

Validation of tracheal intubation of wire-reinforced endotracheal tube with ultrasonography

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ABSTRACT

Objective. The use of ultrasonography (US) is a new method for verifying the location of the endotracheal tube.

Design. Our study was designed as a paired-data and investigator-blind clinical study for evaluating the effectiveness of US for verification of wire-reinforced endotracheal tube (WR-ETT) placement compared with capnography.

Setting. This study was conducted on 56 patients scheduled for elective surgery under general anesthesia.

Patients. Fifty patients completed the study as 6 were excluded for various reasons.

Intervention. Two different investigators performed the ultrasonography and intubation independently from one another. While investigator 1 attempted to verify the location of the WR-ETT with a portable ultrasonography with sagittal trans-tracheal view, investigator 2 intubated the patient and verified the location of the ETT using capnography.

Measurements. Time for verifying the location of the ETT using both US and capnography was recorded.

Main Results. When the ultrasonography method was compared with capnography for verification of the WR-ETT placement, the results showed 95.75% sensitivity and 100% specificity. The average verification times for endotracheal intubation were 12.78 ± 7.46 s. and 24.44 ± 1.45 s. with US and capnography, respectively ($p=0.003$).

Conclusion. Our results suggest that ultrasound identification of a WR-ETT within the trachea is a rapid and accurate method for confirmation of tracheal placement. Larger studies are needed before widespread use of this technique.

Key words: endotracheal tube, intubation, ultrasonography, capnography

INTRODUCTION

Endotracheal intubation is the primary medical procedure used for securing the airway. Confirmation of endotracheal tube (ETT) placement is essential to prevent hypoxia and aspiration. (1-3) Methods used for verifying ETT location include: auscultation of chest and epigastrium, visualization of symmetrical thoracic movement and fogging inside the tube. But these methods are not sufficiently reliable. (1,4-6) Capnography, which detects end-tidal carbon dioxide, is considered as gold standard for verifying the placement of ETT. However, this method also has limitations. Capnography devices do not provide accurate results in cases with low cardiac output and airway obstruction or when epinephrine is used. (7-9) Accuracy of capnography in cardiac arrest is also unclear and studies suggest that up to six breaths may be required before the stomach is completely cleared of CO₂, especially after prolonged bag valve-mask ventilation. The studies have demonstrated that quantitative waveform capnography is the most sensitive tool for confirming tracheal intubation. (2,3,6,8,10) The use of ultrasonography (US) is a new method for verifying the location of the endotracheal tube (ETT) after intubation. (4,7,11) Being non-invasive, cost-efficient and portable, ultrasonography devices are commonly used in emergency services, operating rooms and intensive care units. (1,2,5) Many studies have recently been conducted on the verification of ETT location

through US, including those that attempted to use trachea, diaphragm and intercostal approaches to verify ETT locations. (1-4,7,11-14) Several studies used special expressions, such as sign, bullet sign, comet-tail artifact, and double tract sign to verify the ETT location. (4,7,12,14) Another interesting study focused on viewing the diaphragm at the subxiphoid level and observing the bilateral movement of the pleura with US in order to confirm proper placement of the ETT. (13) Since US allows for rapid visualization of structures that lay superficial to the oral, pharyngeal, or tracheal air columns which are not apparent until direct laryngoscopy, it can accurately delineate appropriate endotracheal tube size, placement, and assessment of airway edema prior to extubation. (15)

A wire-reinforced endotracheal tube (WR-ETT) is generally preferred to avoid kinking during head & neck and neurosurgical cases. Reinforced tubes can also be useful in prone-positioned patients. (16,17) Our study was designed as prospective, paired-data and investigator-blind clinical study for the purpose of evaluating the effectiveness of ultrasonography for verification of intubation with a wire-reinforced endotracheal tube compared to capnography.

MATERIALS AND METHODS

This study was designed as a prospective, paired and investigator-blinded study performed at the Department of Anesthesiology following the approval of the Institutional Review Board (Ref: 1491-57-14/1539). All of the patients were informed about the details of the study and their

written consents were obtained.

Patients eligible for study enrolment were American Society of Anesthesiologists (ASA) physical status I-II, aged 18–65, with body mass index (BMI) < 40 kg/m² who were admitted for elective surgery under general anesthesia and planned for WR-ETT (Sheridan Spiral-Flex® Oral Reinforced Tubes, Hudson RCI®, Temecula, CA 92589-9020 USA) intubation such as intracranial, intra oral surgery (tonsillectomy, dental, gum and tongue surgery) and operations performed in prone position.

Exclusion criteria were: history of previous difficult intubation or suspected difficult intubation (Mallampati score of 3-4), emergency operations and intubations, abnormal airway anatomy including malignancy, patients with low cardiac output and patients with high aspiration risk and esophageal disease. The patients who had severe bradycardia, hypotension and/or hypertension after induction of anesthesia, and patients with more than two unsuccessful intubation attempts were also excluded from the study.

Patient demographics, height, weight and BMI, ASA status and Mallampati scores were recorded.

The patients were hydrated with 8-10 ml/kg of 0.9% NaCl and midazolam 0.03 mg/kg was administered for sedation. Standard monitoring (electrocardiography, noninvasive arterial blood pressure, heart rate, SpO₂ measurement, temperature monitoring) was performed on all the patients.

Anesthesia was induced with 2 mg/kg of propofol and fentanyl 1 mcg/kg, following mask ventilation, neuromuscular blockade was performed with vecuronium bromide 0.1 mg/kg and after two minutes of mask ventilation, endotracheal intubation was attempted by direct laryngoscopy.

Three investigators were involved in the procedure: one anesthesiologist performed the intubation and bag ventilation, the other performed the US and the third, independent anesthesiologist, administered anesthetic drugs and performed the auscultation. Investigators expressed their opinions simultaneously and independently from one other, and the information was recorded on a form. The investigator performing US was blinded from communicating verbally with the others by wearing headphones and a drape was attached to prevent visual contact.

Investigator 1: An experienced investigator, had received US training prior to the procedure and observed intubation with sagittal transtracheal US 20 times before the study. He performed US using transportable ultrasound equipment (SonoSite

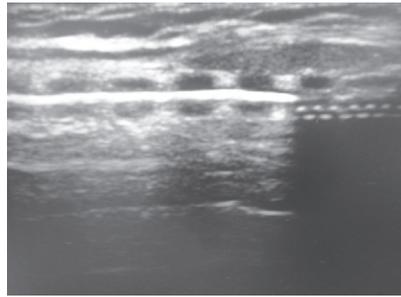


Figure 1. The image of the wire-reinforced endotracheal tube (White arrow), orange arrows: tracheal rings

M-Turbo; SonoSite Inc, Bothell, WA) with an HFL 38 mm 13–6 MHz linear array transducer. The probe was placed sagittally between cricothyroid membrane and suprasternal notch during anesthesia induction. The investigator recorded time for verification of endotracheal intubation with US. Verification time was accepted as the time between the WR-ETT passing the vocal cords and recognition of the image (figure 1). The US probe was moved to the right and left or in tilted position in order to view better imaging. If the investigator was unable to view the WR-ETT on the trachea within 30 seconds, he did not check the tube location further, regardless whether the tube was on the esophagus or not.

Investigator 2: Anesthesiologist, with at least 3 years of experience, used a Macintosh blade number 3-4 to perform the endotracheal intubation after induction of anesthesia and neuromuscular blockade. Maximum number of attempts was limited to two. Laryngoscopic view was classified using the Cormack–Lehane (C-L) classification and recorded. After the tube had passed through the vocal cords, manual bag-valve-mask ventilation was initiated. Capnography waveforms showing a quantity of >4 mmHg CO₂ after six ventilations were used as the criteria for confirming endotracheal intubation. (7) The investigator recorded the time for verifying the location of the ETT using capnography.

Investigator 3: As a standard protocol, the third anesthesiologist auscultated the epigastrium first, then right and left hemithorax, respectively.

STATISTICS

In a small pilot study conducted on 10 patients, the standard deviation (SD) for verification time of WR-ETT by US was approximately 12 s. It was estimated that the SD difference between the two methods

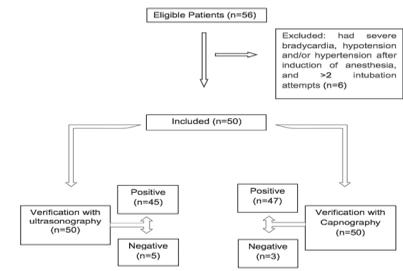


Figure 2. Study flow diagram

would be approximately 9 s. An SD ratio of 0.9, with a two-tailed α error of 5% and a β error of 20%, results and a final power of 80% could be reached by enrolling 40 patients in the study. The possibility of exclusion during the study was taken into consideration and therefore, the number of the patients was raised by 40% and their number determined as 56.

Statistical analysis was done with the SPSS for Windows 15.0 (Chi, IL, USA) statistical package program. Descriptive statistics were given as frequency, mean, standard deviation and proportions. A 2-by-2 table was used to calculate the sensitivity and specificity, for determination of tube placement. For comparison of methods, a paired t-test was used and P-value less than 0.05 were considered statistically significant.

RESULTS

56 patients in total were enrolled but 6 patients (4 had severe bradycardia, hypotension and/or hypertension after induction of anesthesia, 2 had more than two intubation attempts) were excluded from the study. Thus, 50 patients were available for comparison of methods. Baseline characteristics of the patients are shown in table 1. After endotracheal intubation, ETT was verified in trachea with US in 45 patients, while capnography verified 47 endotracheal intubation and 3 patients were not verified with capnography but with esophageal intubation (figure 2). When US method was compared to capnography for verifying endotracheal placement of ETT, there was 95.75% sensitivity and 100% specificity.

Upon comparing ultrasound with capnography, there was a significant difference between the two methods. The average time for verification between US and capnography was 12.78 ± 7.46 s. and 24.44 ± 1.45 s., respectively ($p=0.003$).

Table 1. Baseline Characteristics of the Patients. Mean ± SD

Age (years)	42.9 ± 16.4
Height (cm)	170 ± 8.8
Weight (kg)	73.9 ± 13.4
Body Mass Index (kg/m ²)	25.6 ± 4.4
Gender (Female/Male)	22 / 28
ASA Score (I / II)	33 / 17
Mallampati Score (I / II)	34 / 16
C-L Classification ((I-II) / (III-IV))	41 / 9

ASA, American Society of Anesthesiologists; C-L, Cormack–Lehane.

DISCUSSION

In this, prospective, paired-data and investigator-blind clinical study, we found that the use of the US for verification of the location of WR-ETT had a high success rate, providing approximately 2 times faster results than capnography.

US was initially used on newborn babies to verify intubation in a 1986 study conducted by Slovis et al. (11) The aortic arch was taken as the reference point, and 85% of the intubations provided accurate results. The studies reported that sensitivity and specificity rates of the quantitative waveform capnography during verification of the ETT location were 100% and 100%, respectively. (2-4,6,10) Therefore, we viewed quantitative waveform capnography as the gold standard method for use in verifying WR-ETT location and compared it with US in our study. The capnography device may not give accurate results in cases such as low cardiac output, low pulmonary flow, and airway obstruction or when epinephrine is used. (7-9) Therefore we excluded cases with low cardiac output from the study.

The studies in which US was used to verify standard ETT location have sensitivity and specificity rates of 62.5% and 75%, respectively. (1,2,11-14) We determined the sensitivity and specificity rates as 95.75% and 100%. This result demonstrates that the verification of WR-ETT through US had a high success rate. Since no prior study has been conducted on the verification of WR-ETT through ultrasonography, the data we obtained can be used as a reference for other studies.

In a study Stuntz R et al. (1) conducted on a cadaver, the average amount of time it took to verify ETT location through US was 24.7 s. In another study, conducted by Adi O et al. (2) the average time was re-

ported to be 16.4 s., and ultrasonography was found to be faster than capnography for verifying ETT location. Chou HC et al. (7,14) calculated the time for verifying ETT location as 14 s similarly to our study as it took 12.7 s to verify WR-ETT location through US. This time was equal to half of the average verification time through capnography. This can be attributed to the rapid recognition of the WR-ETT image on US.

Laryngoscopic imaging and intubation success are different concepts. Nearly all of the studies in the literature, including our study, took the laryngoscopic image classification as the basis for intubation success. (18-20) The classification defined by Cormack–Lehane is the most popular laryngoscopic imaging method used in complex airway estimation. (19,20) The C-L III-IV laryngoscopic image is used in practice as an indicator of a complex intubation. (18-20) It should, however, be noted that the improvement of laryngoscopic imaging conditions does not necessarily mean higher intubation success. (20) Although larynx and glottis are imaged very clearly, placing and advancing the endotracheal tube through trachea can sometimes fail. (20) In our study, the number of C-L III-IV patients was determined as 9 (18%). Imaging the upper airway in obese patients through ultrasonography is a complicated procedure. (21) In our study, where the image of the WR-ETT on US was studied for the first time, we excluded the patients whose BMI was ≥40, as we wanted to prevent any unnecessary loss of time. This exclusion, however, served as one of the limitations to our study. Therefore, we plan to conduct a similar study on obese patients as soon as possible.

Another limitation to this study was the absence of esophagus imaging through US. Again, we chose not to use esophageal im-

aging as this would lead to the loss of time for our study since we focused on sagittal transtracheal US for endotracheal confirmation of WR-ETT.

The high sensitivity and specificity rates observed in our study may have partially resulted in excluding the patients suspected of having complex airways (Mallampati III-IV, the patients who have an anatomical deformity of airways) and high risk patients (patients who required urgent surgery or who had low cardiac output) from the study.

Although we emphasize in our study that the sensitivity and specificity of capnography for verifying ETT location was 100%, a meta-analysis conducted by Li et al. (8) determined that the sensitivity and specificity of capnography in 2,192 intubations were 93% and 97%, respectively. As seen from these results, no single method seems to be sufficient for verification of endotracheal intubation. (3) There are also some reports stating that confirmation of optimal ETT depth is possible with US when saline is used to inflate cuff in contrast to capnography, since it does not distinguish between endobronchial and endotracheal intubation. Auscultation may also be insufficient since background noise interferes in emergency department especially. (22,23) Thus, US is a promising approach for confirming not only endotracheal intubation, but also the proper placement of the ETT.

Consequently, the WR-ETT has a very distinctive appearance with sagittal transtracheal US, resulting in high sensitivity and specificity rates for endotracheal intubation verification. Our results suggest that ultrasound identification of a WR-ETT within the trachea is a rapid and accurate method for confirming the tracheal placement. Larger studies are needed before this technique becomes widely used.

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