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TANAFFOS

Diagnostic Accuracy of Chest Ultrasonography versus Chest Radiography for Identification of Pneumothorax: A Systematic Review and Meta-Analysis

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Background: Early detection of pneumothorax is critically important. Several studies have shown that chest ultrasonography (CUS) is a highly sensitive and specific tool. The present systematic review and meta-analysis was designed to evaluate the diagnostic accuracy of CUS and chest radiography (CXR) for detection of pneumothorax.

Materials and Methods: The literature search was conducted using PubMed, EMBASE, Cochrane, CINAHL, SUMSearch, Trip databases, and review article references. Eligible articles were defined as diagnostic studies on patients suspected for pneumothorax who underwent chest computed tomography (CT) scan and those assessing the screening role of CUS and CXR.

Results: The analysis showed the pooled sensitivity and specificity of CUS were 0.87 (95% CI: 0.81-0.92; I2= 88.89, P<0.001) and 0.99 (95% CI: 0.98-0.99; I2= 86.46, P<0.001), respectively. The pooled sensitivity and specificity of CXR were 0.46 (95% CI: 0.36-0.56; I2= 85.34, P<0.001) and 1.0 (95% CI: 0.99-1.0; I2= 79.67, P<0.001), respectively. The Meta regression showed that the sensitivity (0.88; 95% CI: 0.82 - 0.94) and specificity (0.99; 95% CI: 0.98 - 1.00) of ultrasound performed by the emergency physician was higher than by non-emergency physician. Non-trauma setting was associated with higher pooled sensitivity (0.90; 95% CI: 0.83 – 0.98) and lower specificity (0.97; 95% CI: 0.95 – 0.99).

Conclusion: The present meta-analysis showed that the diagnostic accuracy of CUS was higher than supine CXR for detection of pneumothorax. It seems that CUS is superior to CXR in detection of pneumothorax, even after adjusting for possible sources of heterogeneity.

Key words: Pneumothorax; Ultrasonography; Radiography; Diagnostic tests, Routine

INTRODUCTION

Thoracic cavity injuries include 25% of mortalities in traumatic events and are associated with a 40% mortality rate, generally (1, 2). Studies have shown that early diagnosis of such traumas can decrease the mortality rate and the resultant burden, significantly. CT scan with a high priority for detection of chest traumas is the gold standard for diagnosis of thoracic traumas (3-5). Although this diagnostic test has high accuracy, patients undergoing CT scan receive a high radiation dose; thus, it is recommended to use this test only when it is indicated (6-8). In addition, CXR is used as the early diagnostic test in patients with thoracic injuries, yet the accuracy of it is not very high (9-14).

CUS can be a reliable and accurate alternative to CXR. However, diagnostic yield of CUS largely depends on the operator's expertise (15-17). However, structural changes of CUS in recent years have led to higher quality and spatial resolution, resulting in greater accuracy in the critical care and emergency management services (18-23).

One of the most common thoracic injuries is pneumothorax and its early detection in multiple trauma patients is critically important. Several studies have demonstrated the high sensitivity and specificity of CUS (24-28). In this regard, three meta-analyses during the past 5 years showed that the sensitivity and specificity of CUS in diagnosis of pneumothorax varied between 78.6-90.9% and 98.2-99%, respectively (29-31). But, these studies have some limitations such as the small number of included articles, lack of evaluating the inter-study threshold variation, lack of publication bias assessment, and evaluation of only English-language articles. Thus, it seems that another meta-analysis is needed to overcome these limitations. The present systematic review and meta-analysis was designed to evaluate the diagnostic accuracy of CUS and CXR for detection of pneumothorax in comparison with CT scan as the gold standard.

MATERIALS AND METHODS

Search strategy

The study was conducted according to the Meta-analysis Of Observational Studies in Epidemiology (MOOSE) statement providing a detailed guideline of preferred reporting style for systematic reviews and meta-analyses (32). Relevant articles were identified through a literature search of online databases (PubMed, SCOPUS, EMBASE, Cochrane, CINAHL, and Trip databases) with no time or language limitation. The initial search was broad and included the following words: ("ultrasound" or "sonography" or "ultrasonography" or "radiography" or "chest film" or "chest radiograph") and ("pneumothorax" or "aerothorax") and ("sensitivity" and "specificity" or "diagnostic accuracy" or "diagnostic yield"). In addition, we ran a hand search in the reference lists of all articles meeting the inclusion criteria and previous meta-analysis studies to find more studies. In addition, it was attempted to contact the authors of all studies that met the inclusion criteria and request unpublished data and abstracts.

Study Selection and Definitions

Two authors (M.Y, H.A) independently reviewed all potentially relevant studies. Disagreements were solved by discussion and using the viewpoint of a third author (A.M.J). We included all diagnostic accuracy studies regarding patients with pneumothorax from all age groups. These studies had to be prospective, blinded, and original comparing the diagnostic value of CUS and CXR for detection of pneumothorax. Studies also compared the two tests with one gold standard (CT scan) and described the diagnostic criteria for pneumothorax in each test, clearly. Those including patients with known pneumothorax and poor quality studies based on the 14-item Quality Assessment of Diagnostic Accuracy Studies (QUADAS2) tool (33) were excluded. Only pneumothorax cases with CT scan verification were included.

Data extraction and management

Two authors (M.Y, H.A) extracted data independently from studies, using a standardized data abstraction form. They collected data related to study design, patient characteristics, CUS diagnosis criteria and operator, CUS transducer, blinding status, and sampling method. The authors were contacted for clarification of study sample, regarding missing or insufficient data, if necessary. In cases of duplicate reporting, data were used from the study on the largest number of patients or individual patient data from each study, if available.

Quality assessment

We assessed the quality of the included studies using the QUADAS2. Two reviewers (MY, HA) independently reviewed each study and rated their quality as "good," "fair," or "poor". Quality assessment was conducted based on criteria of diagnostic studies, accounting for study design and presence of bias including selection, performance, recording, and reporting bias. The studies with high risk of bias were defined as poor quality, presence of moderate risk (did not affect the results) was considered as fair quality, and those with minimal risk as good quality. In this regard, inter-rater reliability was acceptably high (95%). Disagreements were discussed by a third reviewer (A.M.J) and settled with consensus decision.

Data synthesis and statistical analysis

Statistical analysis was performed using STATA software version 12.0 (StataCorp, College Station, TX, USA). After selecting the relevant studies, data were presented as true positive (TP), true negative (TN), false positive (FP), and false negative (FN) values. In cases reported as hemi-thorax by the findings of the study, the authors were contacted to find the total sample size (number of patients). If they did not respond, estimation methods were used to calculate the TP, TN, FP, and FN values using a web based calculator. If the information had been reported in graphs, data extracted from them as recommended by Sistrom et al. (34).

In analyses, the mixed-effects binary regression model was used, a type of random effect model used when the heterogeneity source is not clear. Statistical heterogeneity was measured using the I^2 and χ^2 tests ($P < 0.10$ was representative of significant statistical heterogeneity) (35). Sensitivity and subgroup analyses were performed to check the expected or measured heterogeneity. The sensitivity analysis was done using studies with good and fair quality levels and applied based on a bivariate meta-regression model. All possible causes of heterogeneity including the operator, ultrasound probe, CUS frequency, study subjects (trauma/non-trauma), CUS signs, and type of sampling (consecutive versus convenience sampling) were included as covariates in the meta-regression model. Publication bias was assessed by funnel plot and associated regression test of asymmetry, introduced by Deeks et al. (36).

To determine whether the patient had pneumothorax, CT scan results were assessed. Patients were divided into two groups: CT positive (CT+: patients with pneumothorax) and CT negative (CT-: patients without any signs of pneumothorax). Finally, the pooled sensitivity and specificity were calculated with 95% confidence intervals (CIs). Diagnostic odds ratio (DOR) and receiver operative curves (ROCs) were also obtained.

RESULTS

A total of 4,209 non-duplicate citations were identified by using search strategies from which 284 potentially relevant papers were screened. Finally, 65 studies were eligible and 28 full-text articles included in meta-analysis and studied in detail (10, 37-63) (Table 1, Figure 1). These articles totally contained 5,314 patients, 1159 cases with CT scan positive and 4,155 cases with CT scan negative findings. The diagnostic accuracy of CUS and CXR was reported in 28 and 22 studies (10, 37, 39-43, 46-49, 51-59, 62, 63), respectively.

A bivariate mixed-effects binary regression model was used for performing analyses, because a significant statistical heterogeneity was found in diagnosis of pneumothorax. No publication bias was observed among included studies (P=0.84 for CUS, P=0.68 for CXR) (Figure 2).

The analysis showed the pooled sensitivity and specificity of thoracic CUS were 0.87 (95% CI: 0.81-0.92; I^2= 88.89, P<0.001) and 0.99 (95% CI: 0.98-0.99; I^2= 86.46, P<0.001), respectively. The pooled sensitivity and specificity of CXR were 0.46 (95% CI: 0.36-0.56; I^2= 85.34, P<0.001) and 1.0 (95% CI: 0.99-1.0; I^2= 79.67, P<0.001), respectively (Figures 3 and 4).

The pooled DOR for CUS was 465.52 (95% CI, 216.37 to 1001.56; I^2= 100.0, P<0.001), whereas for CXR it was 179.75 (95% CI, 52.24 to 564.45; I^2= 100.0, P<0.001) (Figure 5). The summary receiver operating characteristic (SROC) curves for CUS and CXR are presented in Figure 5. The AUC for CUS and CXR was 0.99 (95% CI: 0.98-1.0) and 0.91 (95% CI: 0.88-0.93), respectively (Figure 6).

The subgroup analysis showed that ultrasound being performed by an emergency/non-emergency physician and the trauma/non trauma settings were the main possible sources of heterogeneity. The meta regression showed that the sensitivity (0.88; 95% CI: 0.82 - 0.94) and specificity (0.99; 95% CI: 0.98 - 1.0) of ultrasound were higher when it was performed by an emergency physician. In addition, non-trauma setting was associated with higher pooled sensitivity (0.90; 95% CI: 0.83 – 0.98) and lower specificity (0.97; 95% CI: 0.95 – 0.99). The possible source of heterogeneity in CXR findings was not specified in the analysis (Table 2).

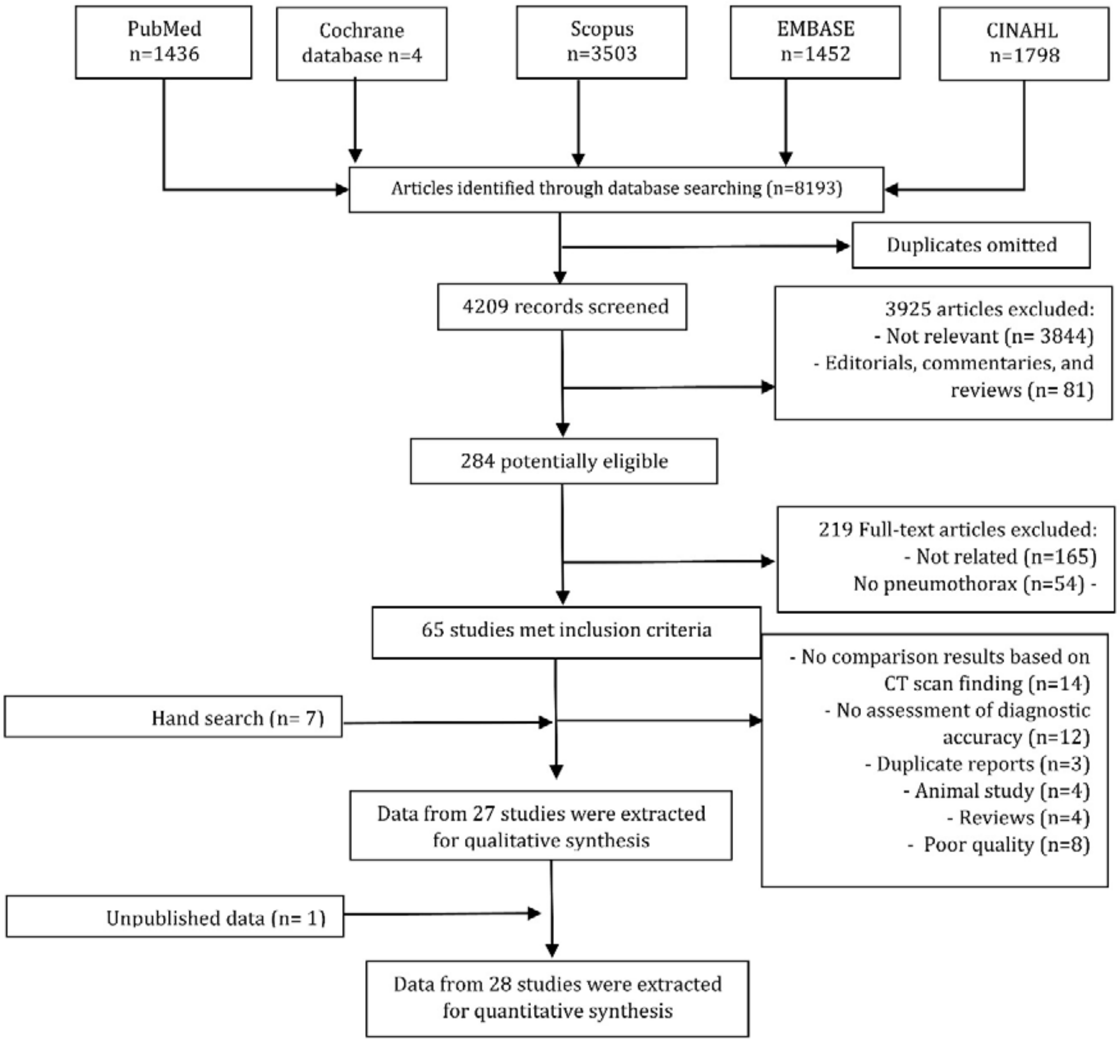

Figure 1. Flow chart of the study. Diagram represents the review process and selection of included studies

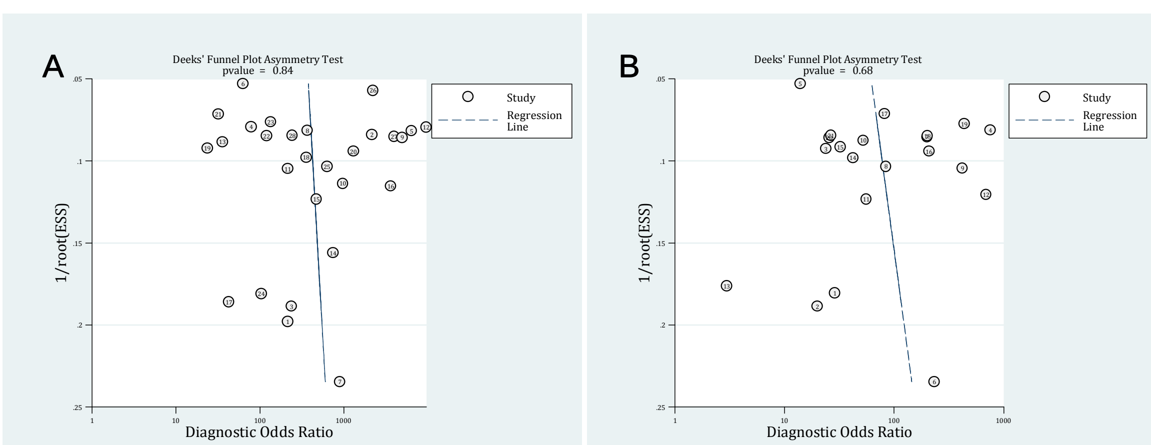

Figure 2. Deeks' funnel plot for publication bias assessment of CUS (A) and CXR (B) for diagnosis of pneumothorax

Table 1. Studies on diagnostic accuracy of ultrasound (US) and chest radiography (CXR) for detection of pneumothorax.

Study	No. of patients	Age[1] (years)	Sex (male, %)	Outcome measure	Transducer / Operator	Sampling/ subject	US signs	Results: Sensitivity (95% CI)	Results: Specificity (95% CI)	Limitations	Quality
Goodman 1999	13 PTX+ / 36 PTX-	NP	NP	CT, US, CXR	7.5 MHz linear/ Radiologist	Consecutive / Iatrogenic	LS, CTA	CXR: 46.2 (20.4–73.9) US: 87.5 (46.7–99.3)	CXR: 100 (88.0–100) US: 100 (89.3–100)	Small sample size	Fair
Lichtenstein 1999	41 PTX+/ 146 PTX-	NP	64.4	CT, US	3.5-MHz convex / Emergency physician	Consecutive / ICU	LS, CTA	US: 100 (89.3-100)	US: 98.4 (94.4-99.8)	Small sample size	Fair
Rowan 2002	11 PTX+ / 27 PTX-	42 (17-83)	92.6	CT, US, CXR	7 MHz linear/ Radiologist	Convenience / Trauma	LS, CTA	CXR: 36.0 (15.0-65.0) US: 100 (74.0-100)	CXR: 100 (81-100) US: 94.0 (72-99)	Small sample size *Possibility of selection bias*	Fair
Kirkpatrick 2004	52 PTX+ / 173 PTX-	NP	NP	CT, US, CXR	5-10 MHz linear/ Surgeon	Convenience / Trauma	LS, CTA	CXR: 20.9 (10.0–36.0) US: 48.8 (33.3–64.5)	CXR: 99.6 (97.5–100) US: 98.7 (96.1–99.7)	Possibility of selection bias	Fair
Blaivas 2005	53 PTX+ / 123 PTX-	NP	57	CT, US, CXR	2 to 4 MHz convex / Emergency physician	Consecutive / Trauma	LS, CTA	CXR: 75.5 (61.7- 86.2) US: 98.1 (89.9-99.9)	CXR: 100 (97.1-100) US: 99.2 (95.6-99.9)	It selected patients who were more severely injured.	Good
Chung 2005	35 PTX+ / 72 PTX-	NP	NP	CT, US, CXR	5–12 MHz linear/ Radiologist	Convenience / Iatrogenic	LS, CTA	CXR: 47.1 (38.7-55.7) US: 80.0 (72.2-86.1)	CXR: 93.9 (90.0-96.4) US: 93.9 (90.0-96.4)	*Possibility of selection bias*	Fair
ReiBig 2005	4 PTX+ / 49 PTX-	64 (NP)	60.4	CT, US, CXR	7.5 MHz linear / Pneumologist	Consecutive / Iatrogenic	LS, CTA, LP	CXR: 75.0 (21.9-98.7) US: 100 (39.6-100)	CXR: 100 (90.1-100) US: 100 (90.1-100)	Small sample size Small PTX cases	Fair
Lichtenstein 2005	32 PTX+/ 146 PTX-	44 (19)	NP	CT, US	5 MHz convex / Intensivist	Consecutive / ICU	LS, CTA	US: 95.3 (82.9-99.2)	US: 94.7 (91.4-96.8)	Possibility of selection bias	Fair
Garofalo 2006	46 PTX+ / 138 PTX-	NP	70.6	CT, US	2.5 MHz convex / Emergency physician	Convenience / Iatrogenic	LS, CTA	US: 95.6 (84.0-100)	US: 100 (96.6-100)	Possibility of selection bias	Fair
Soldati 2006	56 PTX+ / 130 PTX-	52.4 (22.9)	62.9	CT, US, CXR	5 MHz Convex / Emergency physician	Consecutive / Trauma	LS, CTA, LP	CXR: 53.6 (39.8-66.8) US: 98.2 (89.2-99.9)	CXR: 100 (96.4-100) US: 100 (96.4-100)	Inclusion criteria may have introduced bias	Good
Zhang 2006	29 PTX+ / 106 PTX-	45 (15)	84.4	CT, US, CXR	3.5 to 7.5 MHz linear / Emergency physician	Convenience / Trauma	LS, CTA, LP	CXR: 27.6 (11.3–43.9) US: 86.2 (73.7–98.8)	CXR: 100 (100–100) US: 97.2 (94.0–100)	Did not test reproducibility among operators	Good
Soldati 2008	25 PTX+ / 84 PTX-	41.4 (20.5)	62.9	CT, US, CXR	5.2 MHz linear / Emergency physician	Consecutive / Trauma	LS, CTA, LP	CXR: 52.0 (31.8-71.7) US: 91.7 (71.5-98.5)	CXR: 100 (94.6-100) US: 98.8 (92.7-100)	Inclusion criteria may have introduced bias	Good
Brook 2009	43 PTX+ / 126 PTX-	31 (13.2)	85	CT, US, CXR	3.5 MHz linear/ Radiologist	Consecutive / Trauma	LS, CTA	CXR: 16.3 (8.1–29.8) US: 46.5 (32.5–61)	CXR: 100 (98.7–100) US: 99 (97.1–99.7)		Good
Mashayekhian 2010	12 PTX+/ 48 PTX-	36.5 (17.7)	90	CT, US	7.5 MHz Linear / Emergency physician	Consecutive / Trauma	LS, CTA, LP	US: 91.7 (59.8-99.6)	US: 100 (90.8-100)	Small sample size Moderate quality of US set.	Fair
Nagarsheth 2011	22 PTX+ / 57 PTX-	44.5 (15.3)	66.4	CT, US, CXR	2.5 MHz convex / Surgeon	Convenience / Trauma	LS, CTA, LP	CXR: 31.8 (14.7-54.9) US: 81.8 (59.0-94.0)	CXR: 100 (92.1-100) US: 100 (92.1-100)	*Possibility of selection bias*	Fair
Nandipati 2011	21 PTX+ / 183 PTX-	43 (19.5)	74.5	CT, US, CXR	7.5 MHz linear / Emergency physician	Convenience / Trauma	LS, CTA	CXR: 78.9 (53.9-93.0) US: 95.2 (74.1-99.8)	CXR: 99.4 (96.5-100) US: 99.4 (96.5-100)	*Possibility of selection bias*	Fair

Table 1. Continued

Study	No. of patients	Age[1] (years)	Sex (male, %)	Outcome measure	Transducer / Operator	Sampling/ subject	US signs	Results: Sensitivity (95% CI)	Results: Specificity (95% CI)	Limitations	Quality
Xirouchaki 2011	8 PTX+ / 76 PTX-	57.1 (21.5)	90.5	CT, US, CXR	5 to 10 MHz Convex / Intensivist	Convenience / ICU	LS, CTA, LP	CXR: 0.0 (0-37) US: 75.0 (35.0-97.0)	CXR: 99 (93-100) US: 93.0 (85-98)	*Possibility of selection bias.* Small sample size. Time interval between lung ultrasound and CT could not be controlled.	Fair
Donmez, 2012	33 PTX+ / 34 PTX-	NP	NP	CT, US, CXR	5-MHz linear / Radiologist	Convenience / Trauma	LS, CTA	CXR: 82.6 (63.5–93.5) US: 91.4 (75.8–97.8)	CXR: 100 (82.0–100) US: 97.0 (90.9–99.2)	Small sample size Possibility of selection bias	Fair
Hyacinthe 2012	53 PTX+ / 66 PTX-	39 (22-51)	82.0	CT, US, CXR	5.2 MHz Convex / Emergency physician	Consecutive / Trauma	LS, CTA, LP	CXR: 18.9 (9.9-32.4) US: 52.8 (38.8-66.5)	CXR: 100 (93.1-100) US: 95.4 (86.4-98.8)	Did not test reproducibility among operators. Diagnostic value of radiography was considered with physical examination as a whole	Fair
Abbasi 2013	37 PTX+ / 109 PTX-	37 (14)	87.6	CT, US, CXR	7.5 MHz linear / Emergency physician	Convenience / Trauma	LS, CTA	CXR: 48.64 (32.2–65.3) US: 86.4 (70.4–94.9)	CXR: 100 (95.7–100) US: 100 (95.7–100)	Possibility of selection bias	Fair
Jalli 2013	92 PTX+ / 105 PTX-	NP	NP	CT, US, CXR	7.5 MHz linear / Radiologist	Consecutive / Respiratory problems	LS, CTA	CXR: 60.7 (50.1–70.7) US: 80.4 (70.6–87.7)	CXR: 98.1 (92.6–99.7) US: 89.5 (81.6–94.4)	The use of upright CXR in some patients. US exams were performed within 48 h after the chest CT scan acquisition.	Fair
Karimi 2013	72 PTX+ / 68 PTX-	39.4 (15.8)	62	CT, US, CXR	7.5 MHz linear / Emergency physician	Consecutive / Trauma	LS, CTA	CXR: 75.3 (63.6–84.4) US: 84.9 (74.2–91.9)	CXR: 98.5 (90.1–99.9) US: 95.5 (86.6–98.9)	The time interval between CT scan accusation and US was not clear.	Good
Ku 2013	47 PTX+ / 502 PTX-	NP	75	CT, US, CXR	2 to 4 MHz linear / Emergency physician	Convenience / Trauma	LS, CTA	CXR: 40 (23-59) US: 57 (42-72)	CXR: 100 (99-100) US: 99 (98-100)	Possibility of selection bias Possible misclassification bias	Fair
Shostak 2013	8 PTX+ / 177 PTX-	67 (23-92)	47.2	CT, US	5 to 10 MHz convex / Radiologist or clinical investigator	Convenience / Iatrogenic	LS, CTA	Radiologist: US: 75 (35–90) Clinical investigator: US: 88 (35–90)	Radiologist: US: 97 (93–98) Clinical investigator: US: 97 (93–98)	*Possibility of selection bias.* Low prevalence of pneumothorax.	Fair
Uz 2013	33 PTX+ / 74 PTX-	36.7 (19.8)	80.4	CT, US	5-10 MHz linear/ radiologist	Consecutive / Trauma	LS, CTA, LP	US: 81.8 (68-95.5)	US: 100 (93.8-100)	Small sample size.	Fair
Ianniello 2014 (1)	87 PTX+ / 649 PTX-	25 (16-68)	74.2	CT, US	7.5 MHz linear / Radiologist	Consecutive / Trauma	LS, CTA,	US: 77.0 (66.5–85.1)	US: 98.5 (97.1–99.2)	-----	Good
Ojaghi Haghighi 2014	52 PTX+ / 98 PTX-	NP	82.7	CT, US, CXR	6.5 to 9 MHz linear/ Emergency physician	Convenience / Trauma	LS, CTA	CXR: 34.7 (27.2–42.9) US: 96.2 (85.7–99.3)	CXR: 98 (92.1–99.6) US: 100 (95.3–100)	*Possibility of selection bias.*	Fair
Vafaie 2014	48 PTX+ / 102 PTX-	31.4 (13.8)	77.6	CT, US, CXR	7.5 MHz linear/ Emergency physician	Consecutive / Trauma	LS, CTA	CXR: 67.3 (53.26–78.9) US: 83.6 (70.7–91.8)	CXR: 98 (92.1–99.6) US: 92.7 (85.1–96.8)	CXR examinations were done in upright position.	Good

1, Numbers are presented as mean (standard deviation or range); CI: Confidence interval; CT: Computed tomography; CTA: Comet-tail artifact; CXR: Chest radiography; ICU: Intensive care unit; LP: Lung point; LS: Lung sliding; NP: Not presented; PTX: Pneumothorax; US: Ultrasound

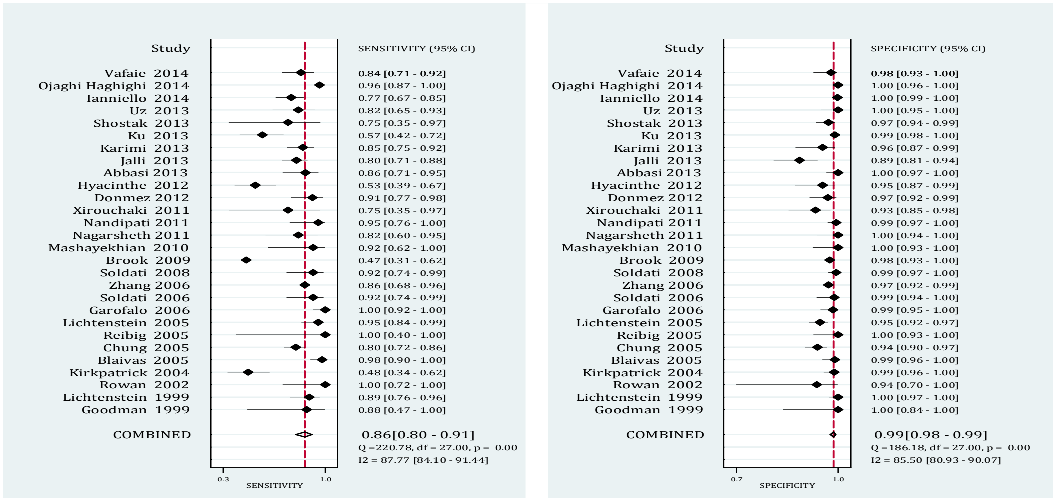

Figure 3. Forest plot for sensitivity and specificity of CUS for diagnosis of pneumothorax.

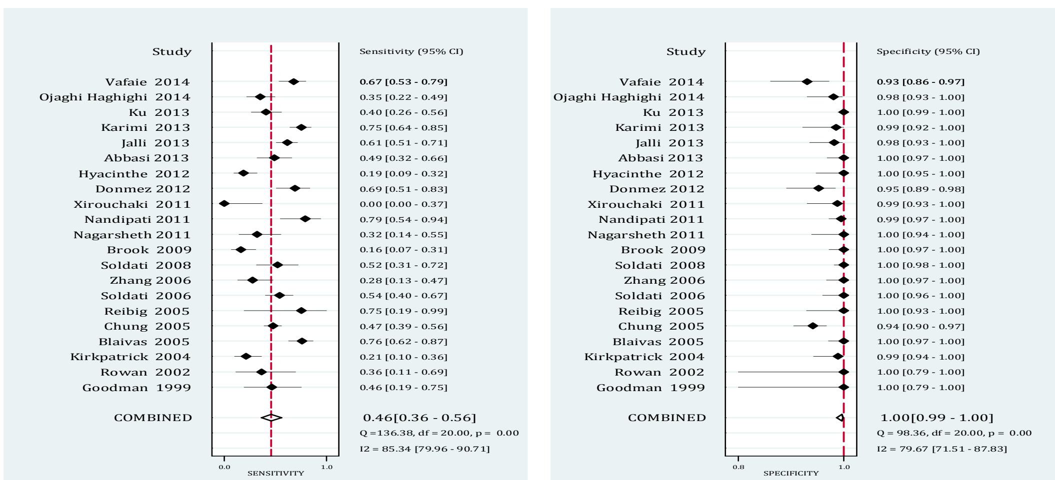

Figure 4. Forest plot for sensitivity and specificity of CUS for detection of pneumothorax.

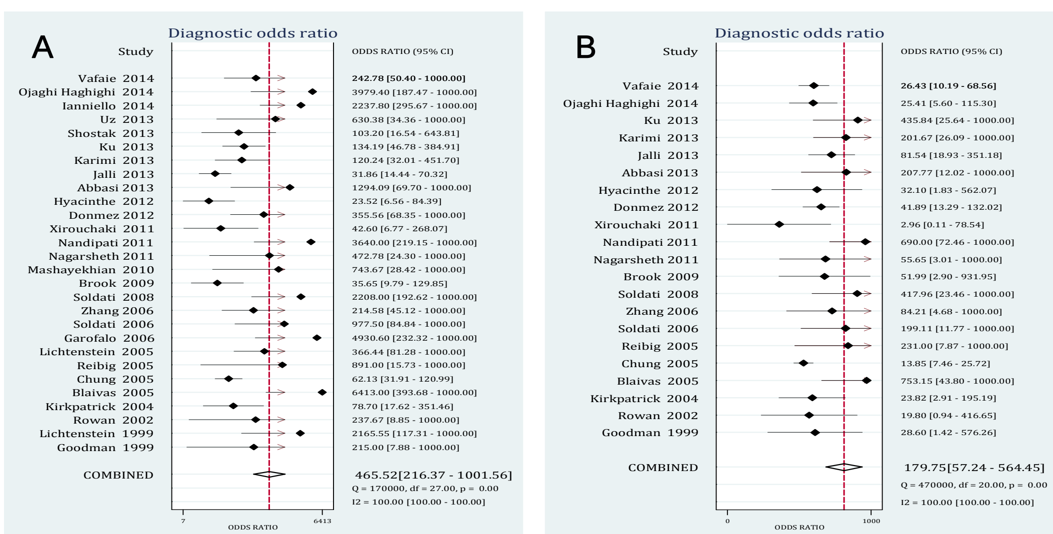

Figure 5. Forest plot for diagnostic odds ratio (DOR) of US (A) and CXR (B).

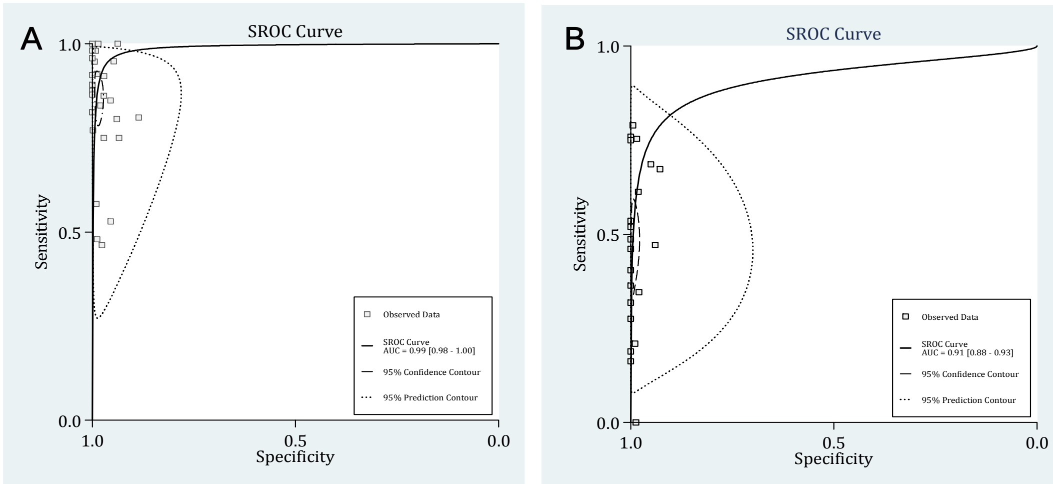

Figure 6. Summary receiver operative curves for US (A) and CXR (B).AUC, Area under the curve

Table 2. Heterogeneity in the pooled sensitivity and specificity of chest radiography or ultrasound for detection of pneumothorax

Covariate	Bivariate random-effect model			
	Sensitivity	Specificity	I2 statistics	P value
Thoracic ultrasonography				
Patient enrollment				
Consecutive	0.87 (0.81-0.94)	0.99 (0.98-1.0)	0	
Nonconsecutive	0.85 (0.77-0.93)	0.98 (0.97-1.0)	0	0.66
Patient type				
Trauma	0.85 (0.78-0.91)	0.99 (0.99-1.0)	76	<0.02
Non trauma	0.90 (0.83-0.98)	0.97 (0.95-0.99)	46	
Operator				
Emergency physician	0.88 (0.82-0.94)	0.99 (0.98-0.1.0)	86	<0.001
Non-emergency physician	0.81 (0.73-0.90)	0.98 (0.96-0.99)	71	
Probe type				
Linear	0.85 (0.78-0.92)	0.99 (0.98-1.0)	0	0.74
Nonlinear	0.88 (0.81-0.95)	0.98 (0.97-1.0)	0	
Frequency				
2-5 Mhz	0.87 (0.81-0.92)	0.98 (0.97-0.99)	0	0.4
5-10 Mhz	0.86 (0.75-0.97)	0.99 (0.98-1.0)	0	
Chest radiography				
Patient enrollment				
Consecutive	0.46 (0.35-0.77)	1.0 (0.99-1.0)	6	
Nonconsecutive	0.44 (0.22-0.66)	0.99 (0.96-1.0)	0	0.35
Patient type				
Trauma	0.46 (0.35-0.57)	0.99 (0.96-1.0)	36	0.21
Non trauma	0.44 (0.22-0.66)	1.0 (0.99-1.0)	0	

DISCUSSION

The present meta-analysis declared that the diagnostic accuracy of CUS was higher than that of supine CXR for detection of pneumothorax. Overall, it seems that CUS is superior to CXR for detection of pneumothorax, even after adjusting for possible sources of heterogeneity (the lowest CUS subgroup sensitivity was 0.81). The odds of accurate diagnosis of pneumothorax by CUS (DOR= 465.52) were significantly higher than CXR (the pooled DOR was 179.75). The non-trauma setting and performing CUS by emergency physician were associated with higher sensitivity of ultrasound in diagnosis of pneumothorax. It may be explained by the fact that the emergency physician was aware of the patient's clinical condition, the injury site, and the mechanism of injury.

A meta-analysis done by Alrajab et al., who reviewed 13 studies, demonstrated a pooled sensitivity of 78.6% and specificity of 98.4% for CUS, while these rates were 39.8% and 99.3% for CXR, respectively (30). Their findings were lower in value than the two previous studies performed by Ding et al. and Alrajhi and colleagues (29, 31). Ding et al. included 15 articles in their analysis and showed that CUS had a pooled sensitivity and specificity of 88% and 99%, respectively (29). Alrajhi et al. included 8 studies in their analysis and declared 90.9% sensitivity and 98.2% specificity for CUS (31). The two latest meta-analyses were in concordance with the present meta-analysis. However, all three mentioned meta-analyses had some limitations. The first limitation was the small number of articles included in their analyses. The second one was lack of publication bias assessment. The third one was that they only considered English-language articles, which may lead to possible publication bias.

On the other hand, we performed an extensive search in several databases to include the maximum number of relevant studies. No language limitation was another advantage of our study. This search strategy led to finding 28 relevant articles. In addition, in the present meta-analysis there was no publication bias. However, our meta-analysis had a number of potential limitations. First, all the included studies were observational so that causal relationships could not be established. Moreover, residual confounders (confounders from unknown variables) might introduce some biases, as in any meta-analysis of observational studies. One of the residual confounders in the present meta-analysis is the operator-dependent nature of CUS accuracy. The quality of operator training is another possible confounding factor, which has not yet been paid attention in included studies. The direction of this bias is unpredictable. Moreover, the heterogeneity between studies was another issue. Therefore, it was decided to use a bivariate mixed random effects model to provide more conservative results.

CONCLUSION

The present meta-analysis showed that the diagnostic accuracy of CUS was higher than that of supine CXR for detection of pneumothorax. It seems that CUS is superior to CXR for detection of pneumothorax, even after adjusting for possible sources of heterogeneity.

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