Research Article

Reliability of Ultrasonography in Confirming Endotracheal Tube Placement in an Emergency Setting

Vimal Koshy Thomas, Cherish Paul[1], Punchalil Chathappan Rajeev, Babu Urumese Palatty

Department of Emergency Medicine, [1]Department of Anesthesia and Critical Care, Jubilee Mission Medical College and Research Institute, Thrissur, Kerala, India

Abstract

Background and Objectives: Over the past few years, ultrasonography is increasingly being used to confirm the correct placement of endotracheal tube (ETT). In our study, we aimed to compare it with the traditional clinical methods and the gold standard quantitative waveform capnography. Two primary outcomes were measured in our study. First was the sensitivity and specificity of ultrasonography against the other two methods to confirm endotracheal intubation. The second primary outcome assessed was the time taken for each method to confirm tube placement in an emergency setting. **Methods:** This is a single-centered, prospective cohort study conducted in an emergency department of a tertiary care hospital. We included 100 patients with indication of emergency intubation by convenient sampling. The intubation was performed as per standard hospital protocol. As part of the study protocol, ultrasonography was used to identify ETT placement simultaneously with the intubation procedure along with quantitative waveform capnography (end-tidal carbon dioxide) and clinical methods. Confirmation of tube placement and time taken for the same were noted by three separate health-care staffs. **Results and Discussion:** Out of the 100 intubation attempts, five (5%) had esophageal intubations. The sensitivity and specificity of diagnosis using ultrasonography were 97.89% and 100%, respectively. This was statistically comparable with the other two modalities. The time taken to confirm tube placement with ultrasonography was 8.27 ± 1.54 s compared to waveform capnography and clinical methods which were 18.06 ± 2.58 and 20.72 ± 3.21 s, respectively. The time taken by ultrasonography was significantly less. **Conclusions:** Ultrasonography confirmed tube placement with comparable sensitivity and specificity to quantitative waveform capnography and clinical methods. But then, it yielded results considerably faster than the other two modalities.

Keywords: Capnography, emergency, intubation, ultrasonography

Introduction

Airway management skills are indispensable for an emergency physician. Unrecognized airway accidents such as esophageal intubation tend to occur more in emergency settings,[1] where it is reported as 6%–16%.[2]

Numerous studies have compared methods used for distinguishing between endotracheal and esophageal placement of the tube. Visual confirmation during laryngoscopy, expansion of the chest wall during ventilation, auscultatory method, capnography, and chest X-ray are modalities currently used in practice. These techniques vary in their degree of accuracy.[3-6]

The Advanced Cardiac Life Support (ACLS) 2015 guidelines recommend continuous waveform capnography in addition to clinical assessment as the most reliable method of confirming and monitoring correct placement of an endotracheal tube (ETT).[7] In 1989, in a study, Vaghadia *et al*. came to a conclusion that end-tidal carbon dioxide ($ETCO_2$) is most accurate for identifying esophageal intubation.[8] Capnography has also been found to be the best method for rapid assessment of tube position.[2] Capnography is considered as the gold standard, but it has many limitations. Waveform capnography works on the principle of detection of carbon dioxide. This is only possible when there is sufficient pulmonary blood flow. In conditions where pulmonary blood flow is compromised such as massive pulmonary embolism and cardiac arrest, capnography is not reliable.[9]

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Address for correspondence: Dr. Cherish Paul, Department of Anaesthesia and Critical Care, Jubilee Mission Medical College and Research Institute, Thrissur, Kerala, India. E-mail: drcherish@gmail.com

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Capnography is freely available in operation theaters but not in many emergency departments (EDs). Ultrasound, on the contrary, is emerging in most EDs as it is used in point of care imaging for trauma as well for guided interventions.[10] Ultrasound machine is portable, noninvasive, and the images are easily reproducible.[11] Various studies have shown that ultrasound is a potential method to confirm proper ETT placement.[12-18] In our study, we aim to find the effectiveness of tracheal ultrasonography to confirm ETT placement with the existing methods.

Methods

This study was initiated after obtaining clearance from the Institutional Research and Ethics Committee. One hundred consecutive patients presented to ED with indication for endotracheal intubation were recruited into the study. Patients with significant neck or lung pathologies that would affect the study methods were excluded from the study. Tracheal sonography was performed using a SonoSite M-Turbo linear probe (13-6 MHz). A Philips M-20 monitor with a mainstream $ETCO_2$ analyzer was used for capnography.

Intubation was performed as per the standard hospital protocol which includes confirmation by quantitative waveform capnography and clinical methods looking for bilateral chest rise and 5- point auscultation. The tube was deemed as endotracheal if a typical square waveform capnography was observed along with detection of carbon dioxide of more than 4 mmHg after five breaths.

The sonographer identified the placement of tube as tracheal or esophageal as follows:

- Tracheal intubation if only one air–mucosal (A-M) interface with reverberation artifact and posterior shadowing was observed [Figure 1]
- Esophageal intubation if two A-M interfaces posterior shadowing were noted, which is called a double tract sign [Figure 2].

Time zero was the time at which the person who did the intubation confirmed the completion of intubation. Following this, three different health-care staff simultaneously confirmed the tube placement, and the time taken by each method was noted using a stopwatch. End time noted was the time when individual health-care staff confirmed tube placement with their modality [Pro forma 1].

Two primary outcomes were measured in our study. First was the sensitivity and specificity of ultrasonography against the other two methods to confirm endotracheal intubation. The second primary outcome assessed was the time taken for each method to confirm tube placement in an emergency setting.

Results

Among the 100 patients who underwent intubation, 59 were male and 41 were female. The mean age ± standard deviation was 50.79 ± 16.15 years. The most common indication for intubation was for airway protection (56%), followed by respiratory failure (23%) and for hemodynamic instability (21%).

Out of the 100 patients who underwent intubation, 95% were tracheal and 5% were esophageal. Tracheal ultrasonography correctly detected all 5% of esophageal intubations but misinterpreted 2% of tracheal intubations as esophageal.

The sensitivity, specificity, positive predictive value, and negative predictive value of the ultrasound method are shown in Table 1.

The sensitivity of the ultrasonography technique was compared with that of the other two modalities using McNemar test (two tail) which showed no statistically significant difference between the groups ($P = 0.47$).

The operating time of the different modalities is shown in Table 2. Statistically ultrasonography method (T1) took significantly less time compared to clinical (T2) and waveform capnography (T3) as shown in Figure 3. This was compared

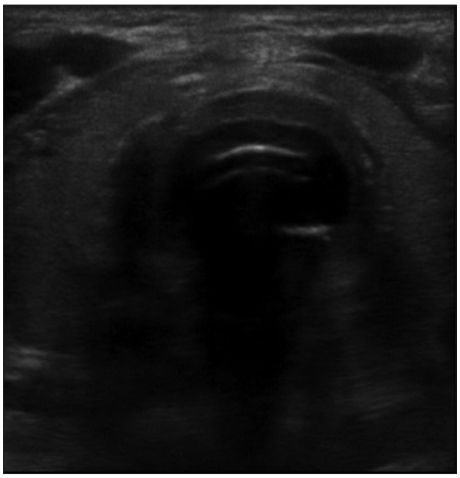

Figure 1: Sonographic image of tracheal intubation

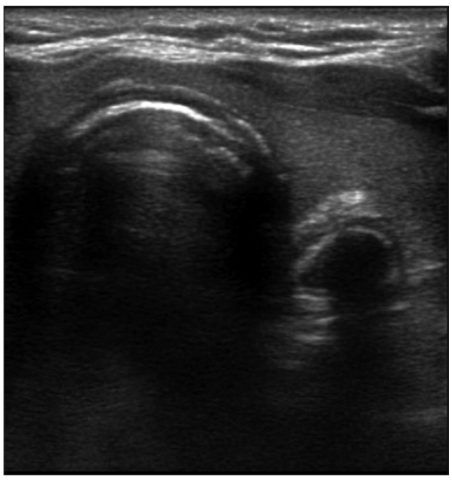

Figure 2: Sonographic image of esophageal intubation with "double tract" sign

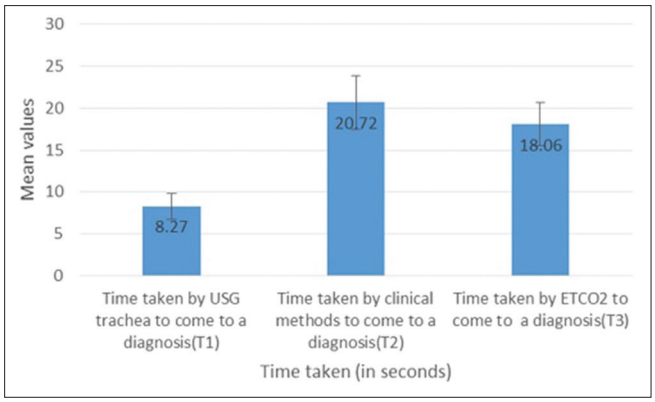

Figure 3: Time comparison

Table 1: Sensitivity and specificity of ultrasonography

	Sensitivity	Specificity	Positive Predictive Value	Negative Predictive Value
USG vs Clinical	97.89%	100%	100%	71.4%
USG vs ETCO2	97.89%	100%	100%	71.4%

Table 2: Operating time of different modalities

Time taken (in seconds)	Min-Max	Mean±SD
Time taken by USG trachea to come to a diagnosis (T1)	5.0-12.0	8.27±1.54
Time taken by clinical methods to come to a diagnosis (T2)	10.20-30.0	20.72±3.21
Time taken by ETCO2 to come to a diagnosis (T3)	13.20-28.30	18.06±2.58
Comparison	**Difference**	***P***
T1- T2	12.46	<0.001**
T1- T3	9.79	<0.001**
T2-T3	2.66	<0.001**
Student *t* test**		

with Student's *t*-test ($P < 0.001$) when ultrasonography was compared with either capnography or clinical methods.

Discussion

Identification of correct placement of ETT has been dependent on the airway specialist's skill in visualizing the vocal cords and on clinical methods to look for equal air entry on both lungs.[19] The vocal cords may not always be visualized, particularly in difficult airway and emergency settings. The accuracy of any technique to identify correct ETT placement is described by its sensitivity and specificity.[20] Many methods have evolved, but no single method has proved to be 100% reliable in distinguishing between tracheal and esophageal intubations.[19]

The ACLS, 2015, mentioned the different methods for identification of ETT placement including ultrasonography by placing a transducer transversely on the anterior part of the neck above the suprasternal notch. In addition, lung sliding sign on ultrasound of the thoracic cavity can identify movement of the lung.[18] It may also help in identifying endobronchial intubation.[20]

Quantitative waveform capnography is not widely available in EDs.[21] In a survey of the American National Emergency Airway Registry series, a total of 77% of physicians reported that colorimetric $ETCO_2$ detectors were available in their hospitals, but only 25% of respondents used continuous quantitative capnography.[22] Hence, another confirmation technique with an easily available equipment is a welcome in EDs. Ultrasound is commonly used in EDs[10] for purposes such as focused intensive care echocardiography,[23] focused assessment of sonography in trauma,[24,25] and for vascular access.[25,26]

Of late, ultrasound is being used in ED for the confirmation of ETT placement.[27]

The use of ultrasound to confirm ETT placement is attractive due to its portability and repeatability with good sensitivity and specificity.[28-31] Moreover, ultrasonographic images are not affected by low pulmonary blood flow as compared to capnography.[32] Tracheal ultrasound detects esophageal intubation even before ventilating the patient, which prevents unnecessary forced ventilation to the stomach and its associated complications.

Using ultrasonography, ETT placement can be confirmed using tracheal, lung, or diaphragmatic scanning. Our study was performed using tracheal sonography which is the most common ultrasound modality used for the same.[12-17,28-37] Transtracheal ultrasound has a sensitivity of 95.7%–100% and a specificity of 96.3%–100% in identifying ETT placement.[38]

Different authors describe different sonographic features to diagnose tracheal and esophageal intubations, but close examination of the ultrasound images revealed that almost similar features were described differently.[12-17,28-37] To date, studies are lacking that directly compare the accuracy of different sonographic features.

Our study results had 5% of esophageal intubations which was comparable to similar studies.[12,29]

Four studies which used tracheal ultrasonography had detected 10% or more esophageal intubations[15,28,32,34] with a high sensitivity and specificity. Three of these studies were conducted at the ED[15,28,32] by emergency medicine (EM) residents while one was conducted at the operating room by anesthesiologists.[34]

One study which used diaphragmatic movement to confirm tube placement had 21% esophageal intubation and detected it with a lower sensitivity (91.7%) and specificity (95.6%).[15]

Three studies which used cadaveric models had higher esophageal intubation rates of 37%–50%.[17,31,35] The sensitivity and specificity of one study was 100%.[17] The cause for high sensitivity and specificity was probably due to the fact that the operators were qualified EM physicians and the study was conducted in a planned laboratory setting.

The other two studies had a lower sensitivity and specificity, probably due to the fact that the operators were residents with <12 months' experience showing operator dependence.

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. Real-time sonographic imaging during intubation had higher sensitivity for detection of esophageal intubation than postintubation scanning.[12,15,30,32,33,35-38]

Using capnography, the patient's lungs would have to be ventilated 5 times for confirmation.[13] 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 to 45 s.[37-39] 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.[40]

Conclusions

Ultrasonography, end-tidal capnography, and conventional clinical methods have comparable sensitivity and specificity in identifying tracheal or esophageal position of ETT.

However, ultrasonography detected the tube placement faster than the other two methods. The time difference is statistically significant, and, considering that the scenario is time critical, it has significant clinical importance. However, multi-centric trials with larger patient groups are needed before routine use of this modality.

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Conflicts of interest

There are no conflicts of interest.

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Pro Forma

Pro forma 1: Ultrasonography for Confirming Endotracheal Tube Placement

Hospital Register No:

Age/Sex:

Vitals:

Indication:

Observer 1: Ultrasonography

Tube placement in - Encircle one

Trachea Esophagus

Total time taken by ultrasonography: T1 (in seconds)

Tube position: Encircle one

Endobronchial Tracheal

Observer 2: 5-point auscultation

Tube placement in - Encircle one

Trachea Esophagus

Time taken by clinical methods: T2 (in seconds)

Tube position: Encircle one

Endobronchial Tracheal

Observer 3: End-tidal capnography

Tube placement in: Encircle one

Trachea Esophagus

Time taken by capnography: T3 (in seconds)

Chest radiography finding

Tube position: Encircle one

Right main bronchus Central Left main bronchus Tube dislodged