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Role of emergency chest ultrasound in traumatic pneumothorax. An updated meta-analysis.

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Abstract

Aim: To assess chest ultrasound (US) diagnostic accuracy in pneumothorax diagnosing. **Material and methods**: Prospective studies related to the US pneumothorax diagnostic accuracy in trauma patients were extensively searched from 2000 up to November 2020. The studies features and findings were gathered using a standardised form and the methodological quality of the investigations was evaluated using the Quality Assessment of Diagnostic Accuracy Studies (QUADAS-2). **Results:** Twelve articles were finally chosen for quantitative analysis. The overall sensitivity of US scan in pneumothorax diagnosis was 89% (95%CI 86-91%). Specificity was 96% (95%CI 95-97%). The diagnostic odds ratio was 193.94 (59.009-637.40) at 95%CI, thus demonstrating high chest US accuracy in pneumothorax diagnosis. **Conclusion:** Despite the limitations of the included studies, this systematic review and meta-analysis concluded that chest US is a reliable method for diagnosing pneumothorax in traumatized patients.

Keywords: Chest ultrasound; diagnostic accuracy; sensitivity; specificity; pneumothorax

Introduction

Traumatic injuries can result in severe health consequences such as premature death. Chest injuries make up to 25% of all trauma-induced causalities [1,2] of which pneumothorax makes up 85% of chest trauma-related cases. Pneumothorax results in increased morbidity and mortality causing extended hospital stays with increased health service expenditures and decreased productivity [3].

Early diagnosis of pneumothorax and chest drainage has lifesaving consequences. The first diagnostic technique involves chest X-ray if clinical examination does not point towards thoracostomy. However, some disadvantages of this method include lesser sensitivity, radiation exposure and patient mobilisation [4-6].

Chest ultrasonography (US) has lately gained favour for pneumothorax diagnosis since it is fast, easy to replicate, does not involve radiation, and allows for real-time scanning and interpretation [4,5]. Pneumothorax is evaluated in the parts of the chest closest to the front and the pleural line may be clearly visible on an US scan. Chest US has gained popularity owing to its portability, speed, replicability and real-time scanning without the use of radiation. It has been successfully used in diagnosing pneumothorax under emergency situations with high sensitivity and specificity [7,8].

The purpose of this systematic review and meta-analysis is to assess the accuracy of chest US for the early diagnosis of pneumothorax in adult trauma patients. Summary metrics were calculated using data from prospective diagnostic accuracy trials utilizing chest US for diverse injuries.

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Material and methods

In this investigation, we followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) normative recommendations [9].

Two separate authors picked and reviewed the research, as well as extracted data and evaluated methodological quality. Disputes were resolved via argument until a consensus was achieved. When an agreement could not be achieved, the problems were handled by a third author.

Data sources and search strategy

Eligible studies were searched in MEDLINE, Embase, Ovid, Scopus, Web of Science, and Journals on web databases, through EBSCO. The search was conducted using MeSH phrases, and open phrases were entered into unique search strategies. The key MeSH terms employed for the search were: 1) pneumothorax; 2) chest ultrasound; 3) specificity; 4) sensitivity; 5) diagnostic accuracy; 6) ultrasonography; and 7) chest trauma. The search limit for literature ranged from the year 2000 up until 2020 as the concluding year and published only in the English language with full text was chosen for inclusion in the study.

Selection of studies

Studies were included if they matched the following criteria: prospective studies, trauma patients attending emergency departments, index test – ultrasonography, target injuries - pneumothorax. The results were the number of true and false positives, as well as the number of true and false negatives.

Extraction of data

The following data were retrieved from the entire text of the included publications using a standardized form: study ID, sample size, location, criteria of the condition, ultrasound type, machine-make, and personnel involved. All the titles and abstracts were screened independently by the reviewers. Following detailed analysis, data was abstracted into a data extraction table.

Endnote X8 soft ware was used to import the search results and remove duplicates. Abstracts were screened for eligibility criteria, and the full text was extracted when an article was selected.

Risk of bias in individual studies

QUADAS-2 criteria evaluated risk of bias of included studies which is a tool for assessing study quality for meta-analysis of diagnostic accuracy [10]. It includes patient selection - random sequencing, index test - detection of the condition, reference evaluation – comparison with flow and timing of the study. Any disagreements in quality review by the authors were resolved by consultation with an expert in the field.

Statistical analysis

The DerSimonian Lair approach was used to determine pooled sensitivity, specificity, and diagnostic odds ratios based on a 2x2 table. The computed diagnostic odds ratio (DOR) demonstrates the effectiveness of the chest ultrasound capacity test to identify pneumothorax. A greater DOR value suggests that the test has a higher diagnostic accuracy. The Cochran Q statistic and the I2 index were also employed to assess the heterogeneity of the included studies. Forest plots were created using Meta disc software, and summary ROC (SROC) curves (the Moses-Littenberg technique) were visually evaluated for potential sources of variability.

Results

Literature search

A total of 593 research articles were retrieved using electronic scanning. By reviewing titles and abstracts, 386 articles were eliminated. Due to duplication, 106 studies were removed from the total of 207. There were 39 full-text articles for final screening, with 27 being eliminated due to inclusion requirements (main reasons for the exclusion being the inappropriate comparison criteria and insufficient evidence to produce 2x2 tables for evaluation). Finally, 12 articles [11-22] were included in our analysis (fig 1).

Characteristics of the studies included

All of the investigations were carried out in a single EDs at a single location. Table I summarises the characteristics of the included studies.

Bias risk

Individual reports reported sensitivity ranged from 86% to 91%, while specificity ranged from 95% to 97%.

Fig 1. Flow chart diagram for article inclusion

Table I. Characteristics of studies involved

Study ID, Country	Number of patients, age	Referred for	Ultrasound type-B mode	Ultrasound machine	Ultrasono-grapher
Corsini 2018 [11], Italy.	124, 33±5 weeks	Neonates with respiratory distress	NA	Philips CX50, 10-12 MHz linear transducer	Neonatologist
Cattarosi 2016 [12], Italy	49, 36±5 weeks	Neonates with respiratory distress	NA	Prosound α7Ultrasound, 13 MHz linear transducer	Neonatologist
Mumtaz 2016 [13], Pakistan	46, 25±9 years	Trauma patients	E - FAST	Philips CX50. 5 MHz linear transducer	Surgical residents
Raimondi 2016 [14], Italy	42, 31±3.5 weeks	Neonates	NA	Prosound α7Ultrasound, 10 MHz linear transducer	Radiologist
Balesa 2015 [15], India	126, 2 months to 88 years age	Hemodynamically stable patients	Chest US	NA	Radiologist
Ziapour 2015 [16], Iran	45, NA	Patients with moderate to severe trauma	FAST	NA, 9.0 MHz or 3.5 Convex MHz transducer	Emergency physicians
Abbasi 2013 [17], Iran	146, 37±11 years	Stable patients inflicted with chest trauma	FAST	NA, 7.5 MHz linear transducer	Emergency physicians
Jalli 2013 [18], Iran	197, NA	Patients with respiratory problems	NA	NA, 7.5 MHz linear array probe	Radiologist
Hyacinthe 2012 [19], France	119, 22±51 years	Chest trauma patients suggested for CT	NA	NA, 2.5 MHz convex transducer	Emergency physicians
Zhang 2006 [20], China	135, 45±15 years	Multiple trauma	FAST	SSD-900, 3.5 MHz convex and 7.5 MHz linear transduce	Emergency department clinicians
Rowan 2002 [21], Canada	27, 42 years (17 to 83)	Blunt chest trauma	FAST	NA, 7.0 MHz linear transducer	Radiologist
Soldati 2006 [22], Italy	185, 51+23 years	Blunt chest trauma	NA	NA, 5.0 MHz transducer convex	Emergency physicians

CT, Computed Tomography; FAST, Focussed assessment with sonography in trauma; E-FAST Extended FAST; NA, not available

As a result, all of the included trials had a minimal risk of bias, according to the QUADAS-2 tool (Table II).

Meta-analysis results

The overall sensitivity of US in diagnosing a pneumothorax was 89% (95% CI 86-91%) and the specificity 96% (95% CI 95-97%). The diagnostic odds ratio was 193.94 (95% CI 59.009-637.40), indicating that chest US is accurate in detecting pneumothorax. The SROC plot displayed an assessment of sensitivity vs. specificity as well as the area under the SROC curve (fig 2-4).

Discussion

In this metanalysis we found that chest US had good diagnostic accuracy in pneumothorax diagnosis, with 89% sensitivity and 96% specificity

Chest US for pneumothorax diagnosis was reported first in 1986 in a veterinary journal [23]. Several researchers have explored its usage since then. The principal method for diagnosing pneumothorax on chest US employed an absent sliding lung sign in the air presence between visceral and parietal pleura [24]. The presence of sliding lung signs acts as an accurate negative predictor for pneumothorax detection. Dulchavsky et al [24] found 100% true negative rate compared to conventional chest radiographs in pneumothorax diagnosis, with sensitivity ranging from 90% to 100%.

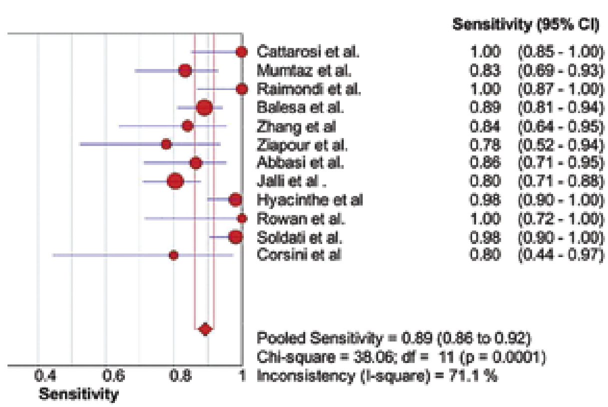

Fig 2. Sensitivity of chest ultrasound in diagnosis of pneumothorax patients.

Table II. Risk of bias assessment for studies included

Study ID	Random sequence generation (selection bias	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias	Other bias
Rowan [21]	-	-	-	-	?	-	-
Soldati [22]	-	-	-	-	?	?	-
Hyacinthe [19]	-	-	-	+	-	-	-
Abbas [17]	+	-	-	+	-	-	-
Jalli [18]	-	-	-	-	?	?	-
Balesa [15]	+	-	-	-	-	-	?
Ziapour [16]	-	-	-	-	-	-	?
Corsini [11]	-	-	-	-	?	?	-
Mumtaz [13]	+	-	-	-	-	-	?
Raimondi [14]	-	-	-	-	-	-	?
Cattarosi [12]	?	-	-	-	-	?	-
Zhang [20]	+	-	-	-	-	?	-

Low risk = -; High risk = +; Uncertain risk = ?

For identifying the pneumothorax the majority of studies utilized the focused assessment with sonography for trauma (FAST) method. Standard FAST protocols assess four locations (pericardial, perihepatic, perisplenic and pelvis) and it is feasible and simple-to widen the scanned regions to assess the chest for haemothorax formally in an accurate and rapid manner [25,26].

Pneumothorax diagnosis can be made based on physical examination and symptom presentation. Confirmation is generally via radiography or CT scanning. Radiographs taken in the later stages pose difficulty in diagnosing pneumothorax because of the patient's condition, distance and other considerations. Also, chest radiograph reliability is questionable and a wrong diagnosis may be expected in 30% of cases [21]. The met analytic study of Ebrahimi et al [26] showed US accuracy in the detection of pneumothorax, with a sensitivity of 0.87 (95%CI 0.81–0.92; I2=88.89; p<0.001) and specificity of 0.99 (95%CI 0.98–0.99; I2=86.46, p<0.001). Our findings are comparable, with a sensitivity of 0.89 and a specificity of 0.96. In contrast to our findings, Alrajab et al [4] found that chest US had a pooled sensitivity of 78.6% (95%CI 68.1-98.1%) and a pooled specificity of 98.4% (95% CI 97.3-99.5%). Chest radiography's pooled sensitivity and specificity were determined to be 39.8% (95% CI 29.4-50.3%) and 99.3% (95% CI 98.4-100%), respectively. Subgroup analysis showed that the sampling method, setting (trauma vs. non-trauma), operator type and probe were significant sources of heterogeneity.

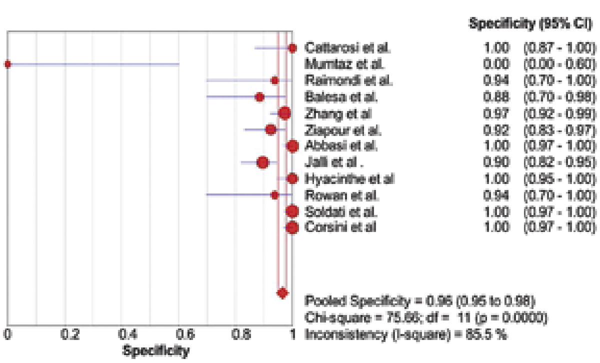

Fig 3. Specificity of chest ultrasound in diagnosis of pneumothorax patients.

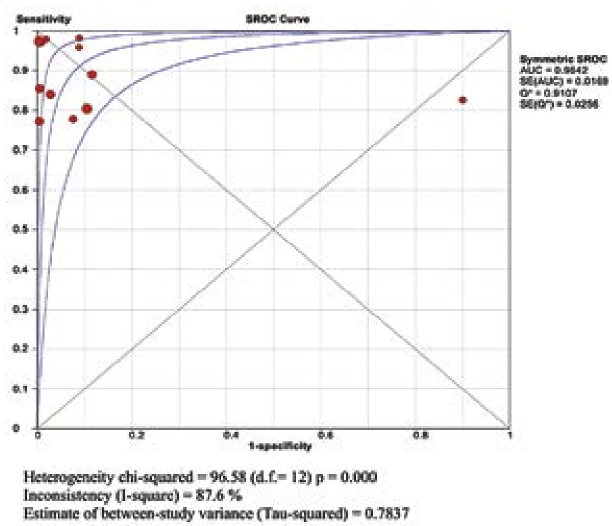

Fig 4. In the primary analysis by pneumothorax, the summary-ROC curve showed the diagnostic accuracy of chest ultrasonography for traumatic pneumothorax. Individual studies are shown by red dots. The AUC=0.9642, indicate high ultrasonography accuracy in diagnosing pneumothorax, with Q*=09107 indicating that its sensitivity matches specificity.

Our results agree with that of Dahmarde et al [27] which supports the high diagnostic accuracy of chest US. The sensitivity, specificity, and odds ratio of chest US in the diagnosis of pneumothorax in neonates was 96.7% (88.3%–99.6%), 100% (97.7%–100%), and 1343.1% (167.20–10788.9), respectively, depicting superior results.

Chest US has the potential to become the first diagnostic tool in the evaluation of trauma patients with pneumothorax. Despite the fact that chest US is an operator-dependent technique, it has a relatively short learning curve for pneumothorax and pleural effusions [5] US, on the other hand, is limited in very obese people and those with subcutaneous emphysema, extensive dressings, or skin disorders.

This study emphasized the relevance of chest US in the immediate identification of traumatic pneumothorax. This point-of-care imaging method, when combined with clinical examination, can improve the sensitivity of the first diagnosis for these injuries. The research has certain limitations, such as the test's differential effects based on patient characteristics and operator skill. Furthermore, the original research authors were not contacted, and studies with a mixed population of patients with traumatic and non-traumatic pneumothoraxes and pleural effusions were eliminated.

In conclusion, our study showed that chest US has a good diagnostic accuracy for pneumothorax and is a valuable tool for use in emergency situations.

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Conflict of interest: none

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