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Original Research Article

Evaluation of End Tidal Capnography and Upper Airway Ultrasonography for Confirmation of Endotracheal Tube Placement in Adult Patients Undergoing Elective Surgery

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Abstract:

Background: Confirmation of correct endotracheal tube (ET) placement is essential after intubation. The present study aimed to compare upper airway ultrasonography and capnography for confirmation of endotracheal tube placement in adult patients undergoing elective surgeries.

Methods: This was an observational cross-sectional study conducted in the Department of Anesthesiology, Atal Bihari Vajpayee Institute of Medical Sciences and Dr. Ram Manohar Lohia Hospital, New Delhi between November 2018, and March 2020 among adult patients (age 18-60 years) undergoing elective surgery under general anaesthesia requiring oral ET intubation with ASA physical status I and II.

Results: The present study enrolled a total of 75 patients. The mean (SD) age of the study participants was 37.3 (12.4) and majority were females (58.7%). Of the 75 patients intubated, the position of ETT in trachea was ensured by capnography in 96.0% and by ultrasonography in 93.3% patients ($p<0.05$). The Kappa measure of agreement was 0.737 between ultrasound and capnography for ET tube in trachea at $p<0.001$ ($r = 0.737$; good correlation). The sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of capnography was 100%; of ultrasonography was 97.2%, 100%,100% and 60.0% respectively. The mean (SD) time taken for ultrasonography to confirm endotracheal tube placement was 14.12 seconds (0.91). On the other hand, the time taken for capnography was 18.13 seconds (0.89).

Conclusion: In addition to being simple, non-invasive, portable, rapid, and repeatable, ultrasonography can detect oesophageal intubation even without ventilating the patient.

Keywords: End tidal capnography, Upper airway ultrasonography, Elective surgery, India.

Introduction

Tracheal intubation is performed to maintain airway patency, to protect airway against aspiration, also in conditions where failure to ventilate and failure to oxygenate. Confirmation of correct endotracheal tube placement is essential after intubation which otherwise may lead to disastrous consequences because failure to do so results in iatrogenic morbidity (brain damage) and mortality.[1] Esophageal intubation is the major complication of airway management. The incidence of esophageal intubation is 6.0% in emergency conditions and 1.75% in elective settings. [2]

Endotracheal intubation can be confirmed by various methods like direct visualization of endotracheal tube passing through vocal cords, observation of chest wall movements, auscultatory method, capnography, chest x-ray, and upper airway ultrasound. However, the accuracy of these modalities may vary. [3-5] although many techniques have been recommended to verify endotracheal tube location, there is no single method that is ideal to every situation. [1]

Capnography, graphic display of instantaneous CO2 concentration versus time (Time Capnogram) or expired volume (Volume Capnogram) during a respiratory cycle, used to confirm airway patency and lung ventilation has been most widely used technique in the recent past. [6,7] CO2 can also be measured by infrared spectrography, Raman spectrography, mass spectrography, photo acoustic

spectrography and chemical colorimetric analysis. Capnography not only provides information about CO2 production but also pulmonary perfusion, alveolar ventilation, respiratory patterns, and elimination of CO2 from the circuit and ventilator. So, it also gives rapid and reliable information about life saving condition such as endotracheal tube placement, ventilatory failure, circulatory failure, and defective breathing circuits. [8] The sensitivity and specificity of capnography was found to be 96.8% and 100%.

Therefore, the end tidal carbon dioxide (ETCO2) is considered as standard for identifying esophageal intubation. [9,10] However, the sensitivity of capnography decreases to 72% in patients with cardiac arrest or decreased cardiac output, so it may be unreliable in these patients. [11,12] This can be explained on the basis that capnography relies on physiological factors like ventilation, adequate pulmonary perfusion and gas exchange for its confirmation. To confirm endotracheal tube placement by capnography, ventilation is required. Therefore, in cases of inadvertent esophageal intubation, the initiation of ventilation for checking capnography can lead to drastic complications.

On the other hand, ultrasound is a simple, non-invasive procedure. [13] The clinical applications of upper airway ultrasonography include identification of endotracheal tube placement, [14] guidance of percutaneous tracheostomy [15,16] and cricothyroidotomy, [17] detection of subglottic stenosis, [18] prediction of difficult intubation [19] and post-extubation stridor, [20] prediction of pediatric ETT, [21] and double-lumen tube (DLT) size. [22] However, for accurate analysis of ultrasound imaging, it requires proper selection of transducer probe, orientation and anatomy of airway. Cadaveric studies of ultrasound confirmation of endotracheal tube placement have yielded promising results. [23] Recently it has been used to confirm endotracheal intubation with real time images by placing a linear ultrasound probe transversely on the anterior aspect of the neck at the level of the cricothyroid membrane. [24] Also, studies have been undertaken in elective surgery, ICU and emergency settings to confirm endotracheal tube placement. Against this background, the present study aimed to compare upper airway ultrasonography and capnography for confirmation of endotracheal tube placement in adult patients undergoing elective surgeries.

Materials and Methods

This was an observational cross-sectional study conducted in the Department of Anesthesiology, Atal Bihari Vajpayee Institute of Medical Sciences and Dr. Ram Manohar Lohia Hospital, New Delhi between November 2018, and March 2020. After obtaining due approval from the Institutional Ethics Committee, adult patients (age 18-60 years) undergoing elective surgery under general anaesthesia requiring oral endotracheal tube intubation with ASA physical status I and II were included in the study. However, the study excluded patients with anticipated difficult airway i.e., Modified Mallampati grade III or IV, thyromental distance <6.5cm, mouth opening <3cm, cervical spine disease, anteriorly protruding incisors, retrognathia; History of difficult intubation, airway stenosis, airway masses; BMI >30 kg/m2; neck circumference >40cm; pregnancy; hypertrophied tonsils (grade 3 and 4); and loose denture.

Based on existing evidence, it was found that the upper airway USG has a sensitivity of 96.8% and specificity of 100%.[10] Taking these values as reference, the minimum required sample size with desired precision of 7.0%, 80.0% power and 5.0% level of significance was 73 patients. The present study enrolled a total of 75 patients based on prespecified inclusion and exclusion criteria. The anesthetic technique, procedures for confirmation of endotracheal tube placement by end tidal capnography and ultrasonography are provided in the Supplemental file 1.

The outcomes of the study were to estimate the strength of agreement between upper airway ultrasonography and capnography for confirmation of endotracheal tube placement and record the time taken. The data was entered in Microsoft Excel spreadsheet and analysis was done using Statistical Package for Social Sciences (SPSS) version 21.0. Categorical variables were presented in numbers and percentages; continuous variables were presented as Mean (SD) and Median (IQR). Normality of the data was tested by Kolmogorov-Smirnov test. We used Wilcoxon signed rank test (data was not normally distributed) to compare ultrasonography and capnography. The strength of agreement was assessed using inter-rater kappa agreement. We also estimated sensitivity, specificity, positive predictive value and negative predictive value of ultrasonography and capnography to predict position of ET tube. Significance was considered if p value is <0.05.

Results

The mean (SD) age of the study participants was 37.3 (12.4) and ranging between 19 and 58 years. Majority (33.3%) of the participants were between 21 and 30 years of age, followed by 26.7% participants between 41 and 50 years of age. We included 44 females (58.7%) and 31 males (41.3%) in the present study (Table 1). Of the 75 patients intubated, the position of ETT in trachea by capnography was found in 72 patients (96.0%). On the other hand, ultrasonography ensured position of ETT in trachea in 70 patients (93.3%). There was a significant association (p<0.05) of ultrasound and

capnography, when compared in patients with ET tube in trachea, with 70 patients having ET tube in trachea by both ultrasonography and capnography and 3 patients ET tube not in trachea by both these methods (Table 2).

The Kappa measure of agreement was 0.737 between ultrasound and capnography for ET tube in trachea at $p<0.001$ ($r = 0.737$; good correlation). In the present study, sensitivity, specificity, positive predictive value, and negative predictive value of capnography was found to be 100% (Table 3). On the other hand, the sensitivity, specificity, positive predictive value, and negative predictive value of ultrasonography was found to be 97.22%, 100%,100% and 60% respectively. We found that the time taken for ultrasonography ranged between 13 and 16 seconds with a median (IQR) of 14 seconds (13 to 15) (Table 4). The mean (SD) time taken by ultrasonography to confirm endotracheal tube placement was 14.12 seconds (0.91).

On the other hand, the time taken for capnography ranged between 17 and 20 seconds with a median (IQR) of 18 seconds (17.25 to 19). The mean (SD) time taken by capnography to confirm endotracheal tube placement was 18.13 seconds (0.89). Importantly, this difference was found to be statistically significant ($p<0.05$) (Figure 1).

Table 1: Distribution of study variables

Variables		Frequency	Percentage
Age in years	18-20	5	6.67%
	21-30	25	33.33%
	31-40	12	16.00%
	41-50	20	26.67%
	51-60	13	17.33%
Gender	Female	44	58.67%
	Male	31	41.33%
Position of ET tube in Trachea by capnography	ETT in Trachea	72	96.00%
	ETT not in Trachea	3	4.00%
Position of ET tube in Trachea by ultrasonography	ETT in Trachea	70	93.33%
	ETT not in Trachea	5	6.67%

Table 2: Inter-rater kappa agreement to find out strength of agreement between ultrasonography and capnography regarding position of ET tube

Position of ET tube by ultrasonography	Position of ET tube by capnography		Total	P value	Kappa
	ETT in Trachea (n=72)	ETT not in Trachea (n=3)			
ETT in Trachea	70 (93.33%)	0 (0.00%)	70 (93.33%)	<0.001	0.737
ETT not in Trachea	2 (2.67%)	3 (4.00%)	5 (6.67%)		
Total	72 (96.00%)	3 (4.00%)	75 (100%)		
*Significant at p<0.05					

Table 3: Diagnostic test to find out sensitivity, specificity, positive predictive value and negative predictive value of ultrasonography and capnography to predict position of ET tube

Diagnostic test	Sensitivity	Specificity	Positive Predictive Value	Negative Predictive Value
Position of ET tube in trachea by ultrasonography	97.22% (90.32% to 99.66%)	100% (29.24% to 100.00%)	100% (94.87% to 100.00%)	60% (14.66% to 94.73%)
Position of ET tube in trachea by capnography	100% (95.01% to 100.00%)	100% (29.24% to 100.00%)	100% (95.01% to 100.00%)	100% (29.24% to 100.00%)

Table 4: Comparison of time taken to detect ET tube placement (in seconds) by ultrasonography with capnography of study subjects

Variable	Mean (SD)	Median (IQR)	Range	p value	Performed
By ultrasonography	14.12 (0.91)	14 (13 to 15)	13 to 16	<0.001	Wilcoxon signed rank test; z value = 7.577
By capnography	18.13 (0.89)	18 (17.25 to 19)	17 to 20		

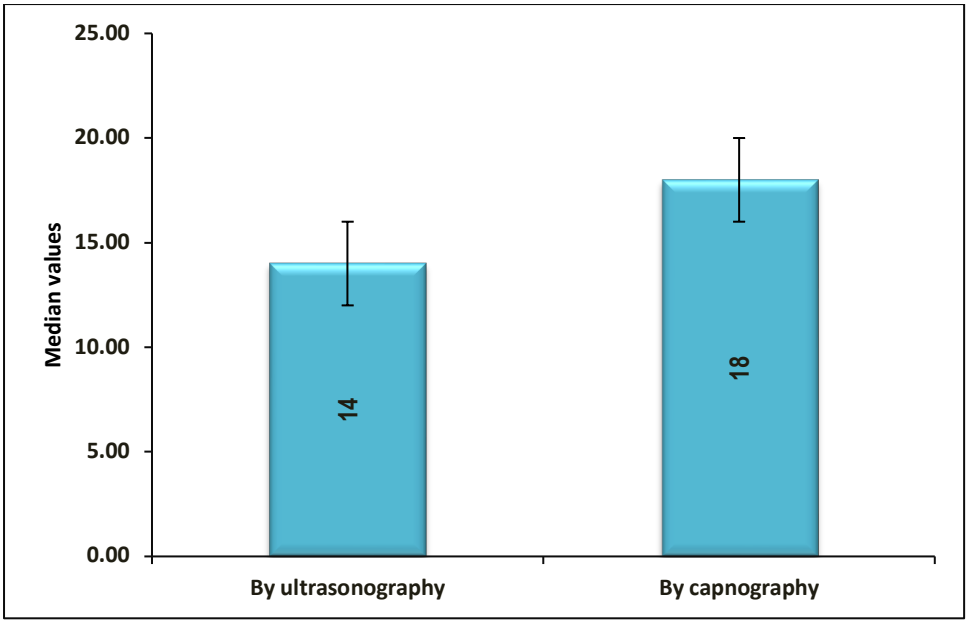

Figure 1: Comparison of time taken to detect ET tube placement (in seconds) by ultrasonography with capnography of study subjects

Discussion

Previous studies undertaken to compare ETCO2, and upper airway ultrasonography have been done on cadavers [25] and in paediatric age groups. Further, most of the studies undertaken on adult population have been carried out in emergency patients and critical care settings. [26] Against this background, the present study was conducted to compare end tidal capnography and upper airway ultrasound for confirmation of endotracheal tube placement.

In the present study, sensitivity and specificity of capnography for confirmation of endotracheal tube placement was found to be 100% (95% CI 95.01% to 100.00%) and 100% (95% CI 29.24% to 100.00%) respectively. Similarly, in a prospective, single-centre, observational study conducted by Osamn adi et al. (2012) to compare quantitative waveform capnography with upper airway ultrasound for confirmation of endotracheal tube placement, it was found that the overall accuracy of bedside upper airway ultrasonography was 98.1% (95% CI 93.0% to 100.0%). Ultrasonography had sensitivity of 98.0% (95% CI 93.0% to 99.8%), specificity of 100% (95% CI 54.1% to 100.0%), PPV of 100% (95% CI 96.3% to 100.0%) and NPV of 75.0% (95% CI 34.9% to 96.8%).

The study concluded that ultrasonography can replace waveform capnography in confirming ETT placement in centres without capnography. [27] In a meta-analysis of selected trials conducted by James Li (2001) to determine the effectiveness of end-tidal CO2 devices for detection of inadvertent esophageal tube placement in emergency populations, it was found that emergency capnography use had an aggregate sensitivity of 93.0% (95% CI 92.0 to 94.0%) and an aggregate specificity of 97.0% (95% CI 93.0 to 99.0%). [28] In the present study, sensitivity, and specificity of ultrasonography for the confirmation of endotracheal tube placement was 97.2% (95% CI 90.3% to 99.7%) and 100% (95% CI 29.2% to 100.0%) respectively. These findings corroborate with the findings of an observational study conducted by Abhishek C et al. (2017). The study found that the upper airway USG had a sensitivity of 96.8% (95% CI 94.3 to 96.8%), specificity of 100% (95% CI 50.6 to 100%), PPV of 100% (95% CI 97.3 to 100%) and NPV of 62.5% (95% CI 31.6 to 62.5). [10] The findings also corroborate with that reported by Bansal P (2018), comparing upper airway ultrasonography with standard waveform capnography and auscultation for confirmation of ETT placement. [29] Ahmed E Kabil AE et al. (2018) compared ultrasonography with brochoscopy and concluded that the sensitivity of ultrasound was found to be 97.2% with a specificity of 100%. The PPV and NPV were found to be 100% and 80% respectively. The authors concluded that ultrasonography was fastest and accurate method to confirm endotracheal tube placement. [30]

In the present study, kappa value of 0.737 indicates good correlation between capnography and upper airway ultrasound. Kappa values reported in other similar literature were 0.85 in Adi O et al., [27] 0.76 in Abhishek et al. study, [10] and 0.92 in Bansal P study, [29] all indicating good correlation. In the present study, mean (SD) time taken for ultrasonography to confirm endotracheal tube placement was 14.12 seconds (0.91). On the other hand, the time taken for capnography was 18.13 seconds (0.89). We found that the difference

in time taken by ultrasonography and capnography was statistically significant. Similarly, in the study conducted by Abhishek C et al., mean (SD) time taken for confirmation of ETT by capnography was 8.9 seconds (1.1) and upper airway USG was 12.0 (1.3) ($p<0.001$). [10] Adi O et al. in his study found the time taken for ultrasonography was 16.4 seconds. [27] Chowdhury AR et al. (2020) compared time taken for ultrasonography vs cheat auscultation vs capnography to confirm ET placement. The results showed that ultrasonography (36.50 ± 15.14 seconds) was the fastest method to confirm endotracheal tube placement when compared with unilateral chest auscultation (50.29 ± 15.50 seconds) vs bilateral chest auscultation (51.90 ± 15.98 seconds) vs capnography first waveform (53.57 ± 15.97 seconds) vs capnography sixth waveform (61.67 ± 15.88 seconds). [24]

To conclude, endotracheal intubation is performed to maintain and protect airway. Capnography is the gold standard method for confirmation of endotracheal tube placement. However, it has its own limitations as it relies on physiological factors like ventilation, adequate pulmonary perfusion, and gas exchange for its confirmation. Nowadays, ultrasound also has gained importance in airway management. In addition to being simple, non-invasive, portable, rapid and repeatable, ultrasonography can detect oesophageal intubation even without ventilating the patient. This prevents the gastric ventilation and aspiration of gastric contents. However, further studies are recommended in emergency situations, patients with difficult airway and in critical care settings.

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