



Transtracheal ultrasound for verification of endotracheal tube placement: a systematic review and meta-analysis

Vérification du positionnement du tube endotrachéal par échographie transtrachéale: revue systématique de la littérature et méta-analyse

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Abstract

Purpose Early confirmation of endotracheal tube placement is of paramount importance to prevent hypoxia and its catastrophic consequences. Despite certain limitations, capnography is considered the gold standard to evaluate the proper placement of an endotracheal tube. Ultrasound is a novel tool with some definitive advantages over capnography. It enables a real-time view and can be performed quickly; furthermore, it is independent of pulmonary blood flow and does not require lung ventilation. In this review, we aimed to evaluate the

diagnostic accuracy of transtracheal ultrasound in detecting endotracheal intubation.

Source We completed an extensive search of MEDLINE®, EMBASE™, The Cochrane Library, KoreaMed, LILACS, OpenGrey, and the World Health Organization International Clinical Trials Registry from their inception to September 4, 2014. The studies that met the inclusion criteria were pooled and a meta-analysis was conducted.

Principal findings Eleven studies and 969 intubations were included in the final analysis. Eight studies and 713 intubations were performed in emergency situations and the others were carried out in elective situations. Transtracheal ultrasonography's pooled sensitivity and specificity with 95% confidence intervals (CIs) were 0.98 (95% CI 0.97 to 0.99) and 0.98 (95% CI 0.95 to 0.99), respectively. In emergency scenarios, transtracheal ultrasonography showed an aggregate sensitivity and specificity of 0.98 (95% CI 0.97 to 0.99) and 0.94 (95% CI 0.86 to 0.98), respectively.

Conclusion Transtracheal ultrasound is a useful tool to confirm endotracheal intubation with an acceptable degree of sensitivity and specificity. It can be used in emergency situations as a preliminary test before final confirmation by capnography.

Author contributions Saurabh Kumar Das and Nang Sujali Choupoo are responsible for the integrity of this work from inception to manuscript preparation. They contributed to the study design, study selection, quality assessment, records review, data synthesis, data analysis, and manuscript composition. Rudrashish Haldar and Amitabh Lahkar contributed to the review process by searching the literature and reviewing the search records and manuscripts. All authors read the final manuscript.

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Résumé

Objectif La confirmation rapide du positionnement du tube endotrachéal est d'une importance capitale pour prévenir l'hypoxie et ses conséquences catastrophiques. En dépit de certaines limites, on considère que la capnographie constitue la référence universelle permettant d'évaluer un bon positionnement du tube endotrachéal. L'échographie est un nouvel outil qui offre des avantages certains par rapport à

la capnographie. Elle permet une vue en temps réel et peut être réalisée rapidement; en outre, elle est indépendante du débit sanguin pulmonaire et ne nécessite pas de ventilation pulmonaire. Au cours de cette étude, nous avons cherché à évaluer la précision diagnostique de l'échographie transtrachéale pour la détection de l'intubation endotrachéale.

Source Nous avons mené une recherche extensive dans les bases de données MEDLINE®, EMBASE™, The Cochrane Library, KoreaMed, LILACS, OpenGrey, ainsi que dans le Registre des essais cliniques internationaux de l'Organisation mondiale de la santé depuis leur création jusqu'au 4 septembre 2014. Les études répondent aux critères d'inclusion ont été regroupées pour permettre la réalisation d'une méta-analyse.

Constatations principales Onze études et 969 intubations ont été incluses dans l'analyse finale. Huit études et 713 intubations ont été pratiquées dans des situations d'urgence et les autres ont été réalisées dans des situations programmées. Après regroupement, la sensibilité et la spécificité de l'échographie transtrachéale, avec intervalles de confiance (IC) à 95 %, ont été respectivement de 0,98 (IC à 95 %: 0,97 à 0,99) et 0,98 (IC à 95 %: 0,95 à 0,99). Dans les situations d'urgence, la sensibilité et la spécificité groupées de l'échographie transtrachéale ont été, respectivement, de 0,98 (IC à 95 %: 0,97 à 0,99) et 0,94 (IC à 95 %: 0,86 à 0,98).

Conclusion L'échographie transtrachéale est un outil utile pour confirmer l'intubation endotrachéale avec des niveaux de sensibilité et de spécificité acceptables. Elle peut être utilisée dans les situations d'urgence comme test préliminaire avant une confirmation définitive par la capnographie.

Introduction

Confirmation of the proper placement of an endotracheal tube (ETT) is a crucial step in airway management since unrecognized esophageal intubation leads to catastrophic consequences. Numerous methods are used to verify ETT placement, including visual confirmation of the ETT passing through the vocal cords during laryngoscopy, expansion of the chest wall during ventilation, visualization of the tracheal rings and carina using a flexible bronchoscope, auscultation, capnometry, capnography, and chest x-ray. These techniques vary in their degree of accuracy.^{1,2} The 2010 - Advanced Cardiac Life Support guidelines recommend the use of quantitative waveform capnography to confirm ETT placement and to check the effectiveness of chest compression^{3,4} Although, capnography is considered the gold standard to confirm tracheal intubation, it has some major limitations. First,

detection of carbon dioxide by capnography depends on adequate pulmonary blood flow; thus, its accuracy may be compromised in patients with massive pulmonary embolism and those suffering from cardiac arrest (especially where cardiopulmonary resuscitation has not yet started or the patient is in a state of cardiac arrest for a prolonged period).⁵ Second, respiration must be maintained for several breaths to accurately confirm the ETT placement. A trauma victim is usually considered to have a full stomach unless it is proven otherwise, and inadvertently ventilating the stomach of such a patient with a misplaced ETT can cause gastric distension, vomiting, and aspiration.⁶⁻⁸ Third, capnography may provide false negative results in cases of airway obstruction or due to the use of epinephrine.^{9,10} Thus, in the face of various limitations of the techniques currently used to verify ETT placement, there is need for a consistently reliable and safe technique that can be used in real time without ventilating the lungs.

Ultrasound, once the domain of the radiologist, has now found its place in pre-hospital applications (e.g., emergency responders), emergency wards, intensive care units, and operation theatres. Portable ultrasound is easy to carry, non-invasive, relatively economical, easily reproducible, and widely available, and it has a good safety record.¹¹ Various studies have shown that ultrasound is a novel tool to confirm proper ETT placement.¹²⁻¹⁹ Confirmation with ultrasound is a potential alternative when detection of CO₂ by capnography is compromised, where capnography is not available, or as an adjunct to capnography.

In recent years, an increasing number of original research publications have evaluated the accuracy of ultrasound for confirming ETT intubation and have reported high sensitivity and specificity using this technique.^{6,7,12-19} Two previous attempts were made to address this important clinical issue, one in 2011 in the form of a systematic review and one in 2012 in the form of a systematic review with a meta-analysis.^{20,21} Both reviews were presented during conferences, but the full texts were not published in any scientific journal. While one study did not report aggregate sensitivity or specificity, the other included only 323 intubations. After 2012, several high-quality studies were conducted, which encouraged us to undertake this systematic review and meta-analysis to test the accuracy of transtracheal ultrasound in detecting ETT intubation. Unlike the previous reviews, which included both transthoracic and transtracheal ultrasound, the focus of our novel review is on transtracheal ultrasound alone.

Data search

On September 4, 2014, we performed a search of the published research evaluating the diagnostic accuracy of

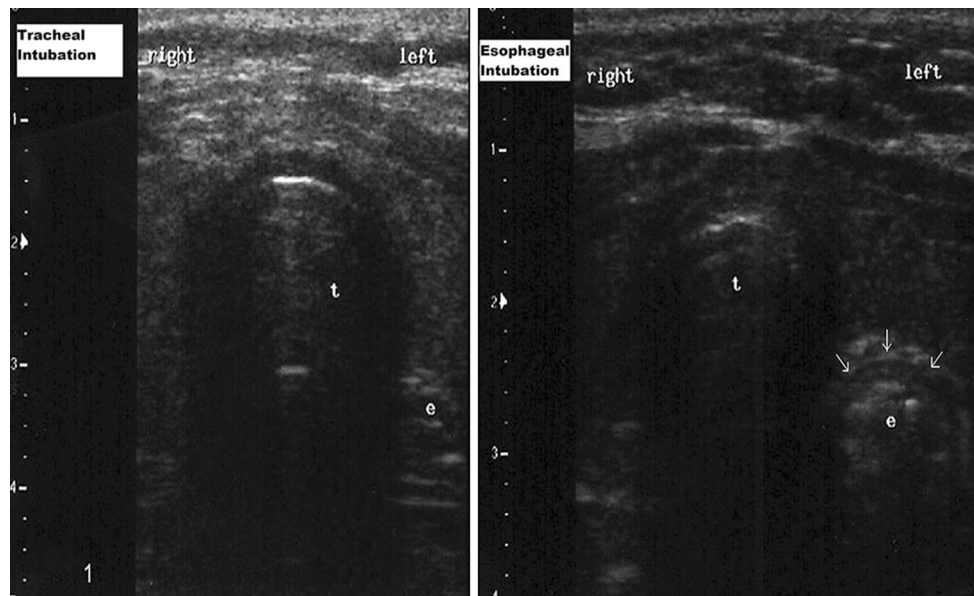


Fig. 1 Shows one air-mucosa interface with comet-tail artifact for tracheal intubation and two air-mucosa interfaces with comet-tail artifact or double-track sign for esophageal intubation. Republished with permission from American Institute of Ultrasound in Medicine (AIUM) from Use of sonography for rapid identification of

esophageal and tracheal intubation in adult patients. Bunyamin Muslu, Hüseyin Sert, Ahmet Kaya, Rüveyda Irem Demircioglu, Muhammet Gözdemir, Brhanettin Usta, Kadriye Serife Boynuklam, 2011;⁷ permission conveyed through Copyright Clearance Center, Inc.

ultrasound. We searched for published literature in the English language in MEDLINE[®] via PubMed, EMBASE[™] via Ovid, The Cochrane Library, and Trip database. For literature published in other languages, we searched KoreaMed and LILACS, and we searched OpenGrey (www.opengrey.eu/) and the World Health Organization Clinical Trials Registry (who.int/ictpr) for unpublished literature and ongoing studies. Details of our search strategy are shown in the Appendix (available as Electronic Supplementary Material). New links displayed alongside the abstracts were followed and retrieved, and the bibliographies in the retrieved articles were searched independently and checked for additional studies. The authors of the articles were contacted where there was any confusion regarding the reported data.

Selection of the studies

Studies using transtacheal ultrasound to verify the ETT position following an emergency or elective intubation were included in this meta-analysis. The ultrasound examination was done by placing a linear or curvilinear probe on the cricothyroid membrane or just above the suprasternal notch. Probe placement was either transverse or horizontal. The ultrasound examination was performed simultaneously with intubation or just afterward. A transverse view at the level of the cricothyroid membrane identified the ETT placement during the process of intubation by the characteristic

“snowstorm sign”, “bullet sign”, or a flutter behind the thyroid cartilage.^{22,23} Upon completion of intubation, ETT intubation was identified by one air-mucosa (A-M) interface with posterior shadowing (comet-tail appearance). Two air-mucosa interfaces with posterior shadowing (double-track) indicated esophageal intubation^{13,14} (Fig. 1).

Study selection was based on the following criteria:

- Studies that evaluated the diagnostic accuracy of transtacheal ultrasound in confirming ETT intubation.
- Studies that verified the result of the index test (ultrasonography) with that of a gold standard (capnography).
- Studies that evaluated the accuracy of ultrasound in living adult humans (i.e., studies on cadavers and neonates were excluded).

Two authors (S.D. and S.C.) and one subject expert (D.P., not an author) independently reviewed the articles, performed a quality assessment, and ascertained the criteria for inclusion in the pooled data analysis. Any disagreement was resolved by consensus. Articles by the same author(s) were carefully investigated to avoid duplication of studies.

The quality of the study reports was assessed with the QUADAS-2 tool (www.quadas.org) (supplement), and the results of the assessment are presented in tabular form.²⁴ QUADAS-2 is recommended for use in Cochrane diagnostic test reviews.²⁵ This tool consists of four key domains that address patient selection, index test (including timing), reference standard (including, flow and timing),

and flow of patients through the study. The tool should be used in four phases: 1. summarizing the review question, 2. developing review-specific guidance, 3. reviewing the published flow diagram of the primary study or construct a flow diagram if none is reported, and 4. assessing risk of bias and concern regarding applicability.²⁴

Data synthesis

We arranged the data in 2×2 tables expressing true positive, false positive, false negative, and true negative. In the primary studies where data were not expressed in contingency tables, we reconstructed 2×2 tables from the number of ETT and esophageal intubations.

Data analysis

We constructed the forest plots with freeware Meta-DiSc, version 1.4 software (<http://www.hrc.es/investigacion/metadisc-en.htm>; Ramon y Cajal Hospital; Madrid, Spain).²⁶ Pooled sensitivity and specificity and their corresponding 95% confidence intervals (CIs) were obtained. To test for heterogeneity among various studies, eyeball tests and the (Cochran Q) were performed. A *P* value of < 0.10 indicated significant heterogeneity. Meta-DiSc computes the inconsistency index (I^2), which has been proposed as a measure to quantify the amount of heterogeneity. Inconsistency (I^2) describes the percentage of total variation across studies that are due to heterogeneity rather than due to chance. The I^2 can be readily calculated from basic 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* is computed by summing the squared deviations of each study's estimate from the overall meta-analytic estimate. Sensitivity analysis was performed to ascertain the robustness of the result of the review after excluding the studies where intubations were done electively in a controlled environment and studies that had more than one area of high or unclear risk of bias. Another sensitivity analysis was done after excluding studies that did not use one A-M interface with comet-tail or reverberation artifact or similar features for tracheal intubation and those that did not use two A-M interfaces with comet-tail or reverberation artifact or similar features for esophageal intubation.

The method of analysis was decided prospectively before commencement of the data search.

Results

The review process and selection of included studies are presented in Fig. 2. Twelve studies met the inclusion

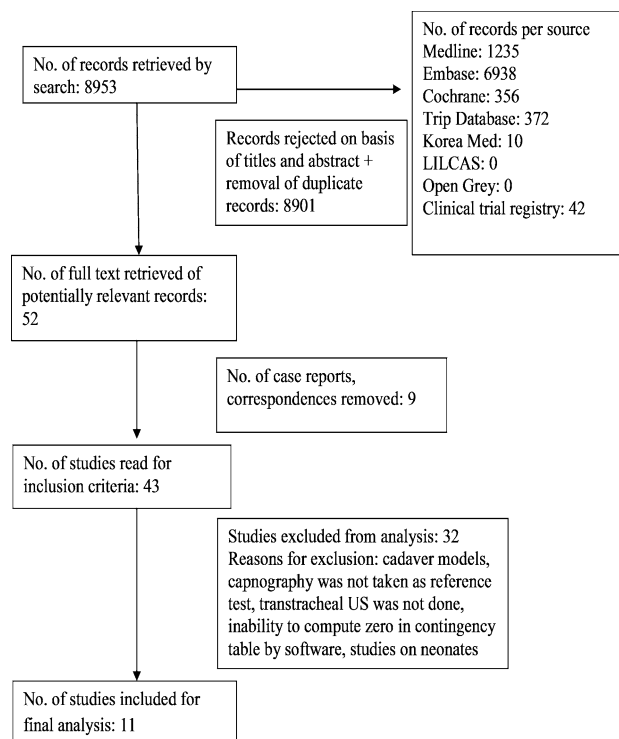


Fig. 2 Represents the review process and included studies

criteria for the present analysis. Three studies examined the accuracy of ultrasound in elective intubations, whereas the others assessed the accuracy of ultrasound in emergency intubations. In most of the studies, the intubations and ultrasound examinations were performed by the emergency physicians. One study was excluded from the final analysis as it was difficult to compute zero in the contingency table using the meta-analysis software.²⁶ Finally, eleven studies and 969 intubations were analyzed. The following characteristics of the included studies are presented in Table 1: year of publication, country of origin, setting of the study, sample size, sonographic features to distinguish ETT or esophageal intubation, type of probe and its position, ultrasound operator, time taken to complete the ultrasound assessment, and the accuracy of the ultrasound.

The quality of the included studies as assessed by QUADAS-2 is presented in Table 2. The majority of the studies had low risk of bias regarding patient selection, index test, reference test, flow & timing, and the applicability of the index and reference tests.

The pooled sensitivity and specificity for detection of proper ETT placement with ultrasound were 0.98 (95% CI 0.97 to 0.99) and 0.98 (95% CI 0.95 to 0.99), respectively (Fig. 3).

Sensitivity analysis was done after excluding three studies with elective intubations. The aggregate sensitivity and specificity of ultrasound in emergency intubations

Table 1 Characteristics of the studies which met the inclusion criteria

Study	Years	Origin	Em/El	n	US sign	US probe	Probe position	Operator	Time*	TP	FP	FN	TN	Sn	Sp
Hoffmann B ²⁷	2014	USA	Em	101	4	7-10 M L	ssn	EP	30 to 120	91	0	0	10	100	100
Sun JT ²⁸	2014	Taiwan	Em	96	1	3.75 M	ssn	EMR	10	89	1	0	6	100	86
Chou HC ¹³	2013	Taiwan	Em	89	1	3.75 M C	ssn	EMR	10	82	1	0	6	100	86
Adi O ²⁹	2013	Malaysia	Em	107	2	10 M L	ctm to ssn	EMR	14 (6)	99	0	2	6	98	100
Abbasi S ²²	2013	Iran	Em	120	3,4,5,6	7.5-10 M L	ssn/ctm	EMR	-	100	0	6	14	94	100
Saglam C ³⁰	2012	Turkey	Em	69	1	10 M L	ssn	EP	< 60	62	1	2	4	97	80
Noh JK ³¹	2012	Korea	Em	19	-	-	ssn	-	5	16	0	0	3	100	100
Muslu B ⁷	2011	Turkey	El	150	7	9-12 M	ssn	Anesth.	3	75	0	0	75	100	100
Chou HC ¹⁴	2011	Taiwan	Em	112	1	3.75 M C	ssn	EMR	9 (8)	94	1	1	16	99	94
Werner SL ⁶	2007	Cleveland	El	66	8	5-10 M	ssn	Physician	-	28	0	0	38	100	100
Milling TJ ²³	2007	New York	El	40	9	3-5H	ctm	EMR	-	34	0	1	5	97	100

Em = study population required emergency intubations; El = study population required elective intubation. Confirmatory ultrasound sign for endotracheal intubations: Sign 1 = one air-mucosa interface with comet-tail artifact for tracheal intubation and two air-mucosa interface with comet-tail artifact for esophageal intubation, or a similar sign. Sign 2 = two symmetrical hyperechoic lines on transtracheal ultrasound indicates tracheal intubation; empty trachea, moving the probe shows dilated esophagus, two hyperechoic lines inside the esophagus indicates esophageal intubation. Sign 3 = one air-mucosa interface with comet-tail artifact for tracheal intubation indicates tracheal intubation; Sign 4 = two air-mucosa interface with comet-tail or reverberation artifact and posterior shadowing or double-track sign indicates esophageal intubation; Sign 5 = snowstorm sign indicates tracheal intubation; Sign 6 = bullet sign indicates tracheal intubation; Sign 7 = hyperechoic shadow or comet sign, opening of esophagus by the endotracheal tube. Sign 8 = shadowing posterior to the tracheal rings, shadowing posterior to the tracheal rings and in the left paratracheal space. Sign 9 = a brief flutter deep to the thyroid cartilage, hyperechoic curved sign with shadowing on side or deep to trachea. Sign 1,2,7, and 8 describe similar ultrasound images

n = number of intubations. Time * = time required in seconds to complete ultrasound examination presented in mean (SD) or median (interquartile range). M = MHz; L = linear probe; C = curvilinear probe; TP = true positive; FP = false positive; FN = false negative; TN = true negative; - = not reported; ssn = just above the suprasternal notch; ctm = cricothyroid membrane; EMR = emergency medicine resident; EP = emergency physician; Anesth = anesthesiologist; Sn = sensitivity; Sp = specificity; US = ultrasound

were 0.98 (95% CI 0.97 to 0.99) and 0.94 (95% CI 0.86 to 0.98), respectively (Fig. 4).

The pooled sensitivity and specificity of the studies using one A-M interface with comet-tail artifact and two A-M interfaces with comet-tail artifact or similar features were 0.99 (95% CI 0.98 to 1.00) and 0.97 (95% CI 0.94 to 0.99), respectively (Fig. 5).

Pooled sensitivity and specificity of studies with a low risk of bias were 0.98 (95% CI 0.97 to 0.99) and 0.98 (95% CI 0.95 to 1.00), respectively (Fig. 6).

The Cochran X^2 and the inconsistency index (I^2) in the forest plots indicated mild to moderate variation across the studies.

Discussion

The present study showed that ultrasound is a novel tool to confirm ETT intubation with an overall pooled sensitivity and specificity of 98% (95% CI 97 to 99) and 98% (95% CI 95 to 99), respectively. The aggregate sensitivity and specificity of ultrasound in emergency intubations were 98% (95% CI 97 to 99) and 94% (95% CI 86 to 98), respectively (Figs. 3, 4).

One meta-analysis of five studies and 323 intubations reported that the pooled sensitivity and specificity of

ultrasound were 91% (95% CI 74 to 97) and 97% (95% CI 89 to 99), respectively.²⁰ This difference in accuracy compared with the present study may be attributed to fewer studies and the smaller sample size of the previous study.

Another study reported that capnography had 100% sensitivity and specificity in both cardiac arrest and non-arrest patients.¹ Based on 2,192 intubations, a meta-analysis of capnography trials resulted in an aggregate sensitivity of 93% (95% CI 92 to 94) and an aggregate specificity of 97% (95% CI 93 to 99) for confirmation of emergency ETT placement.³² The present review showed comparable sensitivity and specificity of ultrasound, although the sample size of the present study was small (2,192 vs 969).

Transtracheal ultrasound is a relatively simple technique and easy to learn.⁷ A transverse view just above the suprasternal notch could be used to visualize both the trachea and esophagus, but a sagittal view is limited to a long-axis view of either the trachea or one of the paratracheal spaces.⁶ Moreover, the esophagus travels more laterally than the trachea as it moves inferiorly from the level of the cricoid cartilage towards the suprasternal notch.⁶ The typical ultrasound image of intubation (air-mucosa artifact) is due to the sound impedance shift at the interface between the water-filled mucosa and air. This standard pattern is easy to detect, although the tube itself is not identified.⁸

Table 2 Quality assessment of the included studies using the QUADAS-2 tool

Study	Risk of Bias				Applicability		
	Patient Selection	Index Test	Reference Test	Flow and Timing	Patient Selection	Index Test	Reference Test
Hoffmann B ²⁷	☺	☺	?	?	☺	☺	?
Sun JT ²⁸	☺	☺	☺	☺	☺	☺	☺
Chou HC ¹³	☺	☺	☺	☺	☺	☺	☺
Adi O ²⁹	☺	☺	☺	☺	☺	☺	☺
Abbasi S ²²	high	☺	☺	☺	☺	☺	☺
Saglam C ³⁰	high	?	☺	☺	☺	☺	☺
Noh JK ³¹	☺	?	?	?	☺	☺	☺
Muslu B ⁷	☺	☺	high	☺	☺	☺	☺
Chou HC ¹⁴	☺	☺	☺	☺	☺	☺	☺
Werner SL ⁶	☺	☺	☺	☺	☺	☺	☺
Milling TJ ²³	☺	☺	☺	?	☺	☺	☺

☺ = low risk of bias; ? = unclear; high = high risk of bias

Fig. 3 Forest plot for sensitivity and specificity of ultrasonography to detect placement of the endotracheal tube

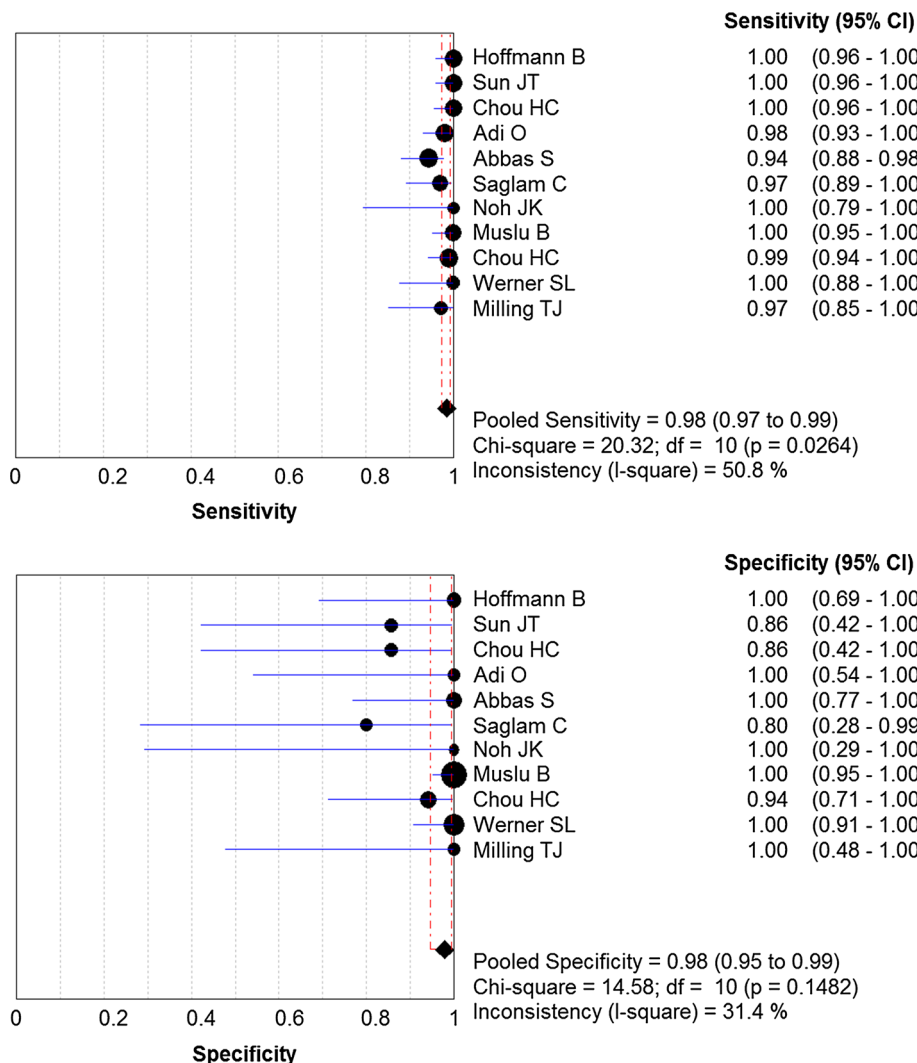
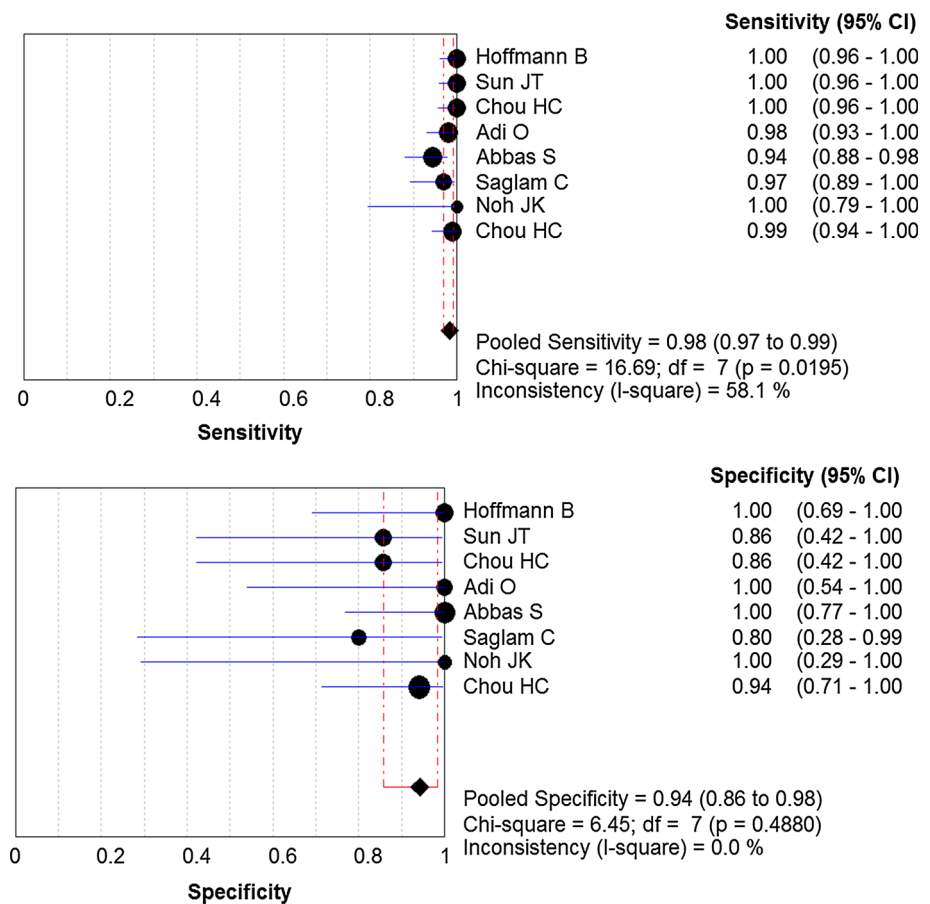


Fig. 4 Forest plot for sensitivity and specificity of ultrasonography to detect placement of the endotracheal tube when study patients required emergency intubation



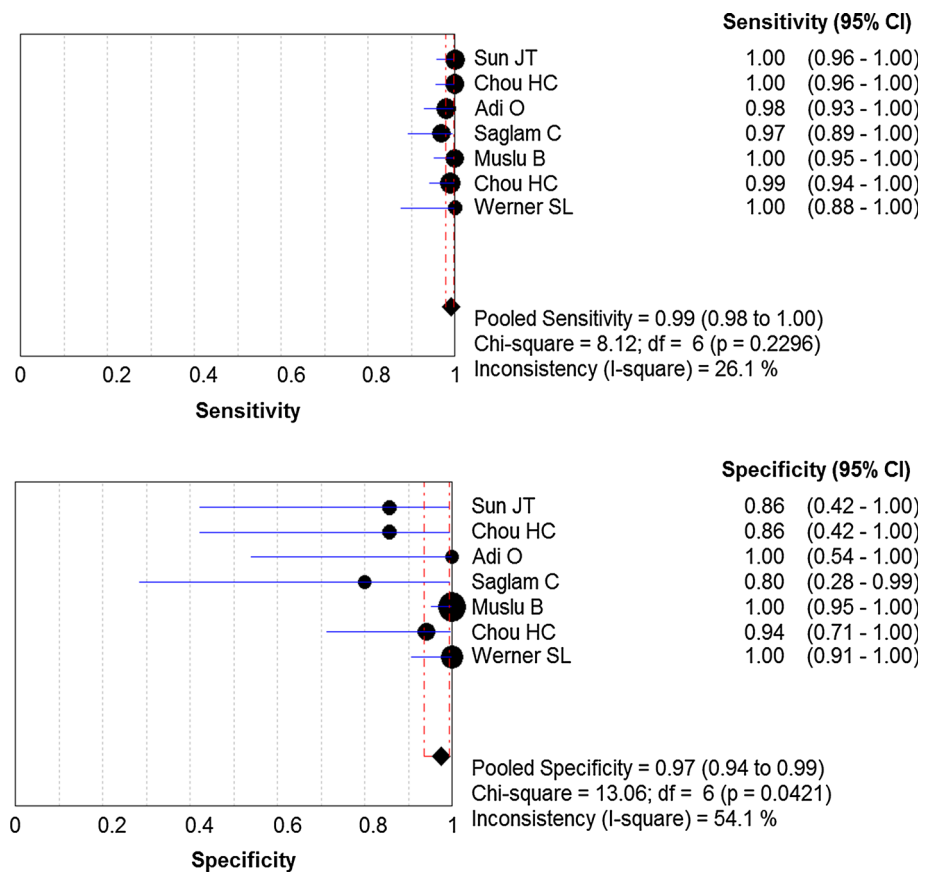
Different authors described different sonographic features to diagnose tracheal and esophageal intubation (Table 1), but close examination of the ultrasound images revealed that almost similar features were described differently. Similar sonographic features of tracheal intubation have been described as follows: one A-M interface with comet-tail or reverberation artifact and posterior shadowing, two symmetrical hyperechoic lines on transtracheal ultrasound, hyperechoic shadow or comet sign, and shadowing posterior to the tracheal rings. On the other hand, there were similar ultrasound features indicating esophageal intubation: two A-M interfaces with comet-tail or reverberation artifact and posterior shadowing, empty trachea and probe movement demonstrating dilated esophagus, two hyperechoic lines inside the esophagus, opening of the esophagus by the ETT, and shadowing posterior to the tracheal ring and in the left paratracheal space. To date, studies are lacking that directly compare the accuracy of different sonographic features. Sensitivity analysis of the studies using one A-M interface with comet-tail or reverberation artifact and two A-M interfaces with comet-tail or reverberation artifact or similar features showed that the pooled sensitivity and

specificity of these signs were 0.99 (95% CI 0.98 to 1.00) and 0.97(95% CI 0.94 to 0.99), respectively (Fig.5).

Several studies of transtracheal or transthoracic ultrasound were performed on cadaver or human subjects, and the diagnostic accuracy of the techniques was reported. These studies reported that transtracheal ultrasound had a sensitivity of 95.7-100% and a specificity of 96.3-100%.^{12,33-37} Transthoracic ultrasound uses either a lung sliding sign or diaphragmatic motion during ventilation to verify the position of the ETT.^{15-19,38} Reported sensitivities and specificities of these methods were 87-100% and 92-100%, respectively.^{15-19,38} We limited our review to the studies pertinent to transtracheal ultrasound. The definite advantage of transtracheal over transthoracic ultrasound is that the former does not need ventilation for confirmation; however, the transtracheal method cannot differentiate between tracheal and bronchial intubation.

The time required to confirm ETT intubation is an important consideration for any method used. Transtracheal ultrasound can be used for verification while the intubation is being performed or upon completion, whereas with capnography, the patient's lungs have to be ventilated a minimum of four to five

Fig. 5 Forest plot for sensitivity and specificity of the studies that used one air-mucosa interface with comet-tail or reverberation artifact and two air-mucosa interfaces with comet-tail or reverberation artifact or similar features



times for confirmation.^{13,14} For this reason, transtracheal ultrasound can diagnose ETT intubation faster than capnography. Various studies have reported that the time required to perform transtracheal ultrasound ranged from 5-45 sec.^{14,29,30} Two studies compared timeliness of ultrasound with that of capnography and found that the median verification time with ultrasound was significantly shorter than with capnography.^{39,40}

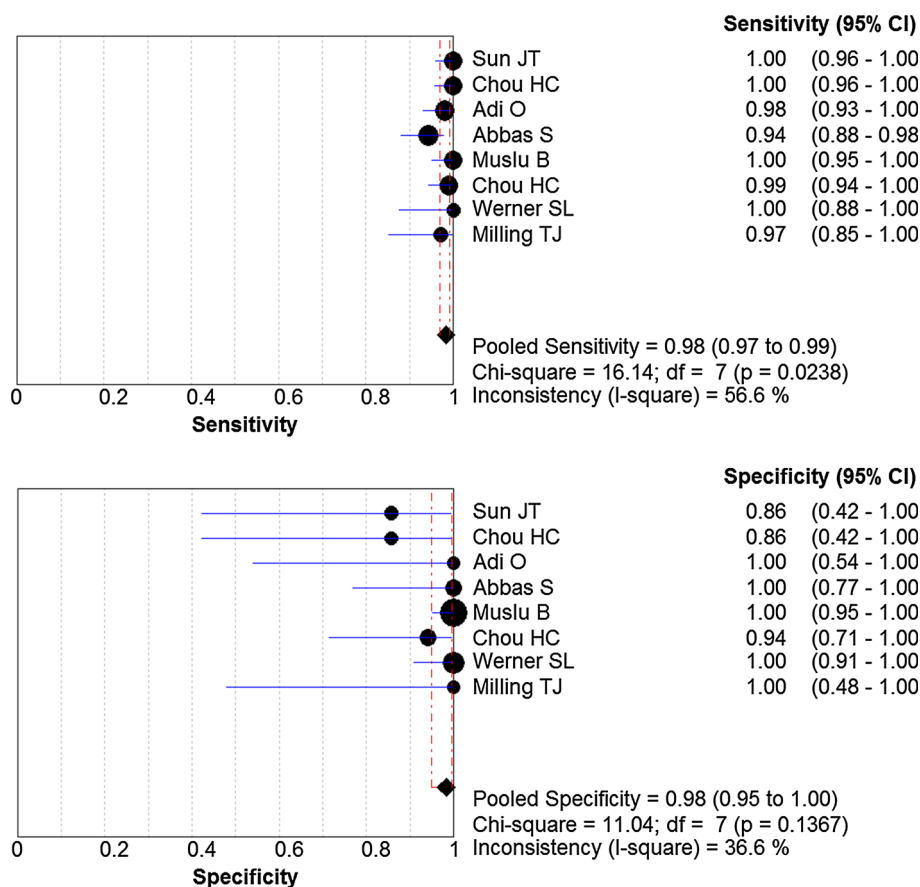
The technique of transtracheal ultrasound to verify ETT placement has potential limitations and pitfalls. The dynamic real-time confirmation approach is potentially challenging because the ultrasound probe is placed at the level of the cricothyroid membrane, and the hand holding the probe lies in the path of the laryngoscope handle during intubation. Moreover, dynamic confirmatory signs, e.g., a brief flutter deep to the thyroid cartilage, can be detected only during real-time monitoring and not after intubation.

The ultrasound device cannot be used instantaneously as it requires start up, warm up, and adjustment of the depth and gain settings. Most in-hospital cardiac arrests occur on the ward in the early hours of the morning;⁴¹ thus, it is more complex and time consuming than simply applying the probe onto the patient's skin, particularly in emergency scenarios. A portable ultrasound device is usually equipped

with a black and white LCD display. Under daylight, in a pre-hospital setting, the reflection of the sunlight on the LCD screen may make it difficult to view ultrasound images. Moreover, surgical emphysema, difficult neck anatomy, and calcification may obscure the ultrasound image.^{8,42} Another drawback is the need for a second person to perform the ultrasound examination, which is not always feasible in emergency conditions.

Unlike capnography, the accuracy of the ultrasound examination is operator dependent, so training and experience of the operator may influence the sensitivity and specificity of the ultrasound examination. In the present review, ultrasound was performed by emergency medicine residents, physicians, or anesthesiologists after briefings for a couple of hours in a workshop, during a didactic lesson, or by a radiologist.^{6,7,13,14,22,23,29,30,39} One recent study found that experienced ultrasound operators (experience performing more than 150 scans) performed transtracheal ultrasound more accurately than their less experienced counterparts.⁴³ Another study evaluated whether a resident with limited training in bedside ultrasound could accurately predict ETT placement. Two medical residents were trained in transtracheal ultrasound for five hours and verified ETT placement with sensitivity and specificity of 88% and 66%, respectively. Therefore, it

Fig. 6 Forest plot for sensitivity and specificity of studies with low risk of bias. (Studies with more than one area of high or uncertain risk of bias were excluded)



is imperative to gain adequate experience in transtacheal ultrasound to verify ETT placement with a greater degree of accuracy.⁴⁴

Another issue is availability of an ultrasound machine to confirm ETT placement. Availability varies significantly by location and by the characteristics of the individual emergency department. A smaller rural emergency department has significantly less access to bedside ultrasound.⁴⁵

In our study, use of ultrasound failed to diagnose four esophageal intubations and 12 ETT intubations. This deserves close examination and explanation. Since the trachea is a superficial structure, visualization with a low-frequency probe would be difficult.^{13,14} Another explanation for misdiagnosis might be the position of the esophagus immediately behind the trachea, which might make it difficult for the sonographer to appreciate the double-track sign. This problem can be overcome by positioning the probe just above the suprasternal notch or exerting cricoid pressure.^{6,46} False negative results may be due to some anatomical artifacts like calcification within the thyroid gland mimicking the double-track sign.¹⁴

The primary method for ETT verification is visualization of the ETT passing through the vocal cords, which is accomplished by direct laryngoscopy or with a

video laryngoscope. In view of various technical limitations, confirmation with direct laryngoscopy remains the standard and ultrasound is secondary even in the absence of pulmonary flow during cardiac arrest.

This review has some methodological limitations. The total sample size of emergency intubations was small, i.e., eight studies consisting of 713 emergency intubations. The number of esophageal intubations was less than the number of ETT intubations due to a lower incidence rate.

We understand from this review that transtacheal ultrasound is a novel technique with an acceptable degree of accuracy to confirm tracheal placement of the ETT in reasonably less time and without ventilation. This method can be used along with capnography as a preliminary test before final confirmation by capnography. Both transtacheal ultrasound and capnography cannot differentiate between tracheal and bronchial intubation; therefore, transthoracic or diaphragmatic ultrasound should also be performed to avoid endobronchial placement of the ETT.^{15,19}

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Conflicts of interest None declared.

References

1. *Grmec S.* Comparison of three different methods to confirm tracheal tube placement in emergency intubation. *Intensive Care Med* 2002; 28: 701-4.
2. *Salem MR.* Verification of endotracheal tube position. *Anesthesiol Clin North America* 2001; 19: 813-39.
3. *Neumar RW, Otto CW, Link MS, et al.* 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Part 8: Adult advanced cardiovascular life support. *Circulation* 2010; 122: S729-67.
4. *Kodali BS.* Capnography outside the operating rooms. *Anesthesiology* 2013; 118: 192-201.
5. *Cook TM, Nolan JP.* Use of capnography to confirm correct tracheal intubation during cardiac arrest. *Anaesthesia* 2011; 66: 1183-4.
6. *Werner SL, Smith CE, Goldstein JR, Jones RA, Cydulka RK.* Pilot study to evaluate the accuracy of ultrasonography in confirming endotracheal tube placement. *Ann Emerg Med* 2007; 49: 75-80.
7. *Muslu B, Sert H, Kaya A, et al.* Use of sonography for rapid identification of esophageal and tracheal intubation in adult patients. *J Ultrasound Med* 2011; 30: 671-6.
8. *Zechner PM, Breikreutz R.* Ultrasound instead of capnometry for confirming tracheal tube placement in an emergency? *Resuscitation* 2011; 82: 1259-61.
9. *Takeda T, Tanigawa K, Tanaka H, Hayashi Y, Goto E, Tanaka K.* The assessment of three methods to verify tracheal tube placement in the emergency setting. *Resuscitation* 2003; 56: 153-7.
10. *Levine RI, Wayne MA, Miller CC.* End-tidal carbon dioxide and outcome of out-of-hospital cardiac arrest. *N Engl J Med* 1997; 337: 301-6.
11. *Sustic A.* Role of ultrasound in the airway management of critically ill patients. *Crit Care Med* 2007; 35(5 Suppl): S173-7.
12. *Galicinac J, Bush AJ, Godambe SA.* Use of bedside ultrasonography for endotracheal tube placement in pediatric patients: a feasibility study. *Pediatrics* 2007; 120: 1297-303.
13. *Chou HC, Chong KM, Sim SS, et al.* Real-time tracheal ultrasonography for confirmation of endotracheal tube placement during cardiopulmonary resuscitation. *Resuscitation* 2013; 84: 1708-12.
14. *Chou HC, Tseng WP, Wang CH, et al.* Tracheal rapid ultrasound exam (T.R.U.E) for confirming endotracheal tube placement during emergency intubation. *Resuscitation* 2011; 82: 1279-84.
15. *Hsieh KS, Lee CL, Lin CC, Huang TC, Weng KP, Lu WH.* Secondary confirmation of endotracheal tube position by ultrasound image. *Crit Care Med* 2004; 32(9 Suppl): S374-7.
16. *Hosseini JS, Talebian MT, Ghafari MH, Eslami V.* Secondary confirmation of endotracheal tube position by diaphragm motion in right subcostal ultrasound view. *Int J Crit Illn Inj Sci* 2013; 3: 113-7.
17. *Lyon M, Walton P, Bhalla V, Shiver SA.* Ultrasound detection of sliding lung sign by prehospital critical care providers. *Am J Emerg Med* 2012; 30: 485-8.
18. *Weaver B, Lyon M, Blaivas M.* Confirmation of endotracheal tube placement after intubation using the ultrasound sliding lung sign. *Acad Emerg Med* 2006; 13: 239-44.
19. *Sim SS, Lien WC, Chou HC, et al.* Ultrasonographic lung sliding sign in confirming proper endotracheal intubation during emergency intubation. *Resuscitation* 2012; 83: 307-12.
20. *Adhikari S, Farrell I, Stolz U.* 46 How accurate is ultrasonography in confirming endotracheal tube placement? A meta-analysis. *Ann Emerg Med* 2012; 60: S18.
21. *Herman D, Rudd B.* AP003 Where is the endotracheal tube? A literature review of rapid ultrasound confirmation. *Resuscitation* 2011; 82(Suppl 1): S10.
22. *Abbasi S, Farsi D, Zare MA, Hajimohammadi M, Rezai M, Hafezjoghdam P.* Direct ultrasound methods: a confirmatory technique for proper endotracheal intubation in the emergency department. *Eur J Emerg Med* 2014; DOI: [10.1097/MEJ.000000000000108](https://doi.org/10.1097/MEJ.000000000000108).
23. *Milling TJ, Jones M, Khan T, et al.* Transtracheal 2-d ultrasound for identification of esophageal intubation. *J Emerg Med* 2007; 32: 409-14.
24. *Whiting PF, Rutjes AW, Westwood ME, et al.* QUADAS-2: a revised tool for the quality assessment of diagnostic accuracy studies. *Ann Intern Med* 2011; 155: 529-36.
25. *Deeks JJ, Wisniewski S, Davenport C.* Chapter 4: Guide to the contents of a Cochrane Diagnostic Test Accuracy Protocol. In: Deeks JJ, Bossuyt PM, Gatsonic C (Eds). *Cochrane Handbook for Systematic Reviews of Diagnostic Test Accuracy Version 1.0.0.* The Cochrane collaboration, 2013. Available from URL: <http://srdta.cochrane.org/> (accessed November 2014).
26. *Zamora J, Abraira V, Muriel A, Khan K, Coomarasamy A.* Meta-DiSc: a software for meta-analysis of test accuracy data. *BMC Med Res Methodol* 2006; 6: 31.
27. *Hoffmann B, Gullett JP, Hill HF, et al.* Bedside ultrasound of the neck confirms endotracheal tube in emergency intubations. *Ultraschall Med* 2014; 35: 451-8.
28. *Sun JT, Chou HC, Sim SS, et al.* Ultrasonography for proper endotracheal tube placement confirmation in out-of-hospital cardiac arrest patients: two-center experience. *J Med Ultrasound* 2014; 22: 83-7.
29. *Adi O, Chuan TW, Rishya M.* A feasibility study on bedside upper airway ultrasonography compared to waveform capnography for verifying endotracheal tube location after intubation. *Crit Ultrasound J* 2013; 5: 7.
30. *Saglam C, Unluer EE, Karagoz A.* Confirmation of endotracheal tube position during resuscitation by bedside ultrasonography. *Am J Emerg Med* 2013; 31: 248-50.
31. *Noh JK, Cho YS.* The comparison of airway ultrasonography and continuous waveform capnography to confirm endotracheal tube placement in cardiac arrest patients: prospective observational study. *Crit Ultrasound J* 2012; 4(Suppl 1): A6.
32. *Li J.* Capnography alone is imperfect for endotracheal tube placement confirmation during emergency Intubation. *J Emerg Med* 2001; 20: 223-9.
33. *Goksu E, Sayrac V, Oktay C, Kartal M, Akcimen M.* How stilet use can effect confirmation of endotracheal tube position using ultrasound. *Am J Emerg Med* 2010; 28: 32-6.
34. *Ma G, Davis DP, Schmitt J, Vilke GM, Chan TC, Hayden SR.* The sensitivity and specificity of transcricothyroid ultrasonography to confirm endotracheal tube placement in a cadaver model. *J Emerg Med* 2007; 32: 405-7.
35. *Uya A, Spear D, Patel K, Okada P, Sheeran P, McCreight A.* Can novice sonographers accurately locate an endotracheal tube with a saline-filled cuff in a cadaver model? A pilot study. *Acad Emerg Med* 2012; 19: 361-4.
36. *Slovis TL, Poland RL.* Endotracheal tubes in neonates: sonographic positioning. *Radiology* 1986; 160: 262-3.
37. *Park SC, Ryu JH, Yeom SR, Jeong JW, Cho SJ.* Confirmation of endotracheal intubation by combined ultrasonographic methods in the emergency department. *Emerg Med Australas* 2009; 21: 293-7.
38. *Kerrey BT, Geis GL, Quinn AM, Hornung RW, Ruddy RM.* A prospective comparison of diaphragmatic ultrasound and chest radiography to determine endotracheal tube position in a pediatric emergency department. *Pediatrics* 2009; 123: e1039-44.
39. *Pfeiffer P, Rudolph SS, Borglum J, Isbye DL.* Temporal comparison of ultrasound vs. auscultation and capnography in verification of endotracheal tube placement. *Acta Anaesthesiol Scand* 2011; 55: 1190-5.

40. Pfeiffer P, Bache S, Isbye DL, Rudolph SS, Rosing L, Borglum J. Verification of endotracheal intubation in obese patients – temporal comparison of ultrasound vs. auscultation and capnography. *Acta Anaesthesiol Scand* 2012; 56: 571-6.
41. Buff DD, Fleisher JM, Roca JA, Jaffri M, Wyrwinski PM. Circadian distribution of in-hospital cardiopulmonary arrests on the general medical ward. *Arch Intern Med* 1992; 152: 1282-8.
42. Xue FS, Liao X, Wang Q. Confirmation of endotracheal tube placement during emergency intubation. *Resuscitation* 2012; 83: e67.
43. Stuntz R, Kochert E, Kehrl T, Schradling W. The effect of sonologist experience on the ability to determine endotracheal tube location using transtracheal ultrasound. *Am J Emerg Med* 2014; 32: 267-9.
44. Sharma N, Cardenas-Garcia J, Tibb A. Limited training in bedside ultrasound can accurately predict endotracheal tube placement. *Chest* 2013; 144: 547A (abstract).
45. Talley BE, Ginde AA, Raja AS, Sullivan AF, Espinola JA, Camargo CA Jr. Variable access to immediate bedside ultrasound in the emergency department. *West J Emerg Med* 2011; 12: 96-9.
46. Smith KJ, Dobranowski J, Yip G, Dauphin A, Choi PT. Cricoid pressure displaces the esophagus: an observational study using magnetic resonance imaging. *Anesthesiology* 2003; 99: 60-4.