EVALUATION OF END TIDAL CAPNOGRAPHY AND UPPER AIRWAY ULTRASONOGRAPHY FOR CONFIRMATION OF ENDOTRACHEAL TUBE PLACEMENT IN ADULT PATIENTS UNDERGOING ELECTIVE SURGERY

(Capnography versus ultrasonography for endotracheal tube placement)

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Summary

Introduction: Capnography has been considered the gold standard method for confirmation of endotracheal tube placement. The current cross-sectional observational study was undertaken to compare upper airway ultrasonography and capnography for confirmation of endotracheal tube placement in patients undergoing elective surgery.

Methods: 75 adult patients (18-60 years of age) belonging to ASA physical status I or II, scheduled for elective surgery under general anaesthesia requiring oral endotracheal intubation were enrolled for the study. After intubation, proper placement of endotracheal tube was confirmed by chest auscultation, end tidal capnography and upper airway ultrasound simultaneously. Sensitivity, specificity, positive and negative predictive values of both capnography and ultrasonography were computed.

Results: Using capnography, the position of endotracheal tube was found to be in the trachea in 72 patients (96%) and not in the trachea in 3 patients (4%). Ultrasonography was able to detect all 3 esophageal intubations but failed to confirm 2 endotracheal intubations. Capnography had sensitivity, specificity, positive and negative predictive values all at 100%. Ultrasonography had sensitivity of 97.22%, specificity of 100%, positive predictive value of 100% and negative predictive value of 60%. The kappa value was 0.737 which indicates a good correlation between capnography and upper airway ultrasound.

Conclusion: Ultrasonography provides a real time dynamic visualization of the endotracheal tube. This study was able to demonstrate that ultrasonography is an acceptable, faster and safer method for confirming endotracheal tube placement. However, further studies are recommended to determine the best approach for emergency situations, patients with a difficult airway, and in critical care settings.

Key words: Capnography; Airway ultrasonography; Endotracheal confirmation

Introduction

Tracheal intubation is performed to maintain airway patency, to protect the airway against aspiration and also in conditions when there is failure to ventilate and oxygenate. Confirmation of correct endotracheal tube placement is essential because failure to do so might have disastrous consequences like iatrogenic morbidity (brain damage) and mortality [1]. Esophageal intubation is the major complication of airway management. The incidence of esophageal intubation is 6% 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 the 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 and there is no single method that is ideal in every situation [1,3].

Capnography is a graphic display of instantaneous CO₂ concentration versus time (Time Capnogram) or expired volume (Volume Capnogram) during a respiratory cycle. It is the most widely used method for rapid assessment of endotracheal tube position [4]. The sensitivity and specificity of capnography was found to be 96.8% and 100% respectively [5]. However, the sensitivity decreases to 72% in patients with cardiac arrest or decreased...
cardiac output, so it may be unreliable in these patients [6]. Also, to confirm endotracheal tube placement by capnography, ventilation is required. However in cases of inadvertent esophageal intubation, the initiation of ventilation for confirming tube placement can lead to drastic complications.

Ultrasound imaging is a simple, fast, non-invasive and promising procedure used in many Intensive Care units (ICU) and emergency departments for airway assessment and management. Cadaveric studies of ultrasound confirmation of endotracheal tube placement have yielded promising results [6]. Thereafter it has been increasingly 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 [7].

Objectives

This cross-sectional observational study was undertaken to compare upper airway ultrasonography and capnography for confirmation of endotracheal tube placement in patients undergoing elective surgery. The primary outcome was to assess the strength of agreement between the two methods and the secondary outcome was to ascertain the time taken to confirm endotracheal tube placement by both methods.

Methodology

This cross-sectional observational study was conducted in the Department of Anaesthesiology at ABVIMS & Dr. Ram Manohar Lohia Hospital from 1st November 2018 till 31st March 2020 after obtaining due approval from the Institutional Ethics Committee and written informed consent from all the patients. Seventy five adult patients (18-60 years of age), belonging to ASA physical status I or II, scheduled for any elective surgery under general anaesthesia requiring oral endotracheal intubation were enrolled for the study. Patients with anticipated difficult airway, history of difficult intubation, presence of airway stenosis or masses, body mass index more than 30 kg/m², neck circumference more than 40 cm, pregnancy, presence of hypertrophied tonsils or loose dentures were excluded from the study.

All the enrolled patients underwent a thorough preoperative evaluation. Patients were fasted over night and premedicated with oral Alprazolam 0.25 mg on the night before surgery. In the operating theatre, ASA standard monitors i.e. electrocardiogram, heart rate, noninvasive arterial blood pressure and pulse oximetry were attached. Venous access was secured. Before induction, patients were given Injection (Inj) Midazolam 0.01 mg/kg i.v. followed by Inj Fentanyl 2 µg/kg i.v. General anaesthesia was induced with Inj Propofol 1-2mg/kg i.v. (till loss of verbal response). Inj Vecuronium 0.1mg/kg i.v. was given to facilitate neuro-muscular blockade after confirmation of adequate bag and mask ventilation. Patients were bag-mask ventilated for 3 minutes with 100% oxygen and sevoflurane at 1 MAC (minimum alveolar concentration). Thereafter, intubation was undertaken by endotracheal tube of appropriate size. After inflation of the endotracheal tube cuff, ventilation was initiated. Proper placement of endotracheal tube was confirmed by chest auscultation, end tidal capnography and upper airway ultrasonography simultaneously.

Confirmation of endotracheal tube placement by end-tidal capnography: After intubation, patients were ventilated and endotracheal tube placement was confirmed by quantitative waveform capnography. Endotracheal intubation confirmation was interpreted when exhaled CO2 was ≥4 mm Hg after five or more breaths with a characteristic CO2 waveform (Figure 1) [8].

Confirmation of endotracheal tube placement by ultrasonography: Before intubation, the ultrasound probe (linear, 9-12 MHz) was placed transversely on the anterior neck just superior to the suprasternal notch. Trachea was identified by a hypechoic air-mucosa (A-M) interface with reverberation artefact posteriorly (comet tail artefact) (Figure 2) [9]. After intubation, the anaesthesiologist performing ultrasonography captured the image of the endotracheal tube in transverse view.

Endotracheal intubation confirmation was interpreted if only one A-M interface with comet-tail artefact and posterior shadowing was observed (Figure 3) [9]. In esophageal intubation, two A-M interfaces with comet tail artefact and posterior shadowing was noted, which is called as “double tract
The time taken for upper airway ultrasonography was defined as the time from completion of endotracheal tube insertion to when the anaesthetist doing ultrasonography has interpreted the sonographic result. In case of detected esophageal intubation, the patient was reintubated. However, only the first attempt was included in the study. Upon completion of the study, the result of upper airway ultrasonography was compared with quantitative waveform capnography. Sensitivity, specificity, positive and negative predictive values of both the modalities of endotracheal tube confirmation were computed to determine the strength of association between them. Categorical variables were presented in number and percentage (%) and continuous variables were presented as mean ± SD and median. Normality of data was tested by Kolmogorov-Smirnov test. If the normality was rejected then non parametric test was used. Quantitative variables were compared using Wilcoxon signed rank test (as the data sets were not normally distributed) between ultrasonography and capnography. Inter-rater kappa agreement was used to find out strength of agreement between ultrasonography and capnography. A p value of <0.05 was considered statistically significant. The data was entered in MS EXCEL spreadsheet and analysis was done using Statistical Package for Social Sciences (SPSS) version 21.0.
Results

The age of the patients in the study ranged from 19 to 58 years. The mean and median age was found to be 37.25 and 35 years respectively. Out of the total of 75 patients enrolled, 44 were females and 31 patients were males. The position of endotracheal tube in the trachea by capnography was found in 72 patients i.e. 96.00%, and not in the trachea in 3 patients i.e. 4.00%. The position of endotracheal tube in the trachea confirmed by ultrasonography was in 70 patients i.e. 93.33%, and not in the trachea for 5 patients i.e. 6.67% (Table 1).

The primary objective of the study was to assess the strength of agreement between upper airway ultrasonography and capnography for confirmation of endotracheal tube placement. Out of the total 75 patients studied, 70 patients had the endotracheal tube in the trachea by both ultrasonography and capnography and 3 patients did not have it in the trachea by both the methods. The p value of < 0.0001 showed a significant association between the two (Table 2). The sensitivity, specificity,
positive predictive value and negative predictive value of capnography was found to be 100%. The sensitivity, specificity, positive predictive value and negative predictive value of ultrasonography was found to be 97.22%, 100%, 100% and 60% respectively (Figure 5). The secondary objective of the study was to compare the time taken for confirmation of endotracheal tube placement by capnography and ultrasonography. The mean time taken by capnography and ultrasonography was 18.13 ± 0.89 sec and 14.12 ± 0.91 sec respectively (Figure 6).

**Discussion**

Over the past two decades, ultrasonography has gained a great importance in airway assessment.
and management. Recently, it has also been used to confirm endotracheal tube placement, even without the need to initiate ventilation in the patient. Primary objective of this study was to assess the strength of agreement between upper airway ultrasonography and capnography for confirmation of endotracheal tube placement. Secondary objective was to compare the time taken by both the methods to do so.

Seventy five adult patients were enrolled in the study, out of which 31 patients were male and 44 patients were female. The mean age of study population was 37.25 ± 12.4 years with a median value of 35 years. Out of 75 patients, 72 patients had endotracheal intubation (96%) whereas 3 patients had esophageal intubation (4%). Using capnography, the position of endotracheal tube was found to be in the trachea in 72 patients (96%) and not in the trachea in 3 patients (4%). Ultrasonography was able to detect all 3 esophageal intubations but failed to confirm 2 endotracheal intubations. Capnography had sensitivity, specificity, positive and negative predictive value all at 100%. Ultrasonography had sensitivity of 97.22% (90.32% to 99.66%), specificity of 100% (29.24% to 100.00%), positive predictive value of 100% (94.87% to 100.00%) and negative predictive value of 60% (14.66% to 94.73%). In 2012, Osamn Adi et al conducted an observational study in 107 patients to compare quantitative waveform capnography with upper airway ultrason- sound for confirmation of endotracheal tube placement. In his study, ultrasonography had sensitivity of 98.0%, specificity of 100%, positive predictive value of 100% and negative predictive value 75.0%.

Figure 6: Comparison of time taken to detect ET tube placement (in seconds) by ultrasonography with capnography

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

<table>
<thead>
<tr>
<th>Position of ET tube by ultrasonography</th>
<th>Position of ET tube by capnography</th>
<th>Total</th>
<th>P value</th>
<th>Kappa</th>
</tr>
</thead>
<tbody>
<tr>
<td>ETT in Trachea (n = 72)</td>
<td>ETT not in Trachea (n = 3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ETT in Trachea</td>
<td>70 (93.33%)</td>
<td>0 (0.00%)</td>
<td>70 (93.33%)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>ETT not in Trachea</td>
<td>2 (2.67%)</td>
<td>3 (4.00%)</td>
<td>5 (6.67%)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>72 (96.00%)</td>
<td>3 (4.00%)</td>
<td>75 (100.00%)</td>
<td></td>
</tr>
</tbody>
</table>

The K value can be interpreted for the strength of agreement as: < 0.20: Poor, 0.21 – 0.40: Fair, 0.41 – 0.60: Moderate, 0.61 – 0.80: Good, 0.81 – 1.00: Very good.
These findings were similar to the results obtained in our study. They also stated that upper airway ultrasonography can replace waveform capnography in the centres were capnography is not available [10]. The study conducted by Chintaman Abhishek et al in 2017 also generated results similar to our study (upper airway ultrasound had a sensitivity of 96.84%, specificity of 100%, positive predictive value of 100% and negative predictive value of 62.5% [5]. In 2018, Priyanka Bansal compared ultrasonography with bronchoscopy and found that ultrasound had a sensitivity of 97.2% and specificity of 100%. The positive predictive value was found to be 100%, while the negative predictive value was 80%. She also concluded that ultrasonography was the fastest and an accurate method to confirm endotracheal tube placement [11].

The kappa value of our study was 0.737 which indicates a good correlation between capnography and upper airway ultrasound. Kappa values of Osamn Adi et al study and Abhishek et al study were 0.85 and 0.76 respectively, which correlates well with our results [5,10].

The mean time taken for confirmation of endotracheal tube placement by ultrasonography was 14.12 ± 0.91 seconds, whereas it was 18.13 ± 0.89 seconds by capnography. The p value was less than 0.0001 and hence statistically significant. Thus it was concluded that ultrasound was a faster method for confirming endotracheal tube placement as compared to capnography. Apala Roy Chowdhury in his study in 2020, compared time taken for ultrasonography with chest auscultation and capnography. His results showed that ultrasonography (36.50 ± 15.14 seconds) is the fastest method to confirm endotracheal tube placement when compared to unilateral chest auscultation (50.29 ± 15.50 seconds), bilateral chest auscultation (51.90 ± 15.98 seconds), capnography first waveform (53.57 ± 15.97 seconds) and capnography sixth waveform (61.67 ± 15.88 seconds) [12].

Limitation of our study was that it was performed in elective surgeries. Further studies are recommended in emergency situations, patients with difficult airway and in critical care settings.

**Conclusion**

Capnography is the gold standard method for confirmation of endotracheal tube placement. But it has its own limitations as it relies on physiological factors like ventilation, adequate pulmonary perfusion and gas exchange for its confirmation. Nowadays, ultrasonography also has gained importance in airway assessment and management. The advantage of ultrasonography is that it is easy, non invasive, portable, easily repeatable and faster than other methods. It also provides a real time dynamic visualization of endotracheal tube. Ultrasonography can detect esophageal intubation even without the need to ventilate the patient. This prevents gastric insufflation and aspiration in case of inadvertent esophageal intubation. To conclude, upper airway ultrasonography is an acceptable, faster and safer method for confirming endotracheal tube placement. However, further studies are recommended to determine the best approach for emergency situations, patients with a difficult airway, and in critical care settings.

**References**


