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Evaluation of Bedside Ultrasonography in the Detection of Traumatic Occult Pneumothorax: A Diagnostic Accuracy Study

Ahmed Adel Morsy*, Mohammad Abdelmoneim Torky
Cardiothoracic Surgery Department, Faculty of Medicine, Tanta University, Tanta, Egypt
*Corresponding author: Ahmed Adel Morsy, E-mail: Ahmadadelmorsy@gmail.com, Phone: +201008607508

Abstract:
Background: Traumatic pneumothorax is a life-threatening condition that may occur in patients with blunt or penetrating chest trauma. Traumatic pneumothorax has different degrees ranges from traumatic occult pneumothorax (TOP) to tension pneumothorax. Early detection of TOP is crucial to predict patients in risk for development of significant pneumothorax and improve patient's outcome. Bedside ultrasonography (US) has emerged as a valuable tool in the emergency department (ED) for the detection of TOP.
Objective: This research aimed to evaluate the diagnostic accuracy of bedside US in detecting traumatic occult pneumothorax in patients with chest trauma.
Patients and Methods: We conducted a prospective study on 150 patients with chest trauma who underwent both chest ultrasonography and computed tomography (CT) scans. The primary outcome measure was the sensitivity and specificity of bedside US in detecting TOP.
Results: The results showed that bedside US had a sensitivity of 80.99% (95% CI: 72.86% to 87.55%) and specificity of 96.09% (95% CI: 92.11% to 98.41%) to detect TOP.
Conclusion: Our study suggests that bedside chest ultrasonography is a reliable tool for the detection of TOP. The high sensitivity and specificity of bedside chest US make it a valuable addition to the diagnostic armamentarium in the ED. Early detection of TOP using bedside chest US can lead to timely intervention and improved patient's outcome.
Keywords: Traumatic occult pneumothorax, Bedside chest ultrasonography, Diagnostic accuracy, Emergency department.

INTRODUCTION

In all age categories, trauma ranks the third leading cause of mortality, after cancer and cardiovascular illnesses. Nonetheless, among those under the age of forty, trauma is the main leading reason for death. Despite the fact that trauma-related injuries can happen to any area of the body, thoracic injuries or their consequences account for one in four death of trauma patients [1].

Chest trauma is still a major concern as the number of high-speed car crashes rises. Thoracic trauma accounts for around sixty percent of polytrauma studied cases and has a twenty percent to twenty-five percent death rate [2]. Research has demonstrated that early detection of such damage can dramatically lower the death rate and associated burden [3].

When a patient has chest wall trauma, up to 50% of them present with pneumothorax (PTX), a well-known but complex condition that needs to be diagnosed and treated properly [4]. The computed tomography (CT) scan is the gold standard for diagnosing thoracic injuries. [5], however, It is advised to use this test only when it is necessary because, despite its great accuracy, CT scan patients receive a substantial radiation dosage [6].

Alternative to CT scan, there are other diagnostic modalities, counting supine chest radiograph (CXR) and chest ultrasonography (US) [7]. The accuracy of chest X-ray, which is also employed as an early diagnostic test in studied cases with thoracic injuries, is not particularly high [8]. Its sensitivity ranges between 36%-48%, and in spite of that, the tenth edition of the Advanced Trauma Life Support (ATLS) Course still views CXR as the main screening technique for traumatic pneumothorax [9].

The incidence of traumatic occult pneumothorax (TOP), a minimum pneumothorax that is identified by a chest CT scan without prior detection or clinical suspicion by a conventional chest X-ray, varies between 2% and 15% [10].

On the other hand, during the past three decades, chest US has shown a substantial increase in its uses in trauma patients. Recent studies have demonstrated that, when it comes to the identification of pneumothorax, its sensitivity and specificity are on par with, if not better than, those of CXR [11]. It's critical to use US to diagnose pneumothorax at the patient's bedside in order to start treatment as soon as possible. One method that has shown promise for identifying pneumothorax in trauma situations is US evaluation of the thorax. According to published studies, chest US is also more sensitive than posteroanterior CXR at identifying small pneumothoraces that are readily missed (hidden cases). Additionally, it offers a notable decrease in diagnostic time. When compared to a chest CT scan, chest US has been confirmed as a dependable method in a different set of research [12].

In this context, this research was conducted to validate the use of chest US for diagnosis of occult pneumothorax, which was hidden or missed by ordinary CXR by comparing its results with CT scan.

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PATIENTS AND METHODS

Study population

This study recruited 245 polytraumatized adult patients (over 18 years) recently (in 24 hours of trauma) presented to Emergency Department at Tanat University Hospital during the period from December 2024 to May 2025. Patients with hemodynamic instability were not involved in the research. Also, studied cases with significant chest wall skin loss, massive subcutaneous emphysema, morbid obesity (BMI over 40), and those having preexisting pulmonary problems like pulmonary resection preventing proper chest US evaluation, were excluded as well.

METHODS

As a part of routine workup, all of those 245patients included in the research were subjected to chest X-ray either in erect position (whenever possible) or supine position. From those patients, 95 showed pneumothorax on chest X-ray and were excluded from the study. In the remaining 150 patients, there was no detectable pneumothorax on chest X-ray. Subsequently, all of the later patients underwent chest US examination using Philips Affiniti 50G Digital Ultrasonic System (Philips, produced in the Netherlands) and Mindray DP-20 Portable Ultrasound (Mindray, produced in China) before whole body CT scanning (Figure 1).

Ethical consideration

This study received approval from research Ethical Committee in Tanta University with the code (36264PR988/12/24). The study adhered to the Helsinki Declaration throughout its execution. Informed consent was obtained from all patients or their caregivers prior to their participation in the study.

Data management

While frequencies (number of cases) and percentages were used to describe categorical data, mean ± standard deviation (± SD), median and interquartile range (IQR) were used to statistically characterize numerical data. SPSS (Statistical Package for the Social Sciences; SPSS Inc., Chicago, IL, USA) version 27 was the computer program used for all statistical computations.

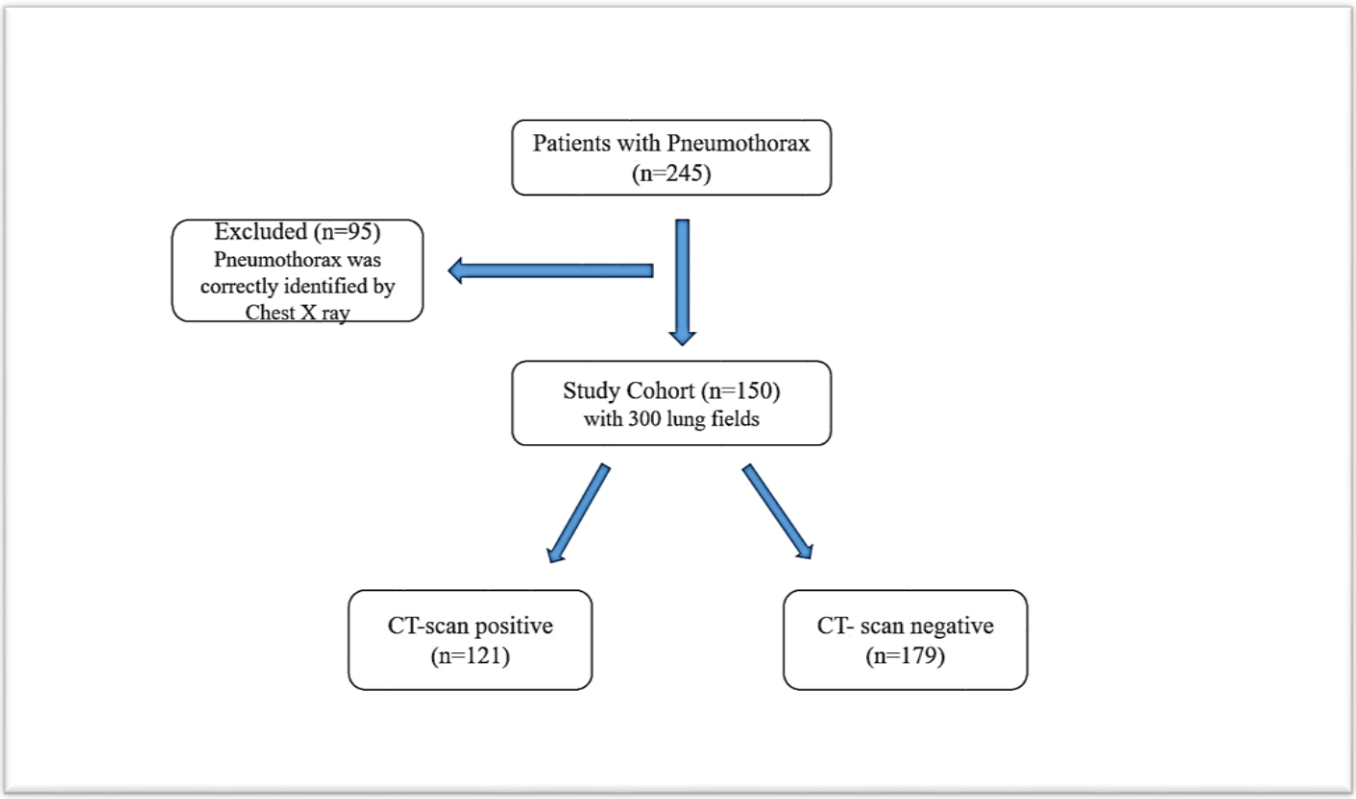

Figure (1): Flow chart of study.

RESULTS

Pneumothorax was identified in 95 out of 245 examined patients by CXR, those patients were excluded from the analysis and didn't require further chest US or CT chest.

One hundred and fifty patients gave negative CXR finding, and required more work-up.

Baseline characteristics and trauma details:

The median age of studied patients was 42.0 (IQR=18.0-65.0) years old, there was male predominance 94 (62.7%). 65 out of 150 patients (43.3%) were active smokers at time of conduction of study. Regarding comorbidities, hypertension was present in 21.3% of patients, while diabetes mellitus was present in 14% of them. Patients or their caregivers were asked about the mode of trauma, 131 out of 150 patients reported blunt trauma, and most of them claimed that the cause was car accident or fall from height. The minority reported penetrating trauma (12.7%). 114 out of 150 patients exhibited rib fracture (Table 1).

Table 1: Baseline characteristics and trauma details of studied patients

Studied parameters		
Age, (years) Median (IQR)		42 (18-65)
Gender, no (%)	Male	94 (62.7)
	Female	56 (37.3)
Smoking, no (%)		65 (43.3)
HTN, no (%)		32 (21.3)
DM, no (%)		21 (14)
Type of injury	Blunt	131 (87.3)
	Penetrating	19 (12.7)
Associated injuries, no (%)	None	21 (14)
	Rib fracture	114 (76.0)
	Hemothorax	23 (15.3)
	Sternal fracture	6 (4.0)
	Pulmonary contusion	96 (64.0)

HTN=Hypertension, DM=Diabetes Mellitus

CT scan findings

CT scan, which is considered the gold standard method in diagnosis of pneumothorax, could detect pneumothorax in 116 out of 150 (77.3%) patients, however no pneumothorax was detected in 22.7% of participants. Only 5 patients were found to have bilateral pneumothorax. The highest percentage of pneumothorax was apical (56.2%) (Table 2).

Table 2: CT finding of studied patients

Studied parameters		
Occult pneumothorax, Patient no (%)	Free	34 (22.7)
	Present	116 (77.3)
Laterality of detected occult pneumothorax, no (%) (n=116 patients) ⊦	Unilateral	111 (95.7)
	Bilateral	5 (4.3)
Location of pneumothorax, no (%) (n=121 lung field) ⊦⊦	Apical	68 (56.2)
	Basal	22 (18.2)
	Medial	6 (5)
	Lateral	25 (20.6)

⊦ *One hundred and sixteen patient who had pneumothorax*

⊦⊦*The location was studied for 116 patients with a total of 121 examined lung fields with pneumothorax.*

Ultrasound finding

The diagnostic accuracy of chest ultrasound was compared to the CT chest for the 150 studied patients. 300 Hemithoraces were examined. US could correctly detect the presence of pneumothorax in 98 lung field, however CT proved presence of the occult pneumothorax in 121 lung field, with a sensitivity of 80.99% (95%CI=72.86% to 87.55%).

For those five patients with bilateral pneumothorax, US was able to detect the pneumothorax bilaterally in only two patients, and surprisingly, it missed the diagnosis of bilateral pneumothorax in 3 cases. Moreover, US gave positive findings in 7 lung fields, which was confirmed as false results later on by CT scan, with a specificity of 96.09%. The calculated overall accuracy of the US was 90.0% (Table 3).

Table 3: Diagnostic performances of ultrasound in diagnosis of occult pneumothorax.

Parameters		CT scan finding		
		Positive (n=121)	**Negative (n=179)**	**Total examined lung fields (n=300)**
US finding	**Present**	98 (TP)	7 (FP)	105
	Absent	23 (FN)	172 (TN)	195
Final US findings				
Sensitivity= 80.99% (95%CI=72.86% to 87.55%)		**PVP=** 93.33% (95%CI=87.08% to 96.68%)	**Positive Likelihood Ratio=** 20.71 (95%CI=9.97 to 43.03)	**Prevalence of occult pneumothorax=**40.33% (95%CI=34.74% to 46.12%)
Specificity= 96.09% (95%CI=92.11% to 98.41%)		**PVN =** 88.21% (95%CI=83.79% to 91.54%)	**Negative Likelihood Ratio=** 0.20 (95%CI=0.14 to 0.29)	**Overall accuracy of US=**90.00% (95%CI=86.03% to 93.15%)

TP=True positive, FP=False positive, FN=False negative, TN=True negative, CI=Confidence interval, PVP=Positive Predictive Value, PVN=Negative Predictive Value, US=Ultrasound.

Statistical Test: ROC-curve analysis

DISCUSSION

Traumatic pneumothorax is a life-threatening condition that may occur in studied cases with blunt or penetrating chest trauma. Traumatic occult pneumothorax (TOP) is a minor degree of pneumothorax that appears in CT chest and not in chest X-ray, and can eventually progress to more severe pneumothorax, endangering the patient's life. So, detecting occult pneumothorax is considered a risk factor that necessitates patient hospital admission and close follow-up by chest X-ray to avoid the risk of developing more severe life-threatening pneumothorax.

Many errors were found in chest X-rays used to diagnose pneumothorax, particularly in studied cases who were unable to be placed in an upright position. However, bedside chest ultrasonography has become a useful, quick, portable, and efficient method for detecting occult pneumothorax in emergency rooms.

Izcue *et al.*, found that the examination of artefacts provides the foundation for the ultrasonographic diagnosis of pneumothorax. Combining the indications of lung sliding, the A and B lines, and the lung point can help confirm or rule out pneumothorax. Lung ultrasonography's accessibility in any emergency, particularly for studied cases in the intensive care unit, is one of its main advantages. Because of this, chest ultrasonography can be used to assess the degree of the pneumothorax and track its progression, as well as to replace plain-film X-rays and CT in studied cases who are critically ill or in studied cases with normal plain films in whom pneumothorax is highly suspected [13].

To find studied cases who are more likely to be unwell, screening is carried out in a clinical context. One test is considered the "gold-standard," which means it is the most accurate and, therefore, the most appropriate to use. When compared to alternative methods, the gold standard test has the highest probability of accurately identifying those who have the disease (specific) and those who do not (sensitive) [14].

A test needs to have a high sensitivity and specificity in order to be considered accurate. Sensitivity and specificity statistically describe the accuracy of a test that confirm the occurrence or absence of a disease respectively. Sensitivity is the true positive rate, and a test with high sensitivity can detect high proportion of positive cases with minimal case missing. On the other hand, specificity means the true negative rate, and a test which reliably excludes patients who do not have the disease, resulting in higher true negatives and lower false positives, will have high specificity [15].

The high sensitivity of bedside US is particularly important in the ED setting, where timely diagnosis and treatment are critical.

Our study found that bedside US had a sensitivity of 80.99% (95% CI: 72.86% to 87.55%) and specificity of 96.09% (95% CI: 92.11% to 98.41%) for the detection of occult pneumothorax. These results indicate that bedside US is a reliable tool for the recognition of occult pneumothorax, with a high sensitivity and specificity.

Our study also investigated the location of pneumothorax in patients with TOP. We found that the apical location was the most common site of pneumothorax, followed by the lateral and basal locations. These results are consistent with the study of **Ezzat and his colleagues** who have reported similar findings [10].

Many studies had investigated the diagnostic accuracy of US in detecting occult pneumothorax compared to chest CT scan which is the gold standard method. In this point, **Ezzat and his colleagues** reported a sensitivity of 90.32%, specificity 88.89%, PVP 69.55%, PVN 72.73, and overall test accuracy 90.0% [10]. Also,

Elgazzar *et al.* reported a sensitivity of 81.0%, specificity 87.5%, PVP 97.1%, PVN 46.7%, and overall test accuracy 82.0% [16].

On contrary, the lowest sensitivity of chest US was recorded by a recent study conducted by **Santorelli *et al.***, among 2,185 patients the reported sensitivity was 46.7%, while the specificity of US was 99.5% [4]. **Kirkpatrick *et al.*** also reported a low sensitivity of chest US (48.8%), and recommended CT scan as gold standard method in revealing TOP [17].

Study limitations

Chest US is an operator dependent technique and interpretation need more practice by the radiologists as well as emergency physicians and thoracic surgeons. Also, the sample size was relatively small, and further studies are needed to validate our results.

CONCLUSION

In conclusion, our study found that bedside ultrasonography is a reliable tool for the recognition of traumatic occult pneumothorax in studied cases with chest trauma. The sensitivity and specificity of bedside chest US were 80.99% and 96.09%, respectively. The positive and negative predictive values of bedside chest US were 93.33% and 88.21%, respectively. These results suggest that bedside chest US can be used to rule in or rule out occult pneumothorax in studied cases with chest trauma.

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