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REALTIME TRANSTRACHEAL ULTRASONOGRAPHY AND WAVEFORM CAPNOGRAPHY TO DETECT ENDOTRACHEAL INTUBATION - A PROSPECTIVE OBSERVATIONAL STUDY

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ABSTRACT

Background and Aims: The most important and lifesaving step of airway management and resuscitation of patients is rapid and accurate endotracheal tube placement. Any delay in confirmation of endotracheal tube placement can lead to potentially life-threatening complications. Capnography, which is considered the gold standard method, also can yield transiently false positive results. We aimed to detect the time taken and to compare the effectiveness of real-time trans-tracheal ultrasonography with waveform capnography to confirm the correct placement of the endotracheal tube. **Methods:** A prospective observational study was conducted at our tertiary care hospital for a period of six months on 100 patients requiring endotracheal intubation under general anaesthesia. Real-time trans-tracheal ultrasonography and waveform capnography were used to confirm the correct placement of the endotracheal tube. Time taken by both methods in seconds was noted down by two different observers. **Results**: The time taken to confirm the correct placement of ETT

by ultrasonography was 19.82 ± 5.14s, 95% CI: 18.8 - 20.84 and for capnography was 32.69 ± 5.73s, 95% CI: 31.55 - 33.83, p < 0.001, with a mean difference of 12.87s, 95% CI: 13.61 to 12.069, p < 0.001. The Pearson's correlation coefficient 'r value' was 0.822, 95% CI: 0.746 - 0.877, p < 0.001. The sensitivity, specificity, PPV, and NPV of ultrasonography against capnography were 100%. **Conclusion**: Transtracheal ultrasonography is a faster, equally accurate and safe technique for confirmation of the correct placement of ETT and can be a good alternative to capnography.

Keywords: Airway, endotracheal intubation, ultrasonography, capnography, POCUS, general anaesthesia.

Introduction:

Endotracheal intubation and securing the airway are crucial steps in patient resuscitation whether in an operation theatre (OT), emergency setting, or in an intensive care unit (ICU). Any delay in confirmation of endotracheal tube (ETT) placement can lead to complications such as aspiration, cardiopulmonary arrest, hypoxemia and hypoxic brain injury ultimately leading to increased mortality and morbidity and even death. [1] Various techniques like visualization of vocal cords during laryngoscopy, fogging or misting of the ETT, chest wall expansion following ventilation, chest auscultation to check for air entry, capnography, real-time ultrasonography, lung sliding, subcostal sonographic view for diaphragmatic movement on ventilation are available for confirmation of ETT placement. [2,3,4]

The American Heart Association/ Advanced Cardiovascular Life Support (ACLS) guidelines 2015 recommended the use of capnography for ETT confirmation. The appearance of six squared waveforms in capnography confirms the correct placement of the ETT [4] and oesophageal intubation yields an abnormal capnographic waveform. Since the

detection of carbon dioxide by capnography depends on adequate pulmonary blood flow, capnography has reduced accuracy in situations like cardiac arrest and massive pulmonary embolism. [5]

The Point Of Care UltraSound (POCUS) is now widely available in all settings and can be used to detect the correct placement of the ETT. The ultrasonographic confirmation of correct ETT placement can be done by identifying the 'empty oesophagus sign' (single bullet sign), while oesophageal intubation manifests as a 'double trachea sign'. [2] Transtracheal ultrasonography (USG) has several advantages such as non-invasiveness, cost-effectiveness, safety record, reproducibility of images, absence of ionizing radiation risk and also has a short learning curve. [6] The primary objective of our study was to observe the rapidity and also the effectiveness of POCUS to detect the correct ETT placement.

Methods:

After obtaining the Institutional Ethical Committee approval [No. EC 326, Dated: 14/03/2023], the study was registered in the Clinical Trial Registry of India [CTRI/2023/05/052412]. A prospective, observational study was conducted at our tertiary care hospital over a period of 6 months. The study was conducted in accordance with the 'Declaration of Helsinki' 2013 and is reported as per 'Strengthening the Reporting of Observational Studies in Epidemiology' (STROBE) guidelines. One hundred patients belonging to the American Society of Anaesthesiologists (ASA) physical status I and II in the age group 18-80 years of either gender, scheduled to undergo elective surgeries with orotracheal intubation under general anaesthesia (GA) were recruited for the study after obtaining written informed consent. Patients with known predictors of difficult intubation, BMI > 30 kg/m^2, previous history of difficult intubation, failure to visualize glottic aperture

in the first attempt or successful intubation on the second attempt were excluded from the study.

All patients were subjected to routine pre-anaesthetic evaluation. Routine investigations as appropriate for the surgeries were obtained and optimized if necessary. All patients were kept nil per oral as per standard Indian Society of Anaesthesiologists (ISA) fasting and feeding guidelines 2020 and received tablet ranitidine 150 mg and tablet alprazolam 0.5 mg the night before surgery. After shifting the patient to OT standard ASA monitoring like heart rate (HR), non-invasive blood pressure (NIBP), oxygen saturation (SpO_2), and electrocardiogram [ECG] were connected. Baseline vital parameters were documented. The patients were preoxygenated with 100% oxygen for 3 minutes, and premedicated with intravenous (IV) midazolam 0.05 mg/kg; IV fentanyl 2 mcg/kg was given for pre-emptive analgesia. A POCUS (Sonosite M Turbo) with a linear array transducer (13-6 MHz) was used. The probe was held over the anterior aspect of the neck transversely 1cm proximal to the suprasternal notch. The tracheal rings, cricoid cartilage and oesophagus were visualized in the same field.

Anaesthesia was induced with IV propofol 1.5 - 2 mg/kg in titrated doses until loss of verbal response, and muscle relaxation was achieved with IV atracurium 0.5 mg/kg to facilitate ETT. Laryngoscopy and intubation were conducted by the principal investigator using a Macintosh blade with a cuffed ETT of a predetermined size. Real-time ultrasonographic confirmation of ETT placement was done by identifying the ‘empty oesophagus sign’ (single bullet sign), while oesophageal intubation manifested as a ‘double trachea sign’.

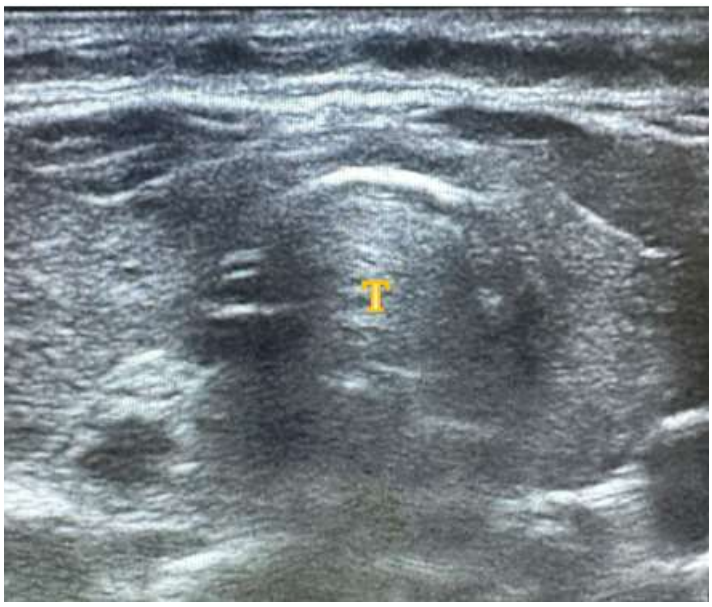

Figure 1: Ultrasound image after tracheal intubation showing – 'Empty oesophagus sign'

Immediately after intubation, the ETT was connected to the ventilator with prefilled bellows and a side-stream EtCO2 analyzer for confirmation of the correct placement of the ETT. The appearance of six squared waveforms in capnography confirmed the correct placement of the ETT. A third person clinically confirmed ETT placement by 5-point chest auscultation. After confirmation of bilateral equal air entry, the ETT was fixed and secured. The time required for the confirmation of correct ETT placement was noted in seconds (s) for both methods by two different observers. Both observers were blinded to each other's observations and were not allowed to communicate with each other.

The time from the beginning of laryngoscopy till the ultrasonographic confirmation of correct placement of the ETT was considered as T1 and the time from the beginning of laryngoscopy till capnographic confirmation of ETT was taken as T2. The patients were monitored throughout the surgery and in the post anaesthesia care unit for 30 minutes and stable haemodynamics were ensured.

Sample size:

Based on a published study [7] for earlier detection of correct placement of ETT by ultrasonography, with an α error of 0.05% and power of 80% a sample size of 81 was needed. To compensate for the possible dropouts and consistent results we studied 100 patients.

Statistical analysis:

Descriptive analysis was carried out by frequency and proportion for categorical variables. Continuous variables were expressed as mean and Standard Deviation (SD) for normally distributed continuous variables. A paired sample t-test was used to compare the two related samples for normally distributed quantitative variables. Results were considered statistically significant at a p-value < 0.05.

Results:

Among the 110 patients, who were assessed for eligibility; 10 patients did not meet the inclusion criteria and 3 patients had two attempts at intubation during the study and hence were excluded from analysis. Finally, 97 patients were analyzed for results.

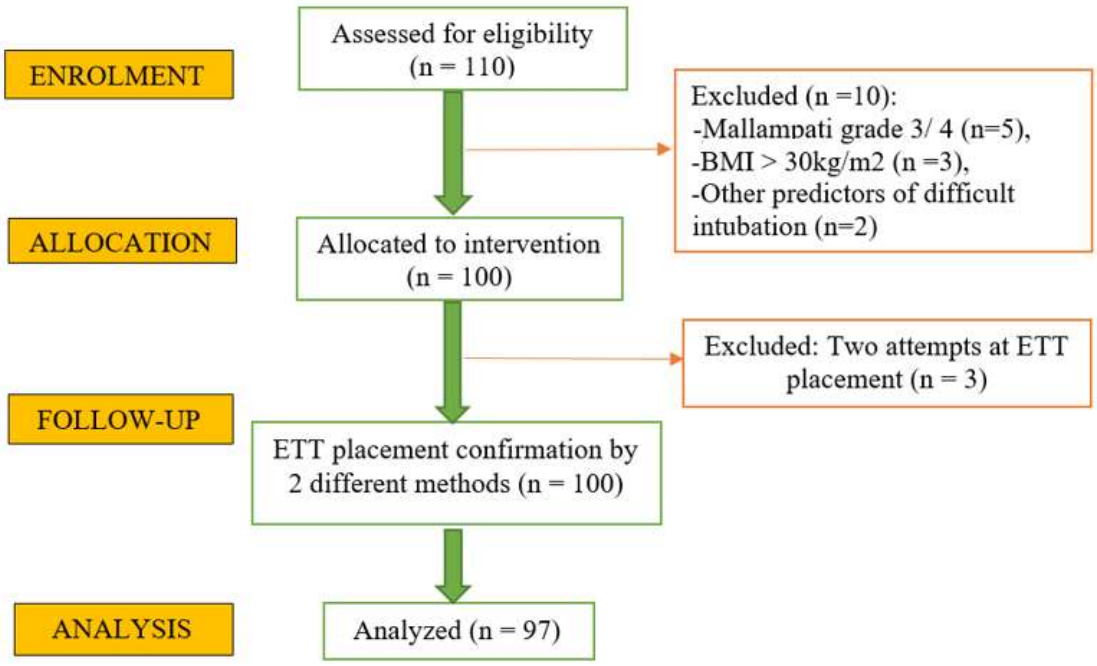

Figure 2: Patient flow for the study as per STROBE statement

The demographic details of the patients is as follows.

Table 1: Descriptive analysis of demographic variables

Variables	Mean ± SD	Range	
		Minimum	Maximum
Age (years)	39.35 ± 14.59	18	78
Weight (kg)	62.96 ± 9.12	40	90
Height (cm)	158.92 ± 6.70	133	178
BMI (kg/m^2)	24.73 ± 3.23	16	29.9

The time taken to confirm the correct placement of ETT by USG was 19.82 ± 5.14s, 95% CI: 18.8 - 20.84 and for capnography it was 32.69 ± 5.73 s, 95% CI: 31.55 - 33.83, p < 0.001, with a mean difference of 12.87s, 95% CI: 13.61 to 12.069, p < 0.001**.**

Table 2: Comparison of time taken by USG & capnography to confirm ETT placement

Time taken to confirm tube position (s)	Mean ± SD	95%CI		p-value
		Lower	Upper	
USG	19.82 ± 5.14	18.8	20.84	< 0.001
Capnography	32.69 ± 5.73	31.55	33.83	

Pearson's correlation coefficient 'r value' was 0.822, 95% CI: 0.746 - 0.877, p < 0.001.

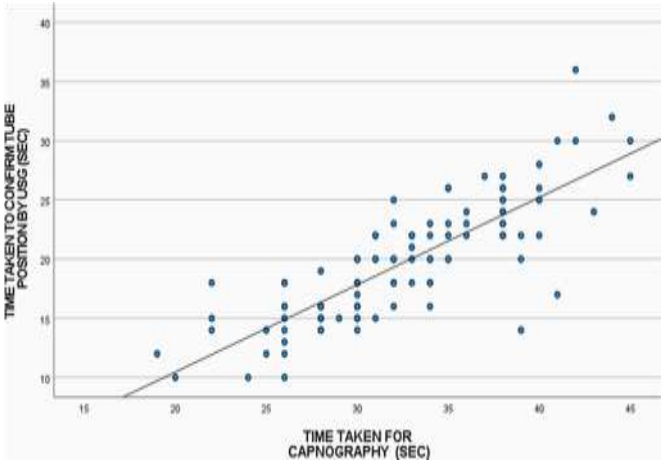

Figure 3: Correlation between time taken for USG vs capnography to confirm ETT position

The sensitivity, specificity, PPV and NPV of ultrasonography against capnography were 100% at 95% CI (96.3 - 100), 100% at 95% CI (29.2 - 100), 100% at 95% CI (96.3 - 100), 100% at 95% CI (29.2 - 100) respectively. The area under the curve (AOC) was 1.

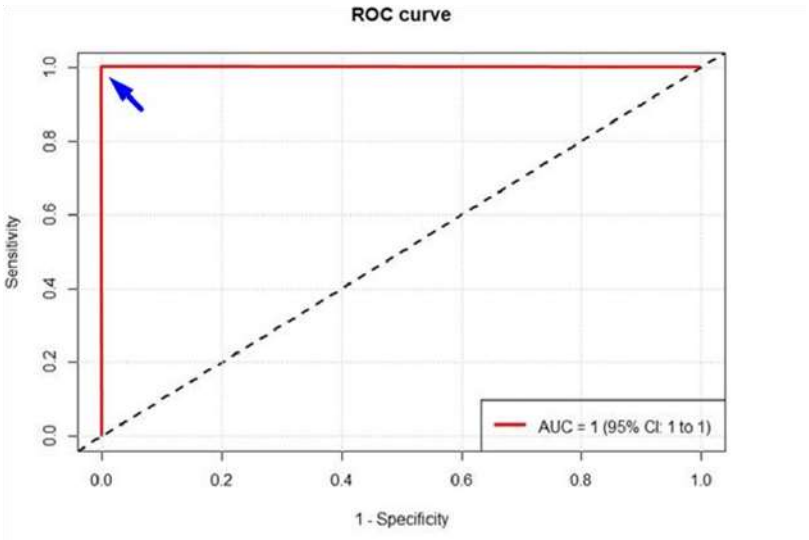

Figure 4: ROC curve for comparing USG with capnography to assess ETT placement

Discussion:

Detection of correct placement of ETT is of paramount importance to prevent the detrimental consequences of prolonged oesophageal intubation. [1] Various methods are available to confirm correct ETT placement including waveform capnography and trans-tracheal USG. The ACLS 2015 guidelines have recommended POCUS as an alternative to waveform capnography (strong recommendation, low-quality evidence). [5,8] It was observed that POCUS confirmed ET intubation earlier and saved lives, particularly in patients with low pulmonary blood flow in comparison with other traditional methods of confirmation. [9] Unlike capnography, USG is a new tool which has clear advantages of detecting oesophageal intubation even before initiation of ventilation. This early detection could prevent forced ventilation and distension of the stomach and its related problems like regurgitation, aspiration and emesis. [10] The time required to confirm correct ETT placement is an important consideration for any method used. Transtracheal USG can be used to verify the ETT placement while intubation is being performed or upon completion, whereas capnography, needs the patient's lung to be ventilated a minimum of 4-5 breaths

for confirmation. [11] Kundra and others in their study on airway ultrasound concluded that USG has become the first noninvasive airway assessment tool in anaesthesia and ICU practice. [12] Similar studies concluded that USG can be a proper screening tool [13] and can be used as an adjunct to help confirm correct ETT placement during intubations. [14]

In our study, we aimed to detect the time taken by USG and to evaluate the diagnostic accuracy of real-time trans-tracheal USG, in comparison with waveform capnography to detect the correct placement of endotracheal tube. Our study results showed that real-time trans-tracheal USG was faster when compared to waveform capnography. Pearson's correlation coefficient (r value) was 0.822, proving a strong positive correlation between both methods. The sensitivity, specificity, PPV, and NPV of ultrasonography were 100% proving that USG can be a potential alternative for capnography. A similar study conducted by Adi et al. showed a very good agreement between both methods concluding that USG can replace capnography in confirmation of ETT placement if capnography is readily not available. [15] A temporal comparison of USG versus auscultation and capnography in verifying ETT placement concluded that USG is as fast as auscultation alone and faster than the standard method of auscultation and capnography. [4] The study by Sethi and others indicated that USG is a rapid technique for the identification of ETT placement. [16] The studies conducted in ICU settings for the same concluded that real-time trans-tracheal ultrasonography is safe, feasible, accurate and can be rapidly performed. [17,18,19] Other studies which used USG to detect emergency intubations stated that ultrasonography is 100% accurate [20,21] and is independent of Cormack Lehane (CL) grading. [21] Other studies have reported the use of USG in cardiac arrest patients and observed it to be an accurate method to identify LMA [22] or ETT position during CPR without interruption of chest compressions. [23,24] The study conducted on adult human cadaver model concluded that USG is an accurate and rapid bedside technique to confirm endotracheal intubation. [25]

Further studies are required as a side-stream EtCO2 analyzer was used in our study, and if a mainstream EtCO2 analyzer was used, the time outcome would have been different; which was a limitation of our study.

Conclusion:

We conclude that in elective surgeries under general anaesthesia with orotracheal intubation, confirmation of correct placement of ETT is faster with real-time trans-tracheal ultrasonography when compared to waveform capnography. USG is an equally accurate and safe technique for confirmation of correct placement of ETT and can be a good alternative for capnography.

Conflict of Interest:

Nil

Financial Support:

Nil

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Nil

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