Original Research Article

To compare upper airway ultrasonography concerning end-tidal capnography in the rapid confirmation of endotracheal tube placement in patients requiring intubation for elective surgeries under general anesthesia and to determine the sensitivity, specificity, positive predictive value and negative predictive value of upper airway ultrasonography

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Abstract

Background: Ultrasound (US) imaging technique has recently emerged as a novel, simple, portable, non-invasive tool helpful for airway assessment and management. It helps in rapid assessment of the airway anatomy in the operation theatre, intensive care unit, and emergency department. Various clinical applications of US imaging of the upper airway include identification of endotracheal tube

(ETT) placement, the guidance of percutaneous tracheotomy, and cricothyroidotomy detection of subglottic stenosis prediction of difficult intubation and post-extubation stridor prediction of pediatric ETT and double-lumen tube (DLT) size.

Aim of the study: To determine the sensitivity, specificity, positive predictive value, and negative predictive value of upper airway ultrasonography and to estimate verification time by ultrasonogram.

Materials and methods: This comparative study was conducted within 100 patients Posted for elective surgeries under general anesthesia at the Department of Anesthesiology, Tirunelveli Government Medical College hospital from April 2018 to March 2019. All intubations were identified and confirmed with USG by a single anesthesiologist. The researcher performed the upper airway USG examination after placement of ETT. The capnography monitor faced away from the sonographer. Intubation was done by another anesthesiologist. Both the researchers were blinded and did not communicate with each other verbally or visually. The procedure of USG confirmation did not interfere with the overall patient intubation procedure or surgery.

Results: More than 95% patient came underscoring of 1 and 2, only 2% of patients came under score 3. The majority of patients belong to the grade 1 category of the Cormack Lehane scoring system. The mean value of neck circumference in tracheal intubation was 36.46 +/-2.91 and esophageal intubation was 37.83 cm+/-5.19 which was not statistically significant (p-value 0.28900). Out of 94 patients, the USG detected the ET tube position in the trachea in 90 patients correctly (sensitivity was 95.74). ET tube position in the esophagus was correctly identified as esophagus by USG in 6 patients (specificity was 100%).

Conclusion: Upper airway USG is as accurate as capnography in diagnosing esophageal intubation. Both upper airway USG and capnography have a good agreement and quick confirmation times; though capnography is about 9 s faster. Therefore both upper airway Ultrasonography and capnography can be used as primary procedures for the confirmation of endotracheal tube placement.

Key words

Upper airway ultrasonography, End-tidal capnography, Positive predictive value, Negative predictive.

Introduction

As the decades unfold, there has been a great revolution in airway management skills. Inability to adequately confirm the placement of an endotracheal tube in a pharmacologically paralyzed patient (as in elective operation theatre) or emergency settings can be a catastrophic situation. Confirmation of successful ET tube placement is very important because the incidence of intubation into the esophagus is approximately 6% in emergencies and 1.75% in elective settings which can be disastrous. 69% of the death was related to airway management [1]. Direct visualization of the ET tube passing through the vocal cord is a proper confirmation of tube placement but not always possible if laryngoscopy is very difficult. The other different way of technique for confirmation of ET tube includes auscultation, observation of chest wall movement visualization of condensed vapor settling in the tube, increasing heart rate, but each of it has its limitation. The gold standard technique is the detection of end-tidal carbon dioxide (ETCO2). Capnography has high sensitivity and specificity [2]. It has false-negative results in severe airway obstruction, low cardiac output, severe hypertension, and pulmonary embolism. Unfortunately, ETCO2 is not freely available, neither is its presence feasible everywhere as in small centers. Therefore we hypothesize to use USG (ultrasonography) is an indispensable method in ETT (endotracheal tube) position confirmation [3]. Several studies of upper airway USG for confirmation of ET tube position showed good results especially for inpatients under controlled

operating room conditions. Ultrasound (US) imaging technique has recently emerged as a novel, simple, portable, non-invasive tool helpful for airway assessment and management. It helps in rapid assessment of the airway anatomy in the operation theatre, intensive care unit, and emergency department [4]. Various clinical applications of US imaging of the upper airway include identification of endotracheal tube (ETT) placement, the guidance of percutaneous tracheostomy and cricothyroidotomy, detection of subglottic stenosis prediction of difficult intubation and post-extubation stridor prediction of pediatric ETT and double-lumen tube (DLT) size [5]. In this prospective observational study, we compared upper airway USG concerning the gold standard method of waveform capnography for rapid confirmation of ET tube placement in patients posted for elective surgeries under general anesthesia [6].

Materials and methods

After obtaining a waiver of consent from the Institutional Scientific and Ethical Committee, a prospective, single-center, randomized double-blinded control study was conducted on 100 adult patients posted for elective surgeries requiring intubation under general anesthesia in the operation theatres of Tirunelveli Medical College Hospital (Tertiary care hospital), Tirunelveli, Tamil Nadu between the period from April 2018 to March 2019. The subjects were enrolled in this study after getting a written informed consent for Upper airway ultrasonography and end-tidal capnography for confirmation of endotracheal tube placement.

Inclusion criteria: Those who are admitted in ENT, General Surgery, and Gynecology ward for surgery more than 18 years of age. Either sex posted for elective surgery under general anesthesia. Mallampatti scoring from I, II, III, IV.

Exclusion criteria: Difficult/abnormal, airway, Distorted neck anatomy, Neck tumors including thyroid, Pregnancy. The subjects were made to lie supine sniffing position with a pillow under the occiput to achieve the optimum head extension and neck flexion. Monitors –ECG, pulse oximeter, and BP were connected. After pharmacological induction and paralysis with neuromuscular blocking agents, intubation was performed with Macintosh laryngoscope and confirmed with waveform capnography. The endotracheal tube was secured only after the confirmation. Simultaneously, USG of the upper airway was performed to confirm ETT placement. Post intubation verification of ETT was confirmed and validated by both researchers by ultrasonography and quantitative waveform capnography. Only then the tracheal tube was secured. All clinical decisions were taken based on capnography results (exhaled $CO_2 \geq 4$ mm of Hg after >or =5 breaths and detection of characteristic CO_2 waveform) and the USG was not involved in any decision making. Upper airway USG was performed with a commercially available ultrasound machine Esaote Europe B.V. The linear ultrasound transducer of frequency 7–12 MHz was used to perform the study. The ultrasound probe was placed transversely on the neck anteriorly, superior to the suprasternal notch before intubation, and identified relevant structures. Immediately after intubation, the linear transducer probe placed just above the suprasternal notch was used to visualize the endotracheal tube in the trachea both longitudinally and transversely. The probe was then moved to the left to look at the esophagus to see whether it was empty or distended by ETT.

Statistical analysis

Data were entered into MS Excel and analyzed in SPSS 24.0 IBM Analytic software (SPSS Inc., Chicago, Illinois, USA). Quantitative data were expressed as mean, range, and standard deviation, whereas qualitative data were expressed as relative frequencies (n/N). We compared the number of tracheal intubations detected by upper airway USG with that detected

by capnography using the Chi-square test. Using kappa statistics, we determined the strength of agreement between airway upper airway USG and capnography. *P*< 0.05 was considered statistically significant. $ETCO_2$ waveform detection and USG images were compared, to determine the sensitivity, specificity, positive and negative predictive values of upper airway USG examination and its possibility to determine the accuracy of correct endotracheal intubation. Also, the verification time required (total time required for USG confirmation taken as the time from endotracheal intubation to USG confirmation) was calculated.

Results

Majority of patients belonged to the age group 21-40 years (53%). The minimum age enrolled was 18 years and the maximum age was 70 years. Less than 20 years were 5 in numbers, 20 – 30 years 31 in numbers, 30-40 years in 22 40-60 years in 37 in numbers and more than 60 years were 6 in numbers. There was no significant difference in sex distribution (**Table – 1**).

Table – 1: Age distribution.

Age group (Years)	Frequency	Percentage
<20	5	5.0%
21-30	31	31.0%
31-40	22	22.0%
41-50	25	25.0%
51-60	12	12.0%
>61	5	5.0%

Table – 2: BMI.

BMI	Frequency	Percentage
<18.5	2	2.0%
18.5-24.9	55	55.0%
25.0-29.9	31	31.0%
>30.0	12	12.0%

Majority of patients belong to the BMI group (18.5-24.9), 31% percent of patients belonged to the overweight and obesity category (**Table – 2**). More than 95% patient come underscoring of 1 and 2, only 2% of patients come under score3 (**Table – 3**).

Table – 3: Modified mallampatti scoring.

Modified Mallampatti scoring	Frequency	Percentage
1	60	60.0%
2	38	38.0%
3	2	2.0%

Table – 4: ASA category.

ASA	Frequency	Percentage
I	45	45.0%
II	54	54.0%
III	1	1.0%

Table – 5: Cormack and Lehane grading.

Cormack and Lehane grading	Frequency	Percentage
1	80	80.0%
2a	12	12.0%
2b	4	4.0%
3	1	1.0%

Most of the patient belonged to ASA Category I, II (**Table – 4**). More than 80%of patients belong to grade 1. Majority of patients belong to grade 1 category of Cormack Lehane scoring system (**Table – 5**). The position ET tube in the esophagus was high in 2a Cormack and Lehane grading compared to grade 1 (**Table – 6**).

The mean value of neck circumference in tracheal intubation was 36.46 +/-2.91 and esophageal intubation was 37.83 cm+/-5.19 which was not statistically significant (p-value 0.28900). Time was taken to detect ET tube position by USG and capnography. The mean value for capnography detection was 16.79 seconds and for USG detection in 25.97seconds. The earliest time for capnography detection was 15 seconds but 1 case showed the waveform only in 24 seconds. In 6 cases the capnography did not detect any waveforms due to esophageal positioning. The earliest time for USG detection is 21 seconds. In one 1case the USG detected only in 33 seconds. The difference between the

meantime of the two methods is statistically significant (p≤0.0001). Out of 94 patients, the USG detected the ET tube position in the trachea in 90 patients correctly (sensitivity was 95.74). ET tube position in the esophagus was correctly identified as esophagus by USG in 6 patients (specificity was 100%) as per **Table - 7**.

Table – 6: Cormack and Lehane grading * Trachea(t)/ Esophagus(e) cross tabulation.

		TRACHEA(T)/ OESOPHAGUS(E)		Total	
		T	E		
Cormack and Lehane grading	1	77	1	78	P value 0.001
	2a	11	3	15	
	2b	3	1	4	
	3	0	1	1	
	3a	3	0	3	
Total		94	6	100	

Table – 7: Neck circumference.

TRACHEA (T)/ OESOPHAGUS (E)		N	Mean	Std. Deviation	P-value
Neck circumference (cm)	T	94	36.46	2.91	0.28900
	E	6	37.83	5.19	

Discussion

A sample of 100 patients was analyzed and 6 had oesophageal intubations. Upper airway ultrasonography showed a sensitivity of 95.74% and specificity of 100%. The positive and negative predictive values were 100% and 60% respectively. The overall accuracy of Upper airway ultrasonography was 96% [7]. The mean confirmation time by USG was 25.97 seconds and that of capnography was 16.79 seconds [8]. This study covers a wide range of patients who differed significantly in age, weight, and surgeries that were done. All the six oesophageal intubations were identified by Upper airway USG but failed to detect 4 out of 94 tracheal intubations (false negatives) [9]. The rate of oesophageal intubation during the initial intubation was 6% (6 out of 100 cases). Upper airway USG detected all six oesophageal intubations which did not show any waveform on capnography [10]. Therefore, upper airway USG was found to be 100% specific for diagnosing oesophageal intubation [11]. The main strengths of our study are its prospective nature, and that a single researcher performed all ultrasounds. In one study, upper airway ultrasound has a sensitivity of 97% and specificity of 100% in detecting endotracheal tube placement [12]. In the prospective study by Gottlieb M, et al. [12] tracheal rapid ultrasound examination (TRUE), showed a sensitivity and specificity of 98.9% and 94.1% respectively. In our study, the sensitivity and specificity of upper airway USG for diagnosing tracheal intubation concerning capnography were 95.74% and 100%, respectively [13]. In the study conducted by Hiremath AS, et al. the probe was placed horizontally starting from the cricothyroid membrane up to the suprasternal notch [14]. In our study, upper airway USG misidentified four cases (four false negatives) which were tested to be positive by waveform capnography [15]. In one study by Masoumi B, two of the false negatives patients observed were found to have subcutaneous emphysema due to pneumothorax which made the identification of two hyperechoic lines difficult. In our study, false-negative subjects were found to be overweight or obese (BMI - 29.8, 32.8, 31.7, 33) with more subcutaneous fat in the neck region (Soft tissue thickness - 11, 11.8, 11.5, 12.5) which might

have made identification of the hyperechoic comet tail shape, posterior shadowing in the transverse view difficult and therefore failed to detect the ETT placement. Another limitation is that upper airway USG is operator dependent, hence its repeatability and generaliability need to be further studied [16]. Milling TJ, have stated that the linear high-frequency transducer is most suitable for imaging superficial airway structures. USG can be used for direct observation of whether the tube enters the trachea or the esophagus by placing the ultrasound probe transversely on the neck at the level of the suprasternal notch during intubation, thus confirming intubation without the need for ventilation or circulation. In our study we used a linear high-frequency probe placed transversely at the level of suprasternal notch during intubation [17]. In the study by Mort TC on direct ultrasound methods, the ultrasonography was performed in dynamic and static phases and concluded that the value of the operating characteristic for prediction of tracheal ETT placement was acceptable with both dynamic and static ultrasonography. In our study too, we had performed ultrasonography both during and after intubation [18]. Muslu B, et al. compared bedside ultrasonography with a colorimetric end-tidal carbon dioxide detector and chest radiographs in the pediatric population and concluded that ultrasound has better timeliness when compared to chest radiographs. In our study, upper airway USG and capnography have a quick meantime of 25s and 16s respectively, but capnography detected ET tube placement faster than ultrasonography [19]. After intubation, there are several methods of confirmation of endotracheal tube placement. The primary confirmation includes direct observation of the tube passing through the glottis, bilateral chest rise, presence of vapor in the tube, auscultation of breath sounds, and quantitative waveform capnography measurement is done before securing the endotracheal tube [20]. The amount of carbon dioxide in the exhaled air is measured by capnography which is a direct method of confirmation. Our study showed that upper airway ultrasound is also a direct method of visualization of upper airway structures in real-time to identify the proper placement of the endotracheal tube. The reliability of quantitative capnography is a suspect in conditions with the low pulmonary flow like cardiac arrest or severe shock, bronchoconstriction, or other situations in which capnography or ETCO2 might be fallacious whereas upper airway USG images remain undisturbed. USG is portable, relatively cheap, painless with no radiation hazards, and proven safe. Hence Ultrasound has gained popularity in upper airway management especially in peripheral centers and emergency settings where Capnography is not always readily available [21]. Therefore in such settings and emergencies, ultrasound can be used for the confirmation of ETT placement. In overweight and obese patients, upper airway USG is superior to auscultation in speed and accuracy in the verification of placement of the endotracheal tube [22]. In our study, USG identified all 6 esophageal intubations but misidentified four cases of tracheal intubation which showed waveform capnography. Both techniques were time-saving, safe, and faster than other techniques such as chest radiographs. Upper airway USG has the above-mentioned advantages. Therefore, this study suggests that upper airway USG may be used in the primary confirmation of endotracheal tube placement [23, 24, 25].

Conclusion

Upper airway USG is as accurate as capnography in diagnosing esophageal intubation. Both upper airway USG and capnography have a good agreement and quick confirmation times; though capnography is about 9 s faster. Therefore both upper airway Ultrasonography and capnography can be used as primary procedures for the confirmation of endotracheal tube placement

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