Medical Science

To Cite:
Alanazi MM, Alnakhli MM, Al-Mula AF. Accuracy of diagnosing traumatic hemothorax and pneumothorax in the emergency department using chest ultrasound: Systematic review. *Medical Science* 2025; 29: e81ms3589
doi: https://doi.org/10.54905/disssi.v29i160.e81ms3589

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Peer-Review History
Received: 12 February 2025
Reviewed & Revised: 25/February/2025 to 29/May/2025
Accepted: 07 June 2025
Published: 12 June 2025

Peer-review Method
External peer-review was done through double-blind method.

Medical Science
pISSN 2321–7359; eISSN 2321–7367

Accuracy of diagnosing traumatic hemothorax and pneumothorax in the emergency department using chest ultrasound: Systematic review

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ABSTRACT

Background: A hemothorax in trauma patients must be diagnosed as soon as feasible because chest drainage can save a patient's life. The purpose of this systematic review was to evaluate the accuracy of chest US for the emergency diagnosis of Pneumothorax and Hemothorax in adult trauma patients. *Method*: This review is reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) standards. With the assistance of a biological librarian, PubMed, Scopus, EMBASE, and Web of Science were searched for articles published from 2016 to 2024. *Result and conclusion*: Five publications that were published between 2016 and 2024 were considered in this analysis. The included papers aimed to assess how well the US performs diagnostically in identifying injuries linked to chest trauma, particularly PTX and HTX. When it comes to PTX and HTX detection, US is as sensitive as CXR. The US facilitates prompt diagnosis and treatment of chest injuries, even when CT is required for confirmation. The US requires additional procedures for confirmation, as it is less sensitive than CT and relies on operator competence. Because the US has a lesser sensitivity than CXR for traumatic PTX, it is not recommended to utilize it alone as a screening tool. Combining CXR with US increases the sensitivity of diagnosis.

Keywords: diagnosing, trauma, hemothorax, pneumothorax, emergency department, ultrasound

1. INTRODUCTION

Chest drainage is regarded as life-saving in the emergency department, so it is critical to diagnose pneumothorax (PTX) and hemothorax (HTX) in trauma patients as soon as possible. When a clinical examination does not suggest an urgent thoracostomy, chest radiography (CXR) is currently the primary

diagnostic technique used. Nevertheless, a number of investigations have documented that CXR is not very sensitive to these lesions (Alrajab et al., 2013; Ding et al., 2011). Patients in the decubitus posture and those utilizing portable equipment have worse picture quality. Furthermore, radiation exposure and patient mobilization are necessary for chest X-ray (CXR) procedures.

In light of this, chest ultrasound (US) has gained popularity in recent years (Montoya et al., 2016). In addition to not using radiation and enabling real-time scanning and interpretation, it is portable, quick, and simple to repeat (Volpicelli et al., 2012). The more anterior areas of the chest are used to evaluate PTX. During US scan, the pleural line—a horizontal hyperechoic line located immediately below the rib surface—is clearly visible. Adhesion between the visceral and parietal pleura is indicated by the presence of lung sliding, which is a faint, brilliant movement of the pleural line throughout the respiratory cycle. Furthermore, the existence of comet tail artifacts—vertical hyperechoic artefacts originating from the pleural line—indicates that the lung parenchyma is subpleural.

Therefore, the lack of these two indicators may indicate a PTX, which is a separation of the visceral and parietal pleura, allowing air to accumulate. The lung point is the most lateral chest point where comet tail or lung sliding artifacts are once again visible. Since it rules out alternative reasons for the lack of lung sliding and comet-tail artifacts, including bullous emphysema or pleural adherences, this symptom is unique to PTX. The apical-posterior-basal chest area is used to evaluate pleural effusions (PE) due to heart failure (HF) and other causes. Pleural diffusion is indicated by an anechoic or hypoechoic picture between the diaphragm and parietal pleura, as well as inspiratory movement of the visceral pleura in the pleural space (Montoya et al., 2016; Volpicelli et al., 2012).

According to the evidence that is currently available, chest US performs exceptionally well in diagnosing PEs and overall pneumothoraces (Ebrahimi et al., 2014; Grimberg et al., 2010; Yousefifard et al., 2016). Regarding CXR, chest US has certain challenges due to the treatment of severe trauma patients. Patients are typically unable to cooperate with the examination because they are immobilized and undergoing further diagnostic and therapeutic procedures. Therefore, it is not possible to fully extrapolate the data on nontraumatic PTX and PEs to the trauma situation.

Assessing the precision of chest US for the emergency diagnosis of PTX and HTX in adult trauma patients was the goal of this systematic review.

2. METHODS

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) criteria are followed in the reporting of this review. The studies were chosen and examined by two separate writers, who also extracted the data and evaluated the methodological quality. Discussions were held to resolve disagreements until a mutually agreed-upon solution was reached. When a third author was unable to establish an agreement, the matter was settled.

PubMed, Scopus, EMBASE, and Web of Science were searched for papers published between 2016 and 2024 with the help of a biological librarian. Concepts pertaining to the US, the thorax, and emergency departments (ED) were covered by the search criteria. Additionally, the reference lists of the included publications and additional systematic reviews were examined.

Studies that satisfied the following inclusion criteria were accepted: the study was published in English, the population and settings consisted of adult trauma patients (16 years old) attending emergency departments, the reference standard was clearly identified, and the target injuries were PTX or HTX. True and false negatives as well as true and false positives were the results. Abstracts and titles were checked for any infractions of the inclusion requirements. All inclusion criteria were checked in the complete texts of the remaining articles. Furthermore, the bibliographical references of the included publications and those of other systematic reviews were examined for further research.

Variables extracted from the full text of the included publications using a standardized form include: study design, outcome, setting, study duration, sample size, population characteristics, inclusion and exclusion criteria, diagnostic modalities, gold standard, analysis, and main findings.

3. RESULTS

In this study, we included five articles (Fig. 1), published between 2016 and 2024. The aim of the five articles is to evaluate the US diagnostic performance in detecting chest trauma-related injuries, specifically pneumothorax (PTX), hemothorax (HTX), and lung contusion, and to compare its effectiveness with traditional imaging methods, such as chest X-ray (CXR) and computed tomography (CT). Vafaei et al., (2016) examined the utility of US in the initial evaluation of thoracic injuries, and found its lower sensitivity compared to CT. Aswin et al., (2023) aimed to assess the effectiveness of US and CXR in detecting PTX and HTX, while also examining the benefits of US in early management. Jahanshir et al., (2020) studied the role of point-of-care ultrasound (POCUS) for traumatic lung

injuries, effectiveness in detecting blunt PTX, HTX, and lung contusion. Temel et al., (2024) explored the effectiveness of bedside thoracic US in diagnosing PTX, particularly in larger injuries, and its role in reducing radiation exposure. Santorelli et al., (2024) compared the sensitivity of lung ultrasound (LUS) and CXR in screening for traumatic PTX. They suggested that physicians be aware when using US alone and advised a combined approach to enhance diagnostic accuracy. Methodology of the included studies is presented in Table 1 and main findings are presented in Table 2.

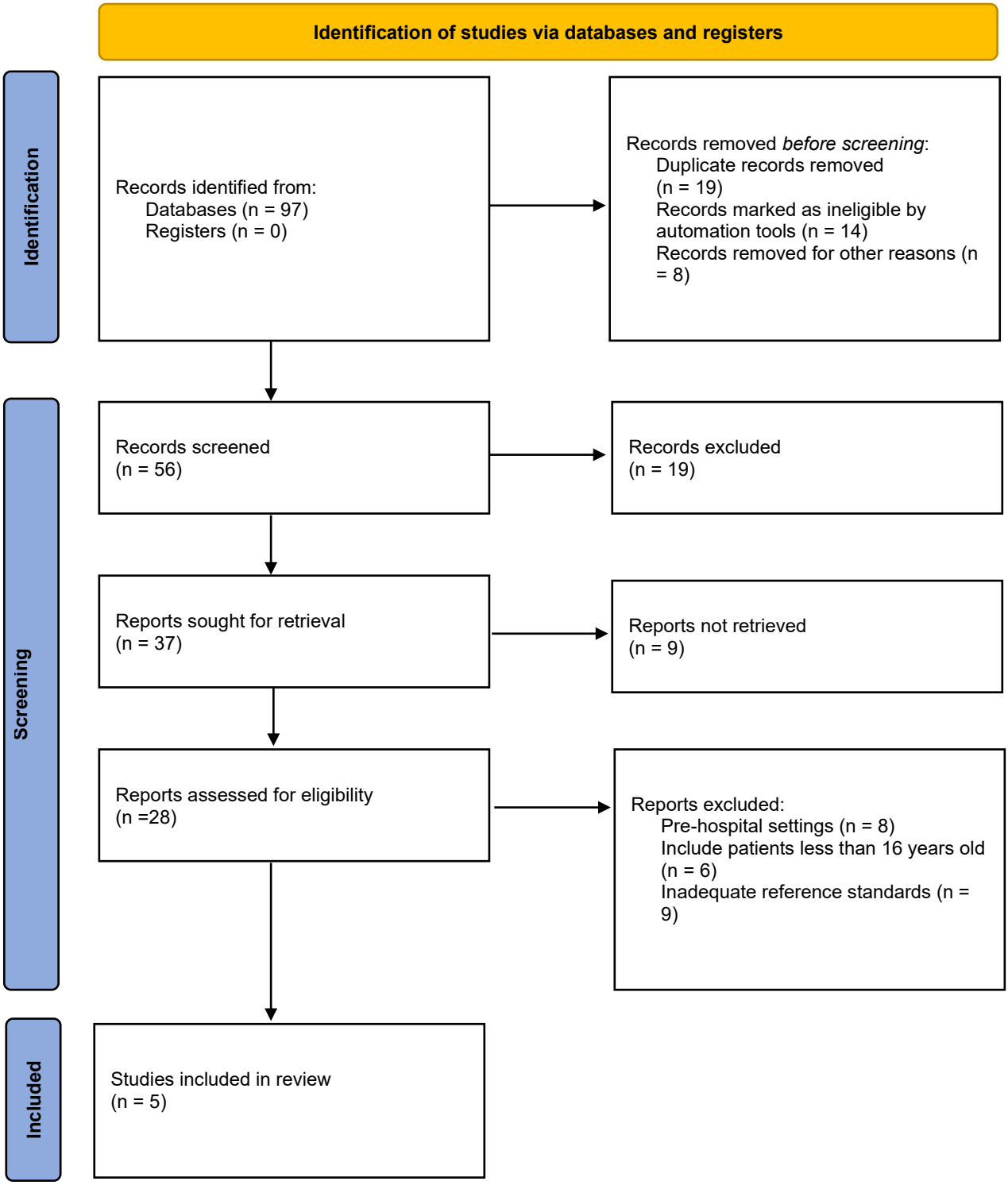

Fig 1: PRISMA consort chart of studies selection

Table 1: methodology of the included studies

Aspect	Kelly et al., 2006	Vafaei et al., 2016	Santorelli et al., 2024	Temel et al., 2024	Jahanshir et al., 2020
Study Design	Cross-sectional diagnostic study	Prospective cross-sectional study	Retrospective observational cohort study	Prospective study	Longitudinal study
Outcome	Diagnostic accuracy of US for detecting PTX and HTX	Diagnostic accuracy of US and chest radiography	Diagnostic accuracy of LUS and CXR for detecting chest injuries	Diagnostic accuracy of US in detecting thoracic injuries	Diagnostic accuracy of PoCUS vs CT in detecting thoracic injuries
Setting	Emergency Department, Jawaharlal Institute of Postgraduate Medical Education and Research, South India	Emergency Department, Imam Hossein Hospital, Iran	Level 1 trauma center, USA	Emergency Clinic, Bakırköy Dr. Sadi Konuk Training and Research Hospital, Turkey	3 University Hospitals (1 Level I, 2 Level II Trauma Centers), Iran
Study Duration	1 year	Dec 2013 - Dec 2014	Feb-Dec 2022	Jan 30 - Jun 30, 2015	Duration not specified, but recruitment was 24/7 in emergency shifts
Sample Size	255 patients	152 patients	1,489	132 patients	157 patients
Population Characteristics	Adults with suspected chest trauma; excluding pregnant women and penetrating trauma	Adults with traumatic intrathoracic injuries; excluding pregnancy, hemodynamic instability, or refusal	Adults with chest wall trauma; excludes emergent tube thoracostomy patients	Adults with chest trauma	Adults with blunt chest trauma, including unconscious, apneic, or those with open chest injuries
Inclusion Criteria	Patients with suspected chest trauma	Patients with traumatic intrathoracic injuries	Patients with chest wall trauma, those undergoing CXR, LUS, and CT	Patients over 18 with thorax trauma	Adult patients with blunt chest trauma, including those with multiple trauma
Exclusion Criteria	Penetrating chest trauma, pregnant women	Pregnancy, hemodynamic instability, and lack of participation interest	No CXR or LUS on arrival, emergent thoracostomy before imaging	Emergency intervention, lack of US physician	Previous chest trauma, lung fibrosis, no CT scan planned

Diagnostic Modalities	POCUS for PTX and HTX, followed by chest radiography	POCUS, chest radiography, and CT scan	LUS assessment, followed by CXR and CT scan	POCUS, followed by CT scan	POCUS followed by chest X-ray and/or CT scan
Gold Standard	CT or chest radiography	CT scan	CT scan	CT scan	CT scan or emergent thoracostomy
Analysis	Sensitivity, specificity, and comparison between US and chest radiography	Receiver operating characteristic curve analysis, sensitivity, specificity, PPV, NPV for US vs chest radiography	Sensitivity, specificity, and accuracy for LUS, CXR vs CT	Sensitivity, specificity, and PPV/NPV for US vs CT	Sensitivity, specificity, PPV, NPV for US vs CT

Table 2: Main findings of the included studies

Study	Mean Age	Gender Distribution	Key Findings
Kelly et al., 2006	43.46 years (SD 16.3)	Predominantly male (226/255)	US is as effective as CXR in detecting PTX and HTX, with higher sensitivity. US helps in the rapid diagnosis and management of chest trauma but requires confirmation by CT.
Vafaei et al., 2016	31.4 years (SD 13.8)	77.6% male	US is preferable to radiography for initial evaluation in traumatic chest injuries. However, US has lower sensitivity than CT and relies on operator skill, requiring confirmation through other techniques.
Santorelli et al., 2024	42 years (median)	male (71.4%)	US has inferior sensitivity compared to CXR for traumatic PTX, recommending caution when using US alone as a screening tool. Combining CXR and US improves diagnostic sensitivity.
Temel et al., 2024	45.38 years (SD 19.12)	76.5% male	US is highly sensitive in detecting PTX, particularly when the size is over 1 cm. It offers high specificity and can be used at the bedside without radiation exposure. Sensitivity decreases for PTX <1 cm.
Jahanshir et al., 2020	38.3 years	85.4% male	POCUS is sensitive for blunt PTX and useful for detecting PTX in stable and unstable patients. It is moderately appropriate for HTX and lung contusion. Combining US with physical exams improves diagnostic accuracy.

4. DISCUSSION

The existing literature for prospective trials on the diagnostic accuracy of chest US for PTX and HTX in adult trauma patients was evaluated in this study. The majority of the included studies evaluated PTX. The research' varied features and outcomes, as well as their generally poor methodological quality, necessitated a careful interpretation of the data. With great specificity for both injuries and moderate sensitivity for HTX and good sensitivity for PTX, chest US demonstrated strong diagnostic accuracy.

Thorax US is a useful technique with a high degree of specificity for detecting PTX, according to research by Temel et al., (2024). Furthermore, as demonstrated by Thorax CT, their study's results show that US has a high degree of sensitivity in identifying PTXs wider than 1 cm. Following thoracic trauma, PTX, HTX, and hemoPTX are the most often encountered diseases; some studies have shown an incidence of more than 35% for PTX (Trupka et al., 1997). US has become a valuable method since it is radiation-free and can be quickly performed at the bedside in the early period, even though Thorax CT has been recognized as the gold standard in the identification of thoracic diseases (Ianniello et al., 2014; Kelly et al., 2006; Kaewlai et al., 2008). Clinicians may do bedside US with ease, however the precision of US in identifying PTX is primarily dependent on the skills of the operators (Ding et al., 2011; Mackenzie et al., 2019).

Although the US sensitivity in the Jahanshir et al., (2020) the trial was lower, but it was still in good agreement with other studies that suggested POCUS is a suitable modality for detecting PTX. In their retrospective evaluation of the diagnostic accuracy of US, Hyacinthe et al., (2012) found that while it was not better than CXR and chest exams, it could identify PTX and contusions (Kelly et al., 2006). Additionally, US is a sensitive screening tool to evaluate PTX, according to review research that assessed US sensitivity in patients with blunt trauma (Wilkerson et al., 2010). The sensitivity, specificity, PPV, and NPV of US as the initial diagnostic modality in patients with significant chest trauma were assessed by Ianniello et al., (2014) to be 77%, 99.8%, 98.5%, and 97%, respectively.

The sensitivity and specificity of US in identifying PTX were 85.7% and 95.3%, respectively, in the research by Aswin et al., (2023). This is in line with Vafaei et al., (2016) who discovered that US had an 83.6% sensitivity and a 97.9% specificity in identifying PTX. Ebrahimi et al., (2014) conducted a meta-analysis in 2014, which revealed that the pooled sensitivity and specificity were 87% and 99%, respectively. Salama et al., (2017) study found that the sensitivity and specificity for PTX were 81% and 100%, respectively. Aswin et al., (2023) studied 41 individuals with subcutaneous emphysema exhibited unclear US windows. This could have somewhat decreased our study's sensitivity and specificity.

A limitation of our study is that the included articles evaluate lung ultrasound (US) or point-of-care ultrasound (POCUS), which depend on the expertise and experience of the operator. This introduces a source of variation to the results, which may impact the extent to which the findings can be applied broadly, particularly in emergency and trauma situations where physician competence levels can vary. Some studies focus on diagnostic accuracy or comparison with a specific imaging modality, while others evaluate sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). This discrepancy makes it more challenging to synthesize and compare results from different investigations.

5. CONCLUSIONS

The US is sensitive to CXR in PTX and HTX detection. Although CT is necessary for confirmation, US aids in the quick diagnosis and treatment of chest injuries. The US is less sensitive than CT and depends on operator expertise, necessitating additional methods for confirmation. It is advised to use caution when utilizing the US alone as a screening tool since it has lower sensitivity than CXR for traumatic PTX. The sensitivity of diagnosis is increased when chest X-ray (CXR) and ultrasound (US) are combined.

List of abbreviations

PTX, Pneumothorax
HTX, Hemothorax
US, Ultrasound
CXR, Chest X ray
CT, Computed Tomography
POCUS, Point of care Ultrasound
LUS, Lung Ultrasound
PPV, Positive Predictive Value
NPV, Negative Predictive Value

PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses
SD - Standard Deviation

Informed consent
Not applicable.

Ethical approval
Not applicable.

Funding
This study has not received any external funding.

Conflict of interest
The authors declare that there is no conflict of interest.

Data and materials availability
All data sets collected during this study are available upon reasonable request from the corresponding author.

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