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Systematic Review

Systematic Reviews on Chest Ultrasonography and Chest Radiography for the Emergency Diagnosis of Traumatic Pneumothorax

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Abstract

Introduction: Early diagnosis of pneumothorax is essential in reducing complications and fatalities among trauma patients. Studies have shown that chest ultrasonography (CUS) is reliable for diagnosing this condition. This review study aims to evaluate the accuracy of CUS and chest radiography (CXR) in detecting pneumothorax in patients who have suffered trauma.

Methods: PubMed, Embase, Scopus, and ISI were searched between January 1, 2013, and January 1, 2024. Also, a manual search using Google Scholar and Google was conducted. Published systematic review articles in the English language were included. After removing any duplicate records, two researchers independently searched and screened the titles and abstracts of the remaining articles. The researchers assessed full-text papers, making sure they met the inclusion criteria. Any differences in opinion were resolved with the help of another investigator.

Results: Overall, 3215 records were discovered. After assessing their eligibility and eliminating duplicates, 145 records were chosen for a detailed textual study. Nine systematic review studies from this group were selected for the final assessment. Studies demonstrated that the sensitivity of CUS in diagnosing pneumothorax ranges from 74% to 91%, while the specificity ranges from 96% to 99%. The sensitivity of CXR in diagnosing pneumothorax ranges from 40% to 52%, while the specificity ranges from 99% to 99%.

Conclusion: According to the current study, ultrasonography is more precise than supine CXR in detecting pneumothorax. The results indicate that CUS has superior diagnostic accuracy compared to supine CXR for diagnosing pneumothorax, making it the preferred alternative.

Keywords: Chest ultrasonography, Chest Radiography, pneumothorax, Trauma.

Introduction

Thoracic trauma can lead to substantial illness and death and is directly responsible for 20% to 25% of trauma-related fatalities[1-3]. Damage to specific crucial intrathoracic organs might lead to instant death[4]. Traumatic pneumothorax is a frequent consequence of thoracic trauma, affecting 15% to 50% of patients with substantial thoracic damage[5]. It is essential to take preventive measures and seek medical attention immediately in cases experiencing thoracic trauma[6].

Timely detection of injuries is a critical factor in lowering the fatality rate and long-term impact on patients. Research indicates that early detection of such injuries can significantly reduce the fatality rate and subsequent impact[7-9]. A CT scan prioritizing the detection of chest traumas is the most reliable method for diagnosing thoracic traumas. Despite their excellent accuracy, CT scans expose patients to significant radiation levels[10]. It is essential to minimize radiation exposure by only utilizing this test when necessary, so it is advisable to utilize it only when necessary. CXR is the initial diagnostic test for patients with thoracic injuries; however, its accuracy is limited[11, 12]. Working

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closely with healthcare professionals and taking advantage of the most effective diagnostic tools available can ensure the best possible patient outcomes[13, 14].

Pneumothorax is the accumulation of air between the parietal and visceral pleurae, leading to the collapse of the lung parenchyma. Traumatic pneumothorax usually occurs when a broken rib injures the pleural lining or punctures the lung, causing air to leak out. Traumatic pneumothorax without rib fracture can be caused by a sudden increase in intrathoracic pressure due to chest compression in a person with a closed glottis, which results in alveolar rupture[15-17].

Pneumothorax causes an imbalance between ventilation and perfusion. Patients commonly describe experiencing dyspnea and chest pain. Timely identification of pneumothorax is crucial for deciding on the treatment and transfer of trauma patients[18]. Not identifying and addressing pneumothorax promptly can result in severe complications such as hypoxia, tension pneumothorax, cardiac failure, or death[19].

CUS can serve as a dependable and precise substitute for CXR. The diagnostic effectiveness of CUS significantly relies on the operator's skill. Recent structural changes in CUS have improved quality and spatial resolution, increasing accuracy in critical care and emergency management services[20]. Pneumothorax is a frequent thoracic injury that requires early identification in patients with multiple traumas. Multiple investigations have shown the high sensitivity and specificity of CUS[20].

CT is the standard method for detecting thoracic injuries, such as pneumothorax. Advancements in CT technology have significantly enhanced picture resolution and sensitivity in detecting pathology.

This study aimed to assess the diagnostic precision of CUS and CXR in detecting pneumothorax compared to CT scans, which are considered the gold standard in systematic review studies.

Methods

PubMed, SCOPUS, EMBASE, Cochrane, and ISI (Web of Science) were searched to find relevant articles with no time or language limitations. The initial search was comprehensive and included the following words: “sonography,” “ultrasound,” “radiography,” ultrasonography,” “chest film,” “chest radiograph,” and (“pneumothorax,” “aerothorax.” In addition, we searched Google Scholar and Google in the reference lists of all articles encountering the inclusion criteria and previous meta-analysis studies to find more studies.

Selection and data extraction

After removing any duplicate records, two researchers independently searched and screened the titles and abstracts of the remaining articles. The researchers assessed full-text papers, making sure they met the inclusion criteria. Any differences in opinion were resolved with the help of another investigator. Information from the included articles was then extracted into a pre-designed checklist form.

Two authors thoroughly reviewed all studies on the accuracy of diagnostic tests for pneumothorax in patients of all ages. In case of disagreements, a third author was consulted to reach a consensus. The criteria for inclusion were studies that compared the effectiveness of Chest Ultrasonography (CUS) and Chest X-ray (CXR) in detecting pneumothorax. These studies also compared the results of CUS and CXR with those of Computed Tomography (CT) scans. The diagnostic criteria for pneumothorax were clearly defined for each of the three diagnostic methods. Cross-sectional studies, review studies, and letters to the editor were not included.

Data synthesis

A narrative synthesis method was used to represent the results. This included recording the type of study, participants, location, study dates, study population, intervention types, and outcomes. The records were composed and managed using Endnote-8 software.

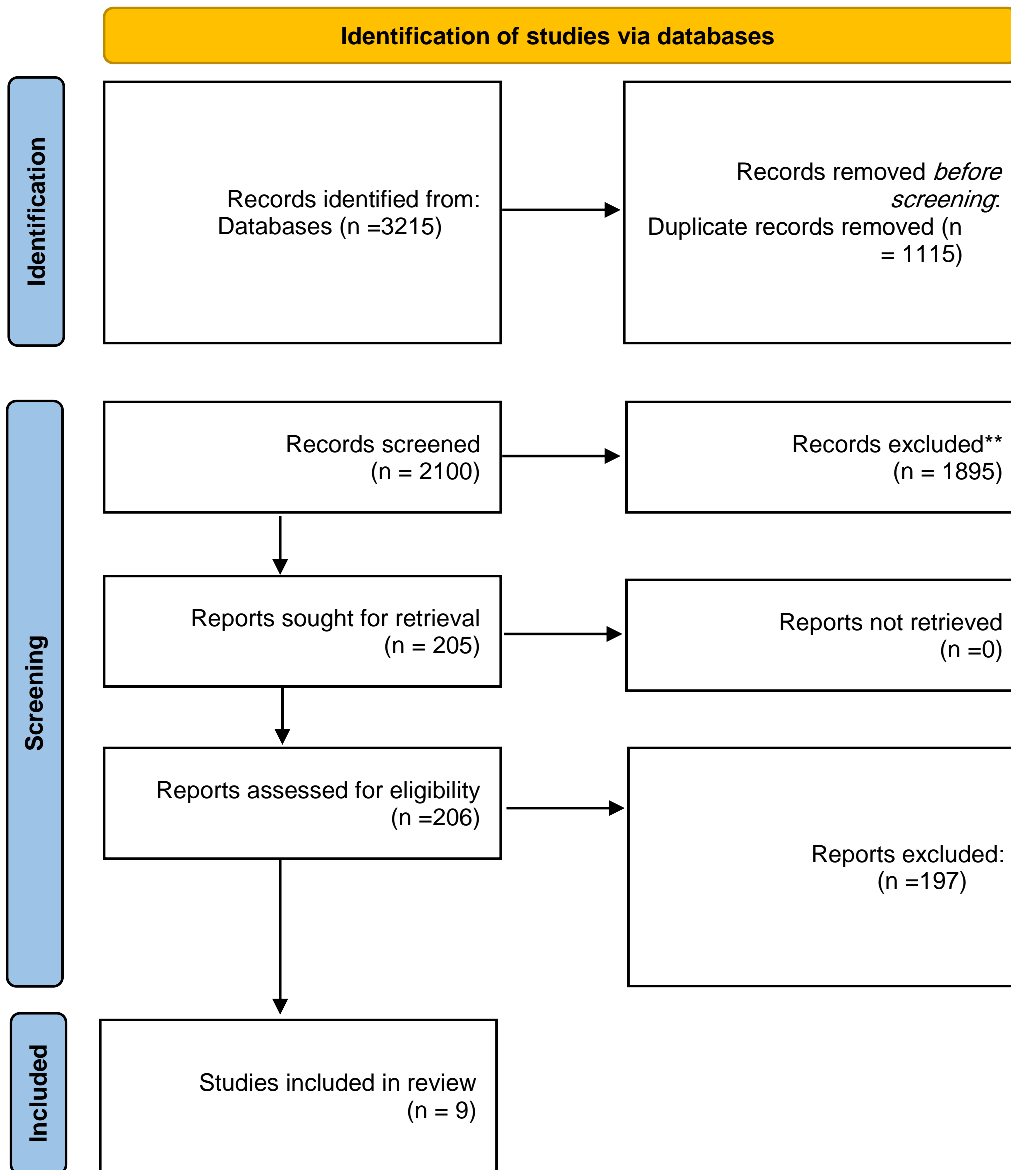

Figure 1: PRISMA flow diagram

Results

Overall, 3215 records were discovered. After assessing their eligibility and eliminating duplicates, 205 records were chosen for a detailed textual study. Nine systematic review studies were selected for the final assessment [20-28]. The reports investigated were primary sources, and their reference lists were reviewed to find further relevant studies. Table 1 summarizes the investigations analyzed in the included systematic review studies.

Studies demonstrated that the sensitivity of CUS in diagnosing pneumothorax ranges from 74% to 91%, while the specificity ranges from 96% to 99%. The sensitivity of CXR in diagnosing pneumothorax ranges from 40% to 52%, while the specificity ranges from 99% to 99% [20-28].

The diagnostic precision of CUS may fluctuate based on factors like patient demographics, pneumothorax

causes, operator expertise (radiologists, intensivists, respirologists, etc.), method quality, and the lack of effective meta-analytic techniques. It is crucial to analyze the etiology of pneumothorax. Typically, trauma patients are placed in a supine position for chest ultrasound (CUS) and chest X-rays (CXR). If a pneumothorax happens due to medical procedures such as a biopsy, central line installation, or post-surgery, CUS and CXR may be less accurate if the patient is not flat on their back.

Alrajab et al. did a meta-analysis of 13 investigations, which revealed that CUS had a combined sensitivity of 78.6% and a specificity of 98.4%. CXR showed a sensitivity of 39.8% and a specificity of 99.3% [26]. Their results were less than those of two earlier investigations by Ding et al. and Alrajhi and associates. In their investigation, Ding et al. incorporated 15 papers and found that CUS had a combined sensitivity of 88% and a specificity of 99% [28]. Alrajhi et al. analyzed eight investigations and reported a sensitivity of 90.9% and a specificity of 98.2% for CUS [27].

Ebrahimi et al.'s thorough study involving 28 participants demonstrated a sensitivity of 0.87 and a specificity of 0.99. The SROC curve's area of 0.99 strongly supports the study's success[25].

Chan et al. (2018) did a meta-analysis of 13 studies on traumatic pneumothorax. Nine studies, which contained 410 patients out of 1271, used patients as the unit of analysis and were included in the primary analysis. The findings indicated that CUS has a sensitivity of 0.91 and a specificity of 0.99. Supine CXR had a sensitivity of 0.47 and a specificity of 1.00[20].

Tian et al. (2018) incorporated 12 studies regarding traumatic pneumothorax. The comprehensive sensitivity of CUS for diagnosing pneumothorax was 89%, with a specificity of 96% [21].

According to Stengel et al. (2018), point-of-care sonography may effectively identify organ damage, free fluid, vascular lesions, and pneumothorax in blunt trauma patients. The method has a sensitivity of 0.74 and a specificity of 0.96 based on 34 trials [23].

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Table 1: studies' characteristics.

Authors name (year)	Participants	Aims	Results	Sensitivity	Specificity
Tian et al. (2023)[21]	12 articles	Examination of the precision of CUS for the early diagnosis of pneumothorax in trauma injuries cases. Summarization metrics were estimated utilizing data from prospective diagnostic precision trials using CUS for various injuries.	CUS is a reliable technique for analyzing pneumothorax in traumatized cases.	89%	96%
Chan et al. (2020)[20]	13 studies (410 traumatic pneumothora x patients out of 1271 patients)	Assessment of the diagnostic accuracy of CUS by frontline non-radiologist physicians vs. CXR for diagnosing pneumothorax in trauma injury cases in the emergency department.	The diagnostic precision of CUS performed by frontline non-radiologist physicians for diagnosing pneumothorax in emergency department trauma injury cases is more precise to supine CXR, independent of the type of injury, CUS operator, or CUS probe employed. These results recommend that CUS for detecting pneumothorax should be integrated into trauma protocols and algorithms in prospective medical exercise schedules and that CUS may beneficially modify the standard administration of trauma.	0.91 vs. 0.4 3	0.99 vs. 1
Staub et al. (2018)[22]	17 studies	To evaluate the accuracy of the CUS for the emergency detection of pneumothorax in traumatic patients.	CUS is a reliable instrument for the diagnostic examination of pneumothorax in trauma patients.	0.81	0.98

Stengel et al. (2018)[23]	34 articles	To determine the detection accuracy of Point-of-care sonography for diagnosing and excluding free fluid, organ injuries, vascular lesions, and pneumothorax compared to a diagnostic reference standard in patients with blunt trauma.	In blunt thoracoabdominal cases, positive Point-of-care sonography findings guide therapy findings. Nevertheless, about abdominal trauma, a negative POCS exam does not rule out injuries and must be confirmed by a reference test such as CT. This is of particular significance in pediatric trauma, where the sensitivity of Point-of-care sonography is poor. Based on a few studies in a mixed population, Point-of-care sonography may have a higher sensitivity in chest damage. This guarantees larger, confirming trials to verify the precision of Point-of-care sonography for detecting thoracic trauma.	0.74	0.96
Ablordeppey et al. (2017)[24]		Comparison of bedside ultrasound and chest radiography to confirm central venous catheter position and detecting pneumothorax.	Bedside ultrasound can recognize pneumothorax faster than radiography after central venous catheter insertion. When there is a malposition of the catheter, bedside ultrasound can detect four out of every five cases earlier than chest radiography.	0.82	0.98
Ebrahimi et al. (2014)[25]		Assess the diagnostic accuracy of CUS and CXR for the detection of pneumothorax.	CUS has a higher diagnostic accuracy for detecting pneumothorax compared to supine CXR. CUS remains superior to CXR in detecting pneumothorax even after adjusting for possible sources of heterogeneity.	0.87 vs. 0.46	0.99 vs. 1
Alrajab et al. (2013)[26]	13 articles	Evaluation of CUS and CXR for the detection of pneumothorax in trauma cases.	CUS is more accurate than CXR for diagnosing pneumothorax. The study provides accurate estimates for bedside CUS and CXR performance parameters for pneumothorax evaluation.	0.78 vs. 0.40	0.98 vs. 0.99
Alrajhi et al. (2012)[27]	Eight articles	Assessment of CUS and supine CXR for pneumothorax diagnosis in trauma patients, utilizing CT scan or chest tube placement as gold standard method.	The study found that CUS is an efficient and effective method for detecting pneumothorax, which is more reliable than supine CXR. Since CUS is a simple and easily accessible test, the study supports its routine use for pneumothorax detection.	0.90 vs. 0.50	0.98 vs. 0.99
Ding et al. (2011)[28]	20 articles	Evaluation of the usage of anterior-posterior CXR with transthoracic ultrasonography to detect pneumothorax.	Clinicians' bedside CUS showed higher sensitivity and similar specificity to CXR in diagnosing pneumothorax. However, CUS's accuracy in diagnosing pneumothorax relied on the operators' skill.	0.88 vs. 0.52	0.99 vs. 1

Discussion

This study conducted a comprehensive review of the existing systematic reviews literature to analyze prospective studies on the diagnostic precision of chest ultrasonography for pneumothorax in trauma patients. There were nine studies included. A recent meta-analysis found that a chest ultrasound is more precise than a supine chest X-ray for detecting pneumothorax[20, 25]. CUS fared better than CXR in detecting pneumothorax, even after accounting for potential causes of variance. The lowest sensitivity in the CUS subgroup was 0.81[22]. CUS had a notably higher accuracy in diagnosing pneumothorax than CXR, particularly in non-trauma scenarios and when conducted by emergency physicians. This could be attributed to the emergency physician's knowledge of the patient's clinical condition, injury location, and injury mechanism. Numerous studies have reported the diagnostic accuracy of CUS in many medical contexts, including the acute care unit, operating room, and bronchoscopy suite. The studies include various healthcare specialists like intensivists, anesthesiologists, radiologists, and different forms of pneumothorax, such as iatrogenic or spontaneous pneumothorax. These investigations involve a wide range of patient groups and pathologies, leading to distinct variations in diagnostic test characteristics. Trauma patients, not radiologists, are often evaluated by frontline physicians in the emergency room[21, 23, 28].

The two most recent meta-analyses concurred with the current meta-analysis25, 27. Nevertheless, each of the three meta-analyses had some constraints. The initial constraint was the limited quantity of papers incorporated into their studies. The second limitation was the necessity of a publication bias evaluation. The third limitation was restricting articles written in English, potentially resulting in publication bias.

The study's findings may not apply to people in different settings with pneumothorax induced by diverse reasons. The study analyzed reports from various continents, focusing on identifying cases of traumatic pneumothorax in the emergency department. The average incidence of traumatic pneumothorax was 30%, ranging from 21% to 52%[20].

The size of a pneumothorax is dictated by the volume of air present in the pleural cavity. A pneumothorax is classified as mild if under 15%, moderate if it falls between 15% and 60%, and substantial if it exceeds 60%. Pneumothoraces may not always be seen on an initial chest X-ray but can be identified with computed tomography (CT). Trapped air in the pleural cavity generates tension in the pneumothorax, displacing mediastinal structures and reducing blood flow to the heart[20].

This review validates the results of previous meta-analyses, emphasizing the precision and dependability of the study. The results prove the study's reliability and potential for future research and therapeutic applications. Some studies analyzed for pneumothorax were not trauma-related and were not prospective. A study by Ebrahimi et al. (2014) indicated that chest ultrasonography is more effective in diagnosing nontraumatic pneumothorax than traumatic instances[25]. Alrajhi et al. reported a sensitivity of 0.90 and a specificity of 0.98 in their examination of traumatic pneumothorax. It is essential to highlight that their review only incorporated six trials[27].

We conducted a comprehensive search across many databases to identify many pertinent studies. Our decision not to restrict our search to a particular language was beneficial. Our search method yielded nine pertinent publications for our meta-analysis. No publication bias was seen in our findings. Nevertheless, our meta-analysis was subject to several limitations despite our diligent efforts. All the research we included was observational; hence, we could not establish social ties. We could not dismiss the likelihood of residual confounders causing biases, a common occurrence in meta-analyses of observational research. One residual confounder was the operator-dependent aspect of the CUS accuracy, and the quality of operator training was another potentially confusing factor. Predicting the direction of this bias is challenging. We used a bivariate mixed random effects model to account for the heterogeneity among the studies and get more cautious outcomes.

Thoracic ultrasonography is a diagnostic technique used to evaluate trauma patients, focusing on detecting the presence of air accumulated in the pneumothorax. The CUS is conducted longitudinally, assessing both sides of the chest in the same patient. However, some studies may concentrate on the lung fields, as a patient's history of trauma, surgery, lung conditions, or pneumothorax can modify the characteristics of the lung fields. For

initial trauma assessment, a chest X-ray is recommended, but it is unreliable in detecting pneumothorax. The X-ray exposes the patient to low radiation dosage, and it must be precisely positioned and timed to coincide with the patient's inhalation. Emergencies related to pneumothorax require prompt diagnosis and treatment to prevent complications and improve outcomes. Recent research suggests that CUS is a superior method for detecting this condition in trauma patients compared to CXR. This means that using CUS could lead to faster treatment with tube thoracostomy, reducing the chances of misdiagnosis and improving patient outcomes. The incidence of misdiagnosis with CUS is relatively low, which means that only a small number of patients may not receive timely treatment. Moreover, the chances of wrongly diagnosing traumatic pneumothorax with CUS are also low, which implies that in some cases, an unnecessary tube thoracostomy may occur. However, the benefits of using CUS to detect pneumothorax outweigh the risks. On the other hand, a chest X-ray has a high chance of missing a traumatic pneumothorax, which means that many patients might not automatically get a tube thoracostomy. The likelihood of incorrectly identifying a traumatic pneumothorax using a chest X-ray is minimal[20-25].

Conclusion

According to this study, ultrasonography is more precise than supine CXR in detecting pneumothorax. The results indicate that CUS has superior diagnostic accuracy compared to supine CXR for diagnosing pneumothorax, making it the preferred alternative.

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Conflict of Interest Disclosures

We declare this is no conflict of interest.

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Authors' Contributions

Concepts, data gathering, writing, and editing: Hussein Soleimantabar, Mersad Mehrnahad, Shabnam Torabi.

Ethical Statement

None.

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