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Ultrasonography for confirmation of emergency department endotracheal tube placement: a meta-analysis

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Abstract. – OBJECTIVE: This meta-analysis aimed to summarize the evidence on the use of ultrasonography for confirming endotracheal tube placement in emergency departments.

MATERIALS AND METHODS: We conducted electronic searches on PubMed, Embase, Web of Science, and Cochrane databases. All databases were searched from their inception until February 2023. We selected studies published in English that used ultrasonography to confirm endotracheal tube placement. Case reports, case series, retrospective studies, cadaveric studies, pediatric studies, animal studies, and conference abstracts were excluded. Two reviewers independently extracted and verified data. Forest plots, hierarchical summary receiver operating characteristic (HSROC) curves, and bivariate random-effects models were used to summarize the test performance characteristics. The Stata statistical software package and Meta-DiSc version 1.4 software were used for statistical analysis.

RESULTS: A total of 1,772 intubations were analyzed. For the detection of endotracheal tube placement, the estimated pooled sensitivity and specificity were 0.98 (95% CI: 0.97-0.99) and 0.92 (95% CI 0.85-0.95), respectively. The pooled positive and negative likelihood ratios were 11.70 (95% CI: 6.49-21.07) and 0.02 (95% CI: 0.01-0.03), respectively. The diagnostic odds ratio of ultrasonography was 221.13, and the area under the HSROC curve revealed an appropriate accuracy of 0.99.

CONCLUSIONS: Current evidence supports the use of ultrasonography as a worthwhile alternative for endotracheal tube identification for intubations performed in emergency departments. This method can be used in conjunction with capnography as a preliminary test before final confirmation with capnography.

Key Words:

Intubation, Meta-analysis, Airway management, Ultrasonography.

Introduction

Endotracheal intubation provides definitive airway control during the resuscitation of critically ill patients in emergency department settings. In a recent international study[1] on critically ill patients, the incidence of emergency intubation was reported to be one in eighteen. It has also been shown[2,3] that unrecognized esophageal intubations resulted in serious injuries in approximately 1 in 1,000,000 tracheal intubations during anesthesia, 1 in 15,000 in the ICU, and 1 in 10,000 in the emergency department. All intubated patients should undergo imaging as soon as possible after intubation to confirm the appropriate placement. Unconfirmed esophageal intubation has been associated[4-6] with increased rates of aspiration, severe hypoxemia, hypertension, and cardiac arrest, but rarely with gastric or esophageal rupture. Therefore, airway assessment immediately after intubation is an essential clinical skill for emergency medicine physicians.

Current clinical assessment and verification methods, including auscultation, bronchoscopy, chest radiography, and capnography, are com-

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monly used in clinical practice to confirm the position of endotracheal intubation[7], but not all of these techniques are reliable enough for confirmation[8]. Chest radiography and pulse oximetry are not reliable as the only techniques for determining endotracheal tubes location[9]. Additionally, capnography is limited by low reliability in patients with embolism or cardiac arrest, recent carbonated beverage ingestion, and recent use of bag-valve masks[7,10]. Fiberoptic bronchoscopy is a good method for identifying endotracheal tube (ETT) placement, particularly in emergencies. However, the fiberoptic bronchoscope should be sterilized before use, limiting its effective use during emergencies. Therefore, no single validation method is reliable for emergencies.

Currently, ultrasonography is commonly performed for other purposes by emergency physicians. It can be considered[11] a quick, inexpensive, and portable method for confirming proper ETT placement. It is important that physicians learn these methods and apply them easily so that they can not only reduce the duration of hypoxia by early detection of esophageal intubation, but also prevent esophageal ventilation and its complications, such as vomiting and accidental aspiration[12]. However, most of the abovementioned studies had small sample sizes, different study settings, and different gold standards, resulting in wide confidence intervals. Related studies[13,14] have shown that ultrasonography can be a useful tool for assessing the ETT position in cardiac arrest cases or when capnography is not available. Therefore, pooling the results of previously published studies in literature before performing ultrasonography examinations during emergencies is necessary. Previous systematic reviews and meta-analyses[15-17] have shown the overall high sensitivity and specificity of ultrasound for the confirmation of ETT. However, no meta-analysis has been performed specifically for its application in patients in the emergency department. Therefore, we performed this meta-analysis in order to evaluate the diagnostic performance of ultrasonography in confirming ETT placement during emergency department intubations.

Materials and Methods

Literature Search

Our study was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines for systematic reviews and the best practice guidelines[18]. We conducted electronic searches on PubMed, Embase, Web of Science, and Cochrane databases. All the databases were searched from their inception until February 2023. The text of the medical subject heading (MeSH) and the text words "intubation" were combined with the MeSH term "ultrasonography". Search terms for primary interventions included "intubation", "tracheal intubation", or "esophageal intubation". The search results were then cross-checked for populations of concern, using "ultrasonography", "sonogram", "ultrasound", "sonography", "echo" and "sono" as search terms. Further details on the search strategy are included in **Supplementary File I**. The protocol was prospectively registered in the Prospective Register of PROSPERO (CRD42023402410).

Eligibility Criteria

Eligible studies were enrolled in our meta-analysis based on the following inclusion criteria: (1) Diagnostic accuracy data comprising true positives, false positives, true negatives, and false negatives directly extractable from a 2*2 table, or data which can be used to calculate these items; (2) Prospective or randomized controlled trials; (3) The diagnostic performance of ultrasonography for detection of the confirmation of ETT placement was reported; (4) Patients were older than 18 years; (5) Studies had been subjected to confirmatory tests (e.g., end-tidal capnography, colorimetric capnography, direct visualization); (6) The study was performed in an emergency department.

Case reports, case series, retrospective studies, cadaveric studies, pediatric studies, animal studies, and conference abstracts were excluded.

Two reviewers (Chen and Wang) independently assessed the eligibility of studies based on these criteria. All abstracts that met the initial criteria were reviewed as full texts. Two extractors were included in the final data analysis to identify studies that met the eligibility criteria for full-text review. Disagreements were resolved by consensus with the third reviewer (Chen).

Data Extraction

Two reviewers (Chen and Wang) independently assessed the eligibility of studies based on these criteria. One reviewer extracted the data (Chen), and the other reviewer (Wang) independently verified the data. The researchers were initially trained, and the data were extracted into predesigned data collection forms. The following information was extracted: last name of the first author, publication year, study country, study population size, type of study, mean age of study patients, sex of study patients, percentage of esophageal intubations, ultrasonography transducer, ultrasonographic findings for identifying endotracheal and esophageal intubations, ultrasonography technique (static or dynamic), intubation confirmation criterion standard, TP, FP, TN, and FN. Static techniques assess the position of the ETT after the intubation attempt, whereas dynamic techniques assess the position of the ETT in real-time during the intubation attempt.

Quality Assessment

Two investigators (Chen and Wang) conducted an independent quality assessment of the studies using the Diagnostic Accuracy Study Quality Assessment-2 tool before the analyses[19]. This tool assesses the characteristics of study designs, populations, index tests, and reference standards which may be associated with the risk of bias, and the results of the assessment are presented in table and image form. Disagreements were resolved through consensus with a third reviewer (Tang).

Statistical Analysis and Data Synthesis

Data synthesis was performed using the methods recommended in the Cochrane Handbook for Systematic Evaluation of Diagnostic Test Accuracy (available at: https://training.cochrane.org/handbook-diagnostic-test-accuracy). All analyses were performed using the Stata statistical software package (Stata Corp., College Station, TX, USA) and Meta-DiSc software 1.4[20]. Diagnostic test statistics (sensitivity, specificity, positive likelihood ratio, negative likelihood ratio, and ETT diagnostic probability) were analyzed and pooled using a bivariate random effects model[21]. In our study, the diagnostic test statistics referred to the ability of ultrasonography to detect the correct placement of the ETT in the trachea. We calculated heterogeneity statistics (Chi-square) χ^2 and inconsistency statistics (I^2) to assess the heterogeneity between studies. A *p*-value for chi-square χ^2 <0.05, or I^2 value > 50%, was regarded as significant heterogeneity.

I^2 describes the total percentage of variation in a study due to heterogeneity, rather than chance. I^2 can be readily calculated from the underlying results obtained from a typical meta-analysis as I^2 = 100% (Q-df)/Q, where Q is Cochran's heterogeneity and df is the degree of freedom. Cochran's Q was calculated by summing the squared deviations of each study's estimates from the overall meta-analysis. A hierarchical summary receiver operating curve (HSROC) analysis was performed to assess the summary accuracy of ultrasonography, and an area under the curve > 0.9 was considered highly accurate for the assessment of accuracy[22]. The analysis method was predetermined prior to the data search. The clinical utility of ultrasonography was assessed using likelihood ratios to calculate post-test probabilities (based on Bayes' theorem) using Fagan column line plots. Deeks' Funnel plot Asymmetry Test was used to investigate publication bias.

Results

Search Results and Study Characteristics

The literature search flowchart is summarized in the PRISMA format (Figure 1). A total of 7,992 studies were identified during the initial search. After removing 2,336 duplicates, the abstracts of the remaining 5,656 studies were evaluated. The full texts of 151 articles were assessed for eligibility, and 131 were excluded based on the exclusion criteria. Ultimately, 20 studies, including 1,772 intubations, met the inclusion criteria for the present analysis[13,14,23-40].

Characteristics of Included Studies

The main characteristics of the included studies are summarized in Table I. The studies were conducted between 2009 and 2023, with sample sizes ranging from 30 to 120. All studies examined the accuracy of ultrasonography in emergency, and ultrasonography examinations were performed by emergency physicians.

Quality Assessment

The quality of the included studies was assessed using QUADAS-2 (**Supplementary Table I**). For most parameters, the overall risk of bias regarding patient selection, index test, reference test, flow and timing, and applicability of the index and reference tests was low for the included studies. Taken together, the overall quality assessment indicated good quality (Figure 2).

Quantitative Data Synthesis Results

The overall pooled sensitivity and specificity of ultrasonography detection for confirmation of

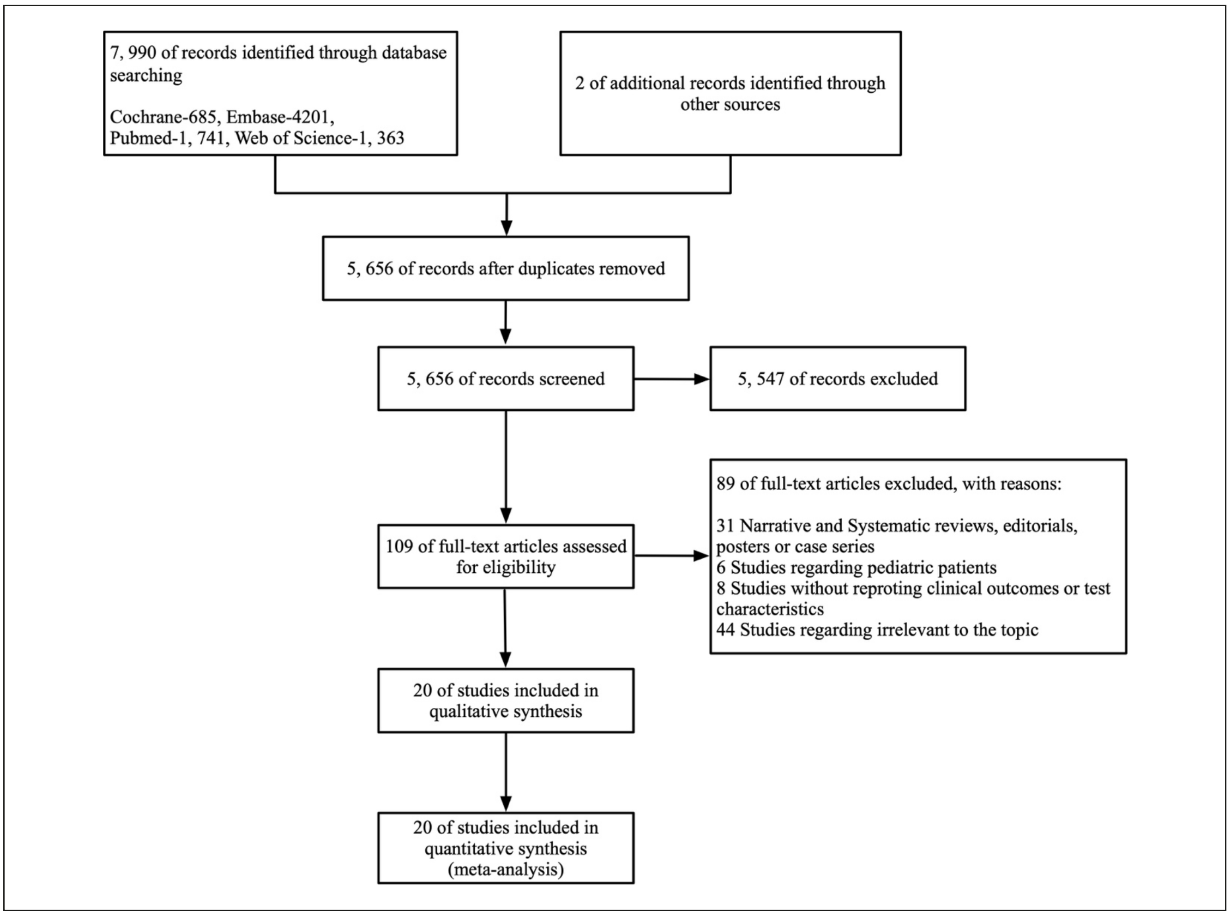

Figure 1. Study selection and inclusion flow chart according to PRISMA.

correctly placed ETT were 0.98 (95% CI: 0.97-0.99) and 0.92 (95% CI: 0.85-0.95), respectively. The positive and negative likelihood ratios were 11.70 (95% CI: 6.49-21.07) and 0.02 (95% CI: 0.01-0.03), respectively (Figure 3). Furthermore, the diagnostic odds ratio of ultrasonography was 221.13 (95% CI: 117.79-415.14). The hierarchical summary receiver-operating characteristic curve (HSROC) revealed an appropriate accuracy of 0.99. The Fagan plot (Figure 4) shows that ultrasonography may be clinically informative because it increases the probability of being previously classified as N+ from 50% (the average prevalence of N+ cases) to 92% when positive, while the same probability decreases to 2% when the negative likelihood ratio scatter plot (Figure 5) shows that the summary points for positive and negative likelihood ratios are located in the upper left quadrant, indicating that the accuracy of ultrasonography is optimal not only for ETT location identification but also for the exclusion of esophageal intubation.

The subgroup analyses were performed using a similar methodology. The results showed good sensitivity, specificity, and positive and negative likelihood ratios in all pre-specified subgroup analyses (Table II). This extends to analyses involving linear transducers, curvilinear transducers, tracheal ultrasound, diaphragmatic ultrasound, cardiac arrest, combined tracheal and lung ultrasound, and static and dynamic techniques. Tracheal ultrasonography was used in thirteen studies[13,14,23,25-29,31,33,34,37], and diaphragmatic ultrasonography was used in two studies[24,36]. Studies using the direct tracheal scan approach have a comparable sensitivity (0.99, 95% CI: 0.98-0.99) to the overall estimated sensitivity (0.98, 95% CI: 0.97-0.99). Dynamic ultrasonography was associated with superior sensitivity (0.99, 95% CI: 0.97-0.99) compared to the static method (0.97, 95% CI: 0.96-0.98). Ultrasonography using a linear transducer was associated with superior sensitivity (0.98, 95% CI: 0.97-0.99) compared to a curvilinear transducer (0.97, 95% CI: 0.95-0.98).

Table I. Characteristics of included studies (N=20).

Author	Year	Country	Study design	Sample	Mean age	Male (%)	Ultrasonic technique	Transducer type	USG sign used	Esophageal intubation (%)	Gold standard
Majidinejad et al (Egs)[23]	2023	Iran	Prospective	104	52.13	70.2	Static	Curvilinear	5	5.8	CAP
Majidinejad et al (Sss)[23]	2023	Iran	Prospective	104	52.13	70.2	Static	Linear	1	5.8	CAP
Mousavi et al (Sss)[24]	2022	Iran	Prospective	66	62.9	63.6	Static	Curvilinear	1,2	9.1	DV+CAP+A
Mousavi et al (Sxs)[24]	2022	Iran	Prospective	66	62.9	63.6	Static	Curvilinear	4	9.1	DV+CAP+A
Afzalimoghaddam et al[25]	2019	Iran	Prospective	90	59.2	58.9	Dynamic	Linear	1	3.3	CAP
Zamani et al[26]	2018	Iran	Prospective	100	57.5	73	Dynamic	Linear	1	6	CAP
Zamani et al[27]	2017	Iran	Prospective	150	58.5	56	Static	Linear	1	11.3	O+AS+ DV+A
Thomas et al[28]	2017	India	Prospective	100	50.8	59	Static	Linear	1	5	CAP
Rahmani et al[30]	2017	Iran	Prospective	75	61.1	62.7	Dynamic	Linear	2	0	DV
Masoumi et al[29]	2017	Iran	Prospective	100	64.5	65	Static	Curvilinear	1	6	CAP
Lahham et al[31]	2017	US	Prospective	72	57.7	56.9	Dynamic	Linear	1	4.2	CAP
Karacabey et al (N-CA)[13]	2016	Turkey	Prospective	85	67.2	NR	Dynamic	Linear	1	38.2	CAP
Karacabey et al (CA)[13]	2016	Turkey	Prospective	30	NR	NR	Dynamic	Linear	1	NR	CAP
Abbasi et al[32]	2015	Iran	Prospective	120	50	61.5	Dynamic	Linear	1,3	11.7	DV+A+CAP
Sun et al[33]	2014	Taiwan	Prospective	96	68.8	67.6	Dynamic	Curvilinear	1	7.3	CAP+A
Hoffman et al[34]	2014	US	Prospective	101	58	NR	Dynamic/Static	Linear	1	10	DV+CAP
Saglam et al[35]	2013	Turkey	Prospective	69	NR	NR	Static	Linear	1,3	7.2	CAP
Hosseini et al[36]	2013	Iran	Prospective	57	59	60	Static	Curvilinear	4	21	DV+A+O
Chou et al[14]	2013	Taiwan	Prospective	89	69.9	69	Dynamic	Curvilinear	1	7.6	CAP+A
Adi et al[37]	2013	Malaysia	Prospective	107	NR	NR	Static	Linear	1	5.6	CAP
Noh et al[38]	2012	Korea	Prospective	19	NR	NR	Dynamic	Linear	NA	15.7	CAP
Chou et al (N-CA)[39]	2011	Taiwan	Prospective	83	67.6	54.5	Static	Curvilinear	1	15.7	CAP
Chou et al (CA)[39]	2011	Taiwan	Prospective	29	NR	NR	Static	Curvilinear	1	10.3	CAP
Park et al[40]	2009	South Korea	Prospective	30	59.6	56.7	Dynamic	Linear	2,3	10	CAP+A

CA = cardiac arrest; non-CA = non-cardiac arrest; ED = Emergency Department; EM = Emergency Medicine; CA = Cardiac arrest; Non-CA = non-cardiac arrest; Eps = epigastric sonography; Sss = Suprasternal sonography; Sxs = Subxiphoid sonography; USG Sign used:1 = Double tract sign or similar signs (endotracheal tube placement was considered esophageal if two air-mucosa interfaces with comet-tail artefacts and posterior shadowing were noted); 2 = Bullet sign (Triangular appearance of laryngeal inlet changes to rounded shape of bullet's head); 3 = Lung sliding (presence of pleural movement when linear transducer is placed in second intercostal space); 4 = Diaphragmatic movements visualization with curvilinear probe placed in subcostal area in mid-axillary line vertically; 5 = epigastric ultrasound (After placing the probe in the epigastric region, if air entered the stomach, it appeared red, and when the air exit, it appeared blue. the ETT was inserted into the esophagus instead of the trachea, indicating the incorrect placement of ETT, and when red and blue were not seen, indicating that the ETT was inserted into trachea and its placement was correct); Gold standard of endotracheal tube placement confirmation: A = Auscultation; CAP = Capnography; DV = Direct Visualization; O = Oxygen saturation monitoring; AS = Aspiration of endotracheal tube; FOB = Fiber-optic Bronchoscopy.

Figure 2. Bias risk assessment.

Publication Bias

Evaluation of the studies using Deeks' test (p=0.15) showed no significant publication bias. Furthermore, the funnel plots of the included studies revealed no significant publication bias (Figure 6).

Discussion

Our results showed that the overall pooled sensitivity and specificity of ultrasonography to confirm the placement of the ETT in emergency departments were 0.98 and 0.92, respectively.

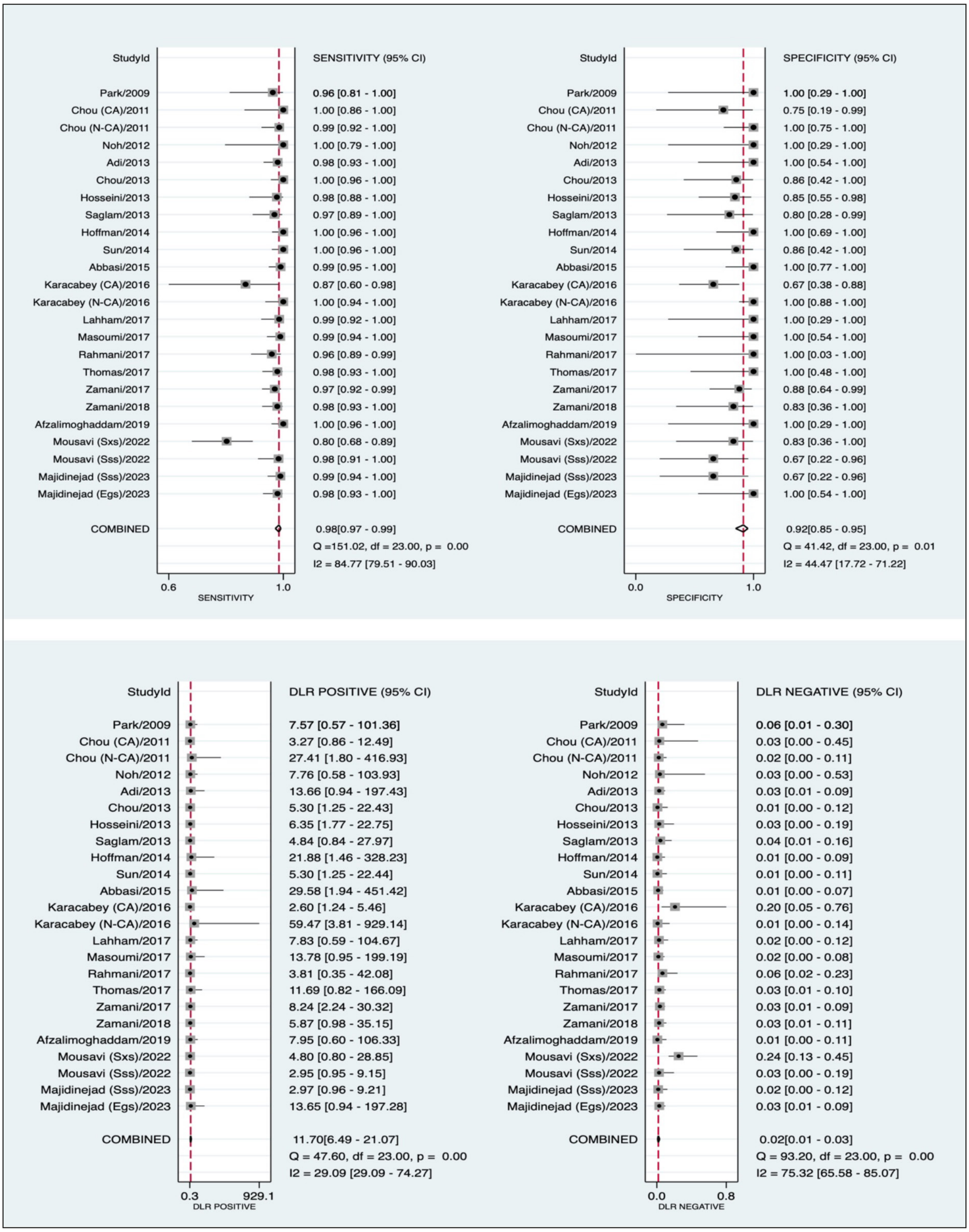

Figure 3. Forest plot for sensitivity, specificity, and negative and positive likelihood ratios for the use of ultrasonography to detect placement of ETTs.

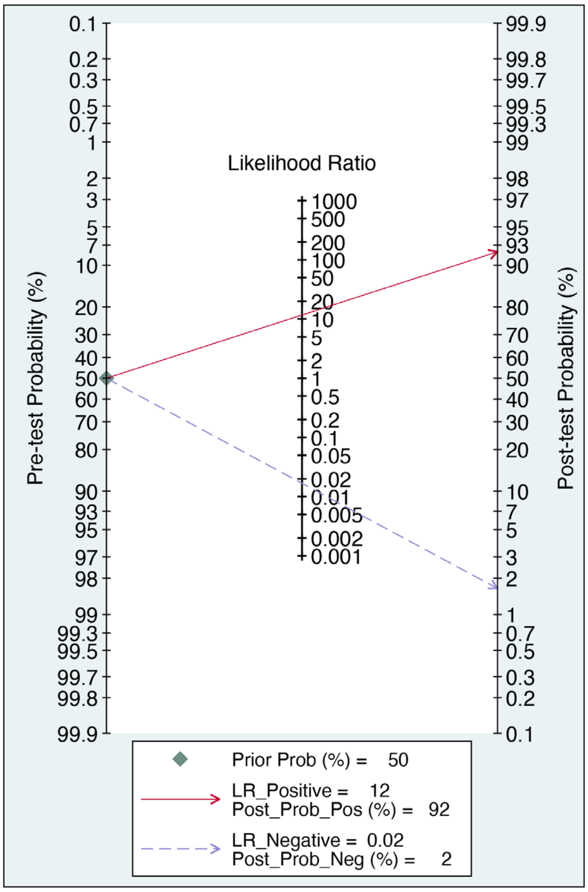

Figure 4. Fagan plot evaluating the effect of the ultrasonography result on the probability of ETT position, considering a given pre-test probability.

The diagnostic odds ratio for ultrasonography was 221.13, and the area under the HSROC curve showed an accuracy rate of 0.99. This study showed the excellent sensitivity and specificity of emergency resident ultrasonography in confirming the location of tracheal intubation. This suggests that this imaging technique can be used to confirm or exclude ETT placement in adult patients during emergencies. In a similar study, Farrokhi et al[16] performed a meta-analysis including 33 eligible studies from different settings, including operating rooms, intensive care units, and emergency departments, to evaluate the efficacy of ultrasonography to confirm the ETT placement, and they found that the sensitivity and the specificity were 0.98 (95% CI: 0.98-0.99) and 0.94 (95% CI: 0.91-0.96), respectively. In another meta-analysis[41,] including 38 studies with 3,268 patients, the pooled sensitivity and specificity of ultrasonography for confirming the position of the ETT were 0.98 and 0.98, respectively. Although these estimated pooled sensitivities were similar to those found in our study, their pooled specificities were higher. These variations can be partially explained by the number of studies included, study sites, patient sample sizes, reasons for patient admission, and different diagnostic standards. Therefore, our study further confirms

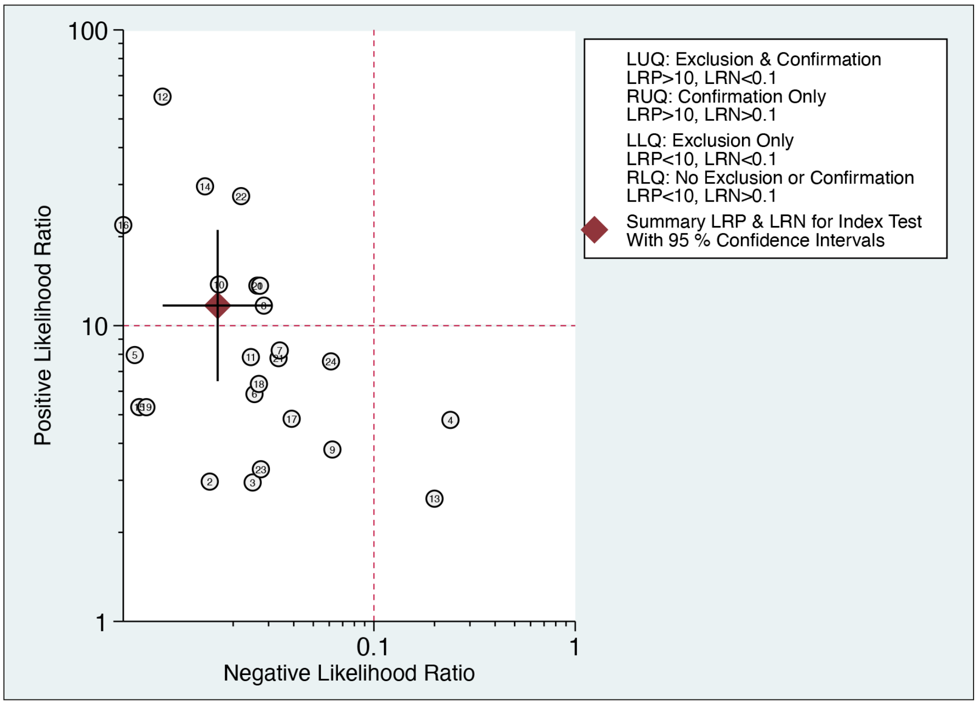

Figure 5. Likelihood scattergram for confirmation ability of ETT location by ultrasonography. Likelihood ratio (LR) scatter plots define informative quadrants based on desired thresholds (positive LR > 10, negative LR < 0.1): left upper quadrant (for both diagnostic, exclusion, and confirmation tests), right upper (for confirmation only), left lower (for exclusion only), and right lower (neither confirmation nor exclusion).

Table II. Subgroup analyses of ultrasonography for ETT placement confirmation.

Variables	Sensitivity (95% CI)	Specificity (95% CI)	LR+	LR-	AUROC	Diagnostic OR	I^2 (%)
Ultrasound[13,14,23-40]	0.98 (0.97-0.99)	0.92 (0.85-0.95)	11.70 (6.49-21.07)	0.02 (0.01-0.03)	0.99	221.13 (117.79-415.14)	11.6
Tracheal ultrasound[13,14,23,25-29,31,33,34,37]	0.99 (0.98-0.99)	0.92 (0.84-0.95)	5.72 (3.47-9.41)	0.03 (0.02-0.04)	0.99	316.59 (132.39-757.10)	24
Diaphragmatic ultrasound[24,36]	0.88 (0.80-0.93)	0.84 (0.60-0.97)	5.78 (2.04-16.35)	0.09 (0.00-1.96)	NA	64.61 (5.72-729.88)	52.4
Static ultrasound[23,24,27-29,35-37,39]	0.97 (0.96-0.98)	0.88 (0.80-0.94)	5.15 (3.24-8.19)	0.03 (0.02-0.07)	0.97	199.27 (92.46-429.44)	0
Dynamic technique[13,14,25,26,30-33,38,40]	0.99 (0.97-0.99)	0.94 (0.85-0.98)	16.48 (6.31-43.03)	0.01 (0.00-0.03)	0.99	269.17 (78.92-918.09)	38.9
Linear technique[13,23,25-28,30-32,34,35,37,38,40]	0.98 (0.97-0.99)	0.91 (0.85-0.96)	6.01 (3.50-10.34)	0.03 (0.02-0.05)	0.98	233.22 (98.98-549.50)	22.2
Curvilinear transducer[14,23,24,29,33,36,39]	0.97 (0.95-0.98)	0.88 (0.78-0.95)	5.08 (3.01-8.57)	0.03 (0.01-0.09)	0.96	216.11 (81.96-569.79)	0.3
Cardiac arrest patient[13,14,33,39]	0.99 (0.97-1.00)	0.76 (0.58-0.89)	3.32 (1.92-5.74)	0.03 (0.00-0.20)	0.62	129.42 (13.41-1248.65)	59.7
Tracheal + lung ultrasound[32,35]	0.98 (0.95-1.00)	0.95 (0.74-1.00)	9.38 (1.35-65.11)	0.03 (0.01-0.07)	NA	424.01 (26.93-6676.54)	43.8

NA, data not available because of the limited number of studies; LR, likelihood ratio; OR, odds ratio.

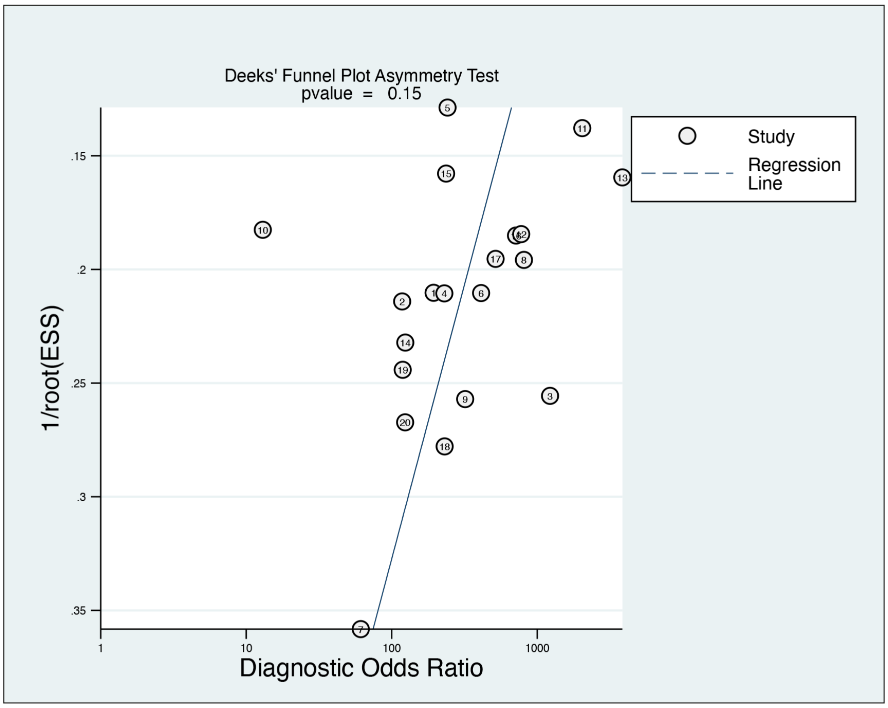

Figure 6. Funnel plot of studies assessing the accuracy of ultrasonography in identifying endotracheal tube location.

that emergency ultrasound assessment of tracheal location is equally accurate and provides a rationale for the further use of ultrasound in emergencies.

Our findings confirm the validity of ultrasound as an aid in assessing the position of the ETT during intubation. It should be noted that these results are important because the accuracy of capnography is thought to be low, especially in patients with cardiac arrest with a low sensitivity ranging from 65% to 68%[42,43]. Our results showed that the pooled sensitivity and specificity of ultrasonography to confirm the placement of the ETT in cardiac arrest were 0.99 and 0.76, respectively. Our findings demonstrate the potential value of ultrasound use during resuscitation.

Advanced Cardiac Life Support guidelines[44] emphasize early chest compressions and minimize interruptions. Even before clinical auscultation, this can be performed in parallel with an ultrasound assessment of the ETT position without interrupting chest compressions, with a decreased risk of unintended extubation. Thus, a recommendation from the 2015 Advanced Cardiac Life Support guidelines suggests that ultrasonography may be a valuable alternative to quantitative waveform EEG (strong recommendations, low-quality evidence)[44]. However, the findings of previous abovementioned studies and those of the current study support this hypothesis.

In the present study, the dynamic technique showed a trend toward higher sensitivity and specificity, although the difference was not statistically significant. Gottlieb et al[17] performed a meta-analysis to identify studies evaluating the efficacy of ultrasonography for confirming ETT placement. Their systematic search yielded 17 eligible studies in intra-operative and emergency settings. In this study, the sensitivity and specificity of dynamic ultrasonography to confirm the ETT placement were 0.99 and 0.99, respectively. This may be because of the ability of this technique to better visualize motion artifacts. The main reason for this difference might be that one-third of the subjects in this study were surgical patients who underwent non-emergency tracheal intubation, thus significantly improving sensitivity and accuracy. Dynamic techniques have higher sensitivity and specificity, but may be infeasible if only one provider is available because the same provider may be performing the intubation. Coughing, swallowing, and restlessness during intubation affect the accuracy of ultrasound evaluation of ETT location. In these cases, a static technique may be optimal. The results of the current study also showed a non-statistically significant trend toward increased sensitivity and specificity of the linear transducer compared to the curved transducer. This may be due to the increased resolution of the linear transducer in the near field. This result is generally consistent with those of other meta-analyses[17,45]. Therefore, it is recommended to choose real-time ultrasound or linear array probes as much as possible to improve the accuracy of ultrasound evaluation of ETT placement in emergencies.

Additionally, this study included tests to evaluate multiple intubation confirmation techniques, including lung sliding and diaphragmatic excursions. The results of this study show that lung sliding combined with tracheal ultrasonography has superior sensitivity and specificity. Pfeiffer et al[46] found that lung sliding combined with tracheal ultrasound was as fast as capnography, with a mean confirmation time of 48 seconds. However, the application of data from Gottlieb et al[17] using transtracheal ultrasound alone suggests that it may be almost four times more rapid than capnography. Although lung sliding combined with tracheal ultrasound improves sensitivity and accuracy, the prolonged evaluation time during resuscitation of critically ill patients may affect patient prognosis.

Although the current study indicates that ultrasonography can be a worthwhile alternative for ETT identification, it is necessary to be aware of the following when using ultrasound First, placing the ultrasound transducer on the trachea during the intubation attempt may result in greater difficulty in intubation by exerting downward pressure on the trachea. This may have affected the success rate of tracheal intubation. Second, ultrasound may not be indicated for specific populations. Neck surgery, neck masses, abnormal upper airway anatomy, and extremely short necks can make visualization more difficult and may limit the ability of ultrasonography to reliably detect the position of the tracheal tube.

Limitations

There are several limitations to this study. First, most studies did not explicitly list previous experience with ultrasonography, so there may be gaps in experience that affect the results of the study. Second, various confirmation methods were used as gold standards to assess the sensitivity and specificity of ultrasound for the confirmation of ETT placement. However, we consider all of these to be criteria for confirmation of ETT placement.

Conclusions

Our study showed that ultrasonography can be a worthwhile alternative for ETT identification in emergencies. This method can be used in conjunction with capnography as a preliminary test before final confirmation, and in resource-limited or prehospital emergency settings. Further large-scale studies are necessary to confirm the applicability of ultrasound in standard protocols for tracheal intubation during emergencies. With advances in medical technology, future studies will need to determine the best non-invasive imaging modality to improve the evaluation of tracheal intubation and rule out esophageal intubation.

Conflict of Interest
The Authors declare that they have no conflict of interests.

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Authors' Contribution
The Authors declare that they have no conflict of interests.

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Authors' Contribution
Gensheng Zhang (Review, editing, and supervision); Weiting Chen (Project administration, writing - original draft); Min Tang (Writing - review and editing); Hongyang Wang (Collating data); Minyan Wang (Collating data).

Data Availability
The datasets generated during and analyzed during the current study are available from the corresponding author upon reasonable request.

Ethics Approval and Informed Consent
Not applicable.

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