size calculator [15] using a mathematical formula for validity studies as mentioned below [16], based on sensitivity and specificity values reported by Gilbertson *et al.*, [14]. TP+ FN= (Za/2)2 Sensitivity (1-Sensitivity)/e2. Sample size (n1) = TP + FN/ Prevalence of Disease. Key parameters considered in the calculation include a sensitivity of 89.3% and specificity of 98.4% for chest ultrasonography in detecting rib fractures, a prevalence of rib fractures in blunt chest trauma of 39.0%, a confidence level of 95%, and an absolute precision of 5.0% for both sensitivity and specificity [14]. The final sample size was estimated to be 106 patients, recruited through non-probability consecutive sampling. Eligible participants included adult patients of either gender presenting to the Emergency Department with chest trauma, suspected fractured ribs with signs/symptoms including chest pain, swelling or tenderness, bruising of skin at the site of trauma and pain during breathing. Patients with critical illness, severe or penetrating trauma, unstable hemodynamic conditions, or those who did not provide consent were excluded. Before data collection, the study obtained ethics approval, and informed consent was taken from all eligible participants or their attendants. Demographic and clinical data were recorded for each patient. Chest ultrasonography was performed using a Honda HS-2600 ultrasound machine along with a high-frequency (5–10 MHz) linear probe. The transducer was placed along the long axis of the rib at the site of maximal pain as indicated by the patient. Rib fractures, costochondral junction involvement, and costal cartilage interruptions were identified based on specific sonographic findings, including interruption of the anterior margin, linear acoustic edge shadowing, or focal hematoma. The duration of each ultrasound examination was also recorded. Following ultrasonography, all patients underwent a CT scan of the chest, which served as the reference standard. A radiologist, blinded to the ultrasound results, interpreted all CT scans to confirm the diagnosis. Data were extracted from the collection tool and analyzed using IBM SPSS software (version 29.0). Descriptive statistics of quantitative variables were expressed as mean ± SD. A 2×2 contingency table was used to classify true and false, positive and negative cases. Standard formulas were used to calculate and report accuracy. Significance was calculated using the Fisher-Exact test, where a p-value of ≤0.05 was considered statistically significant. Rib fractures, costochondral junction involvement, and costal cartilage interruptions were identified based on specific sonographic findings, including interruption of the anterior margin, linear acoustic edge shadowing, or focal hematoma (Table 1).

Table 1: Ultrasound Findings Suggestive of Rib Fractures

Ultrasound Parameters	Availability
Breaks in Cortical Alignment	Present
	Absent
Linear Edge Shadow	Present
	Absent
Interruption in Anterior Margin	Present
	Absent
Focal Hematoma	Present
	Absent

The image of normal echogenic border of the rib shows these specific ultrasound signs (Figure 1).

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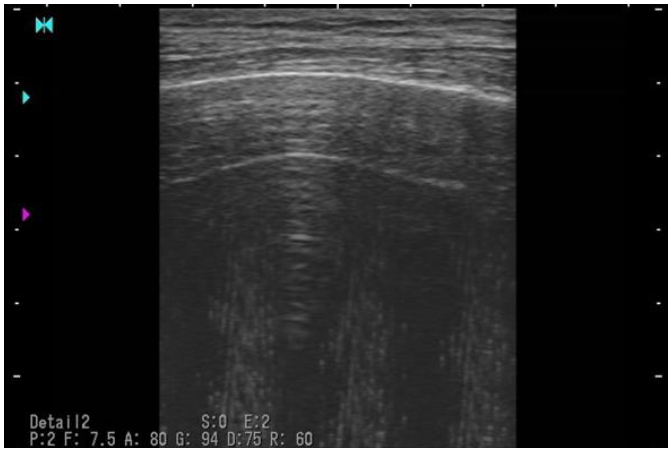

Figure 1: Normal Echogenic Border of Rib

The image of breaks in the cortical alignment of the rib shows these specific ultrasound signs (Figure 2).

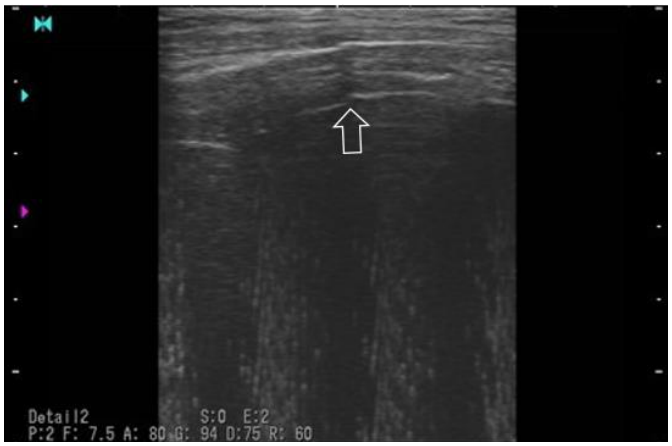

Figure 2: Breaks in Cortical Alignment

The image of a linear edge shadow (arrow) and focal hematoma (solid arrow) of the rib shows these specific ultrasound signs (Figure 3).

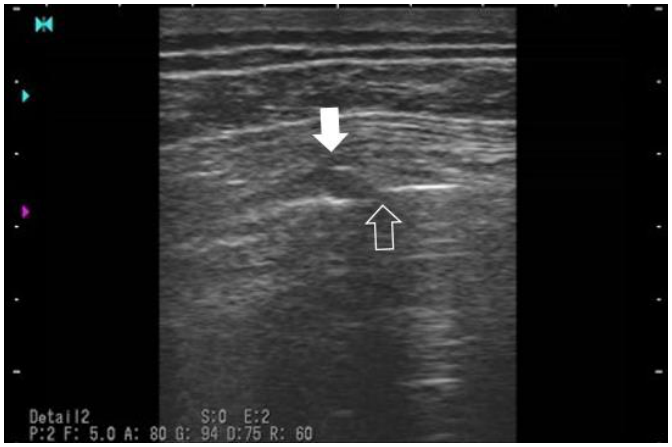

Figure 3: A Linear Edge Shadow (Arrow) and Focal Hematoma (Solid Arrow)

The image of interruption in anterior margin of the rib shows these specific ultrasound signs (Figure 4).

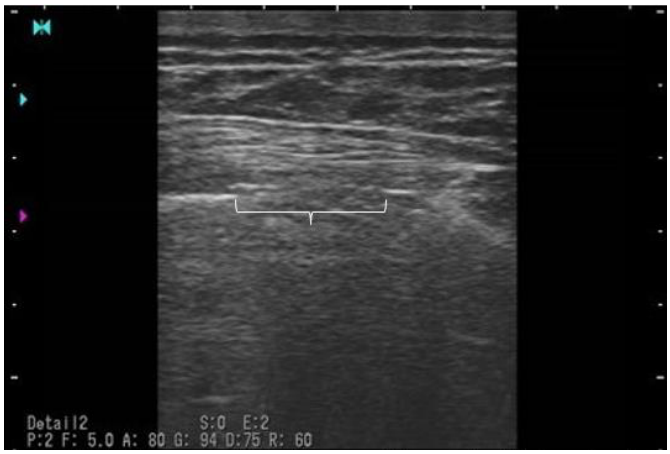

Figure 4: Interruption in Anterior Margin

RESULTS

There were a total of 106 participants; the mean age reported was 35.3 ± 5.93 years. A majority of the participants, comprising 78 individuals (73.5%), were above 40 years of age. Of the 106 patients, 61 (57.5%) were male, and 45 (42.4%) female. The demographic data are summarized (Table 2).

Table 2: Sociodemographic of Participants (n=106)

Characteristics	Frequency (%)
Age (Year)	35.3 ± 5.93
Age Categories (Year)	
≤40 Years	78 (73.58%)
>40 Years	28 (26.41%)
Sex Distribution	
Female	45 (42.45%)
Male	61 (57.54%)

All patients underwent chest ultrasonography followed by computed tomography (CT) for confirmation of fractures. The pattern of ultrasound findings among the study participants is given (Figure 5).

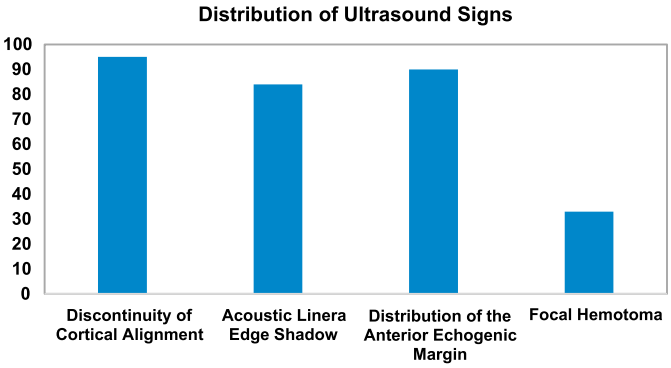

Figure 5: Distribution of Ultrasound Signs Suggestive of Rib Fracture (n=61)

Discontinuity of cortical alignment was present in 58 (95.0%) participants, acoustic linear edge shadow was present in 51 (83.6%), disruption of the anterior echogenic

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margin was found in 55 (90.1%), while the focal hematoma was evident in 21(34.4%) participants. Among patients who tested positive on ultrasonography, 59 were confirmed as true positives, whereas 2 were identified as false positives. In contrast, among those who tested negative on ultrasonography, 40 were confirmed as true negatives, while 5 were classified as false negatives. Some of the true positive cases missed rib fracture diagnosis on the ultrasound and vice versa; the difference was significant (p=0.0001*)(Table 3).

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

Variables	Rib Fracture Present on CT	Rib Fracture Absent on CT	P-Value
Rib Fracture Present on USG Scan	59 (TP)**	02 (FP)****	0.0001*
Rib Fracture Absent on USG Scan	05 (FN)***	40 (TN)*****	

The p-value was calculated using Fisher-exact test, *significant p-value, **-TP=True positive ***-FP=False positive ****-FN=False negative *****-TN=True negative

The ability of ultrasound to detect fractured ribs, considering CT-chest as reference standard, demonstrated 92.1% sensitivity, 95.2% specificity, 96.7% and 88.8% positive and negative predictive values, and overall accuracy of 93.3% (Table 4).

Table 4: Diagnostic Parameters for Ultrasound Technique to Diagnose Rib Fractures

Parameters	Value %
Sensitivity	92.18%
Specificity	95.23%
Positive Predictive Value	96.72%
Negative Predictive Value	88.88%
Diagnostic Accuracy	93.3%

DISCUSSION

Chest ultrasound is a promising diagnostic technique to diagnose fractured ribs in chest trauma presenting in the emergency center. Ultrasound technique has several pros over conventional chest CT scan as it avoids ionizing radiation exposure, is mobile, is capable of quick imaging and is more acceptable to patients at the same time. Nonetheless, it is easily accessible and cost-effective as well. The literature reports the efficiency and utility of chest ultrasound in diagnosing rib fractures in emergency settings, but studies from Pakistan are relatively few. The goal was to establish the efficacy of chest ultrasonography in Pakistan's local context to diagnose fractured ribs in emergency settings. We included one hundred and six patients from the Emergency Department, presenting with blunt chest trauma suspected to have fractured ribs. Ultrasound chest was found to be sensitive (92.1%) and specific (95.2%) in correctly diagnosing rib fractures. The predictive values were also reported, 96.7% and 88.8% positive and negative, respectively, along with an accuracy of 93.3%. The negative predictive value was found to be slightly lower in this study; the reasons can be due to the limited sample size. Several studies done worldwide demonstrated the ultrasound method to be as effective as chest CT in terms of sensitivity and specificity to diagnose rib fractures [17-19]. Results of the current study also demonstrated similar results with fairly high diagnostic test parameters for the ultrasound technique compared with CT chest as a standard. A systematic review by Gilbertson *et al.*, based on seven studies from the literature, reported a pooled sensitivity of 89.3% for the chest ultrasound to diagnose rib fracture, and a pooled specificity of 98.4% [14]. The most significant of the ultrasound parameters used in included studies was the cortical irregularity. The results reported in this systematic review are almost identical to the results of the current study, where relatively high diagnostic power is reported for the chest ultrasound method. In the current study, the discontinuity of cortical alignment was found in 95% of the participants, while 83.6% showed acoustic linear edge shadow, 90.1% had disruption of the anterior echogenic margin, and 34.4% had focal hematoma. Authors, including Çelik *et al.*, conducted a study on one hundred and forty-five patients presenting in the ER with blunt chest trauma injury and assessed the utility of ultrasound to diagnose the rib fractures [17]. The authors reported an overall accuracy of 80%, which is slightly less than what was reported in the current study, along with 72.7% specificity, which is also somewhat lower than what was reported in the current study and 91.2% sensitivity, which is similar to the value reported in the current study. The differences in these values can be due to variations in sample size, study population and other contextual factors. The authors concluded that if a patient with blunt chest trauma comes to the emergency with pain on one side, ultrasound can be used to check for rib fractures, and if the ultrasound does not show any fractures at the most painful spot and nearby ribs, it strongly suggests that a rib fracture is unlikely [17]. Jelyani *et al.*, conducted a study on one hundred and thirteen patients to compare the diagnostic power of chest ultrasound to diagnose rib fractures, and the authors reported that out of the total, 66.3% of patients were found to have at least one broken rib by CT and 54.9% by ultrasound [18]. Overall, the authors reported 81.5% sensitivity of ultrasound, but with one fractured rib, the sensitivity was reported to be 73.1%, while for five fractured ribs, the sensitivity was reported as 100%. In the current study, researchers did not consider the number of fractured ribs while determining the diagnostic power of ultrasound, but overall, the findings of both studies tend to

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be in a similar direction. Kumar *et al.*, conducted a study in India with a similar aim. The authors considered data from sixty consecutive patients presenting with chest trauma in the ER and reported that in sixty patients, there were 72 fractured ribs, out of which 62 were correctly picked up on the ultrasound test [19]. The authors did not report diagnostic accuracy in terms of sensitivities or specificities, but the conclusion supports that chest ultrasound is as effective in picking up broken ribs as chest X-ray and Chest CT scan, so these can be used alternatively in clinical settings. Devadoss *et al.*, reported the diagnostic accuracy of e-Fast ultrasound in stable blunt trauma injury to diagnose fractured ribs, and the authors reported that this technique is a good alternative to conventional techniques to diagnose fractured ribs in patients with chest trauma [20]. This study emphasizes the importance of using chest ultrasound to diagnose broken ribs compared to chest CT scan. As a non-invasive and cost-effective imaging method, ultrasound avoids ionizing radiation exposure, making it a safer alternative to traditional techniques like chest X-rays and CT scans. Additionally, its affordability, widespread availability, and ability to be performed at the bedside make ultrasound highly valuable in emergency settings and resource-limited areas. If a high diagnostic yield is established, ultrasonography (USG) may serve as a valuable alternative for patients with multiple trauma who are hemodynamically unstable or in intensive care settings, where mobilizing the patient for CT can be challenging. By enabling timely and accurate diagnoses, ultrasound can help clinicians improve patient outcomes.

CONCLUSIONS

It was concluded that chest ultrasound was found to have good diagnostic power (93.3% accuracy) to establish the diagnosis of broken ribs in blunt chest trauma patients in emergency settings compared with chest CT scan.

Authors Contribution

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