ORIGINAL ARTICLE ASIAN JOURNAL OF MEDICAL SCIENCES

Transtracheal ultrasonography versus end-tidal capnography in rapid confirmation of endotracheal tube placement

Shruthi Rioniz[1], Nischala Dixit[2], Preethi Rioniz[3], Thomas T Vellapally[4], Nayanthara Joachim[5], Siddhanth Suresh[6]

[1]Senior Resident, [2]Professor, [4,5]Assistant Professor, Department of Anaesthesiology, St. John's Medical College Hospital, Bengaluru, [3]Senior Resident, Department of Pharmacology, Chikkamagaluru Institute of Medical Sciences, Chikkamagaluru, [6]Junior Resident, Department of Radiodiagnosis, St. John's Medical College Hospital, Bengaluru, Karnataka, India

Submission: 12-01-2025 Revision:30-01-2025 Publication: 01-03-2025

ABSTRACT

Background: Prompt confirmation of proper endotracheal (ET) tube placement after intubation is imperative to averting life-threatening consequences. Waveform capnography, although the gold standard method, poses some limitations while transtracheal ultrasonography (USG) is a reliable real-time technique that has shown much promise. Existing literature on the faster method has yielded conflicting results. **Aims and Objectives:** This study aims to determine the mean time taken to confirm the correct placement of the ET tube using both transtracheal USG and end-tidal capnography. A comparative assessment of the faster method will supplement patient care by helping anesthesiologists avoid accidental esophageal/endobronchial intubation and the associated morbidity. **Materials and Methods:** Consenting adult patients posted for elective surgeries under general anesthesia were recruited over a period of 18 months. The time taken for confirmation of correct tube placement by both transtracheal USG and capnographic end-tidal carbon dioxide tracing was recorded. A paired samples t-test was used to compare the means (±standard deviation). **Results:** The study included 112 patients aged 40.1 ± 12 years of whom 59 (52.6%) were females. The mean time taken to confirm tube placement by USG and capnography was 35.8 ± 9.8 s and 67.4 ± 13.7 s, respectively, with a mean time difference of 31.6 ± 7.8 s which was found to be statistically significant ($P < 0.001$). **Conclusion:** Transtracheal USG is the faster method to confirm the proper placement of an ET tube during intubation when compared to waveform capnography. USG is also beneficial in detecting and avoiding accidental esophageal intubations.

Key words: General anesthesia; Airway management; Intubation; Capnography; Ultrasonography; Endotracheal tube

Access this article online

Website: https://ajmsjournal.info/index.php/AJMS/index

DOI: 10.71152/ajms.v16i3.4411

E-ISSN: 2091-0576

P-ISSN: 2467-9100

INTRODUCTION

Endotracheal (ET) intubation is a crucial skill that every practicing anesthesiologist must master.[1] Immediate confirmation of the proper placement and depth of the ET tube is imperative post-procedure, as failure to do so could lead to serious complications such as endobronchial or esophageal intubation.[2,3] According to the 2020 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care, continuous waveform capnography is recommended as the most reliable method to confirm correct ET tube placement.[4] However, capnography has several limitations, including dependence on physiological factors such as adequate pulmonary blood flow, ventilation, and gas exchange.[1]

Address for Correspondence:
Dr. Thomas T Vellapally, Assistant Professor, Department of Anaesthesiology, St. John's Medical College Hospital, Sarjapur Road, Bengaluru - 560 034, Karnataka, India. **Mobile:** +91-9746717055. **E-mail:** thomastvellapally@gmail.com

Recent studies have highlighted the high sensitivity and specificity of transtracheal ultrasonography (USG) in confirming ET intubation.[5] This technique is reliable, non-invasive, real-time, easily reproducible, and benefits from the widespread availability of portable ultrasound machines.[5-7]

A critical consideration in comparing these two methods is the time required for confirmation.[8] Capnography, for instance, necessitates waiting for at least six continuous waveforms post-intubation to confirm that the end-tidal carbon dioxide trace is coming from the trachea.[9,10] In contrast, transtracheal ultrasound allows for simultaneous performance and interpretation during intubation, providing real-time feedback.[1,5]

Head-to-head comparisons between capnography and transtracheal ultrasound for confirming ET intubation have produced conflicting evidence, with studies yielding contradictory results regarding which method is quicker.[7,8,11,12] Most of these comparisons have been conducted in emergency settings, with limited research conducted in the controlled environment of elective surgery operating rooms. Establishing a rapid and reliable method to confirm proper ET intubation would be advantageous in preventing complications during surgical procedures.

Aims and objectives

In this study, we aimed to ascertain the faster method of confirming correct ET intubation between transtracheal USG and the existing gold standard method, end-tidal capnographic monitoring. The objective of the study was to determine and compare the mean time taken to confirm proper tube placement using both these methods.

MATERIALS AND METHODS

This hospital-based observational study was conducted by the Department of Anaesthesiology in the operation theatres of St. John's Medical College Hospital, Bengaluru, Karnataka, India, over an 18-month period from June 2021 to December 2022. The study sample included adult patients aged 18–59 years, classified as American Society of Anesthesiologists (ASA) grades I to III, who were scheduled for elective surgeries under general anesthesia. Pregnant women and patients with known predictors of difficult intubation *viz.*, body mass index >30 kg/m^2, Modified Mallampati Class IV, LEON (Look-Evaluate-Obstruction-Neck mobility) score ≥3, history of cervical spine disease, musculoskeletal disease, previous difficult intubation and neck surgery, were excluded from the study.

Written informed consent was obtained from all study participants, followed by patient interviews and chart reviews to gather relevant medical history using a structured case record form. Baseline demographic characteristics of the participants were recorded, and a comprehensive airway assessment was conducted. Anesthesia protocols were standardized for all patients.

Study procedure

After confirming nil per os status, participants were shifted to the operation theatre where standard ASA monitors were connected and their vital signs were recorded. Patients were pre-oxygenated with 100% oxygen until end-tidal oxygen concentration exceeded 90%, using a properly fitted face mask. General anesthesia was induced with intravenous fentanyl (2–3 μg/kg) and propofol (1.5–2.5 mg/kg), and titrated to achieve the loss of verbal response. Following confirmation of adequate mask ventilation, muscle relaxation was achieved with atracurium (0.5 mg/kg), and patients were ventilated with a bag-mask apparatus for 3 min.

The study procedure involved three team members:

1. Laryngoscopist: An anesthesiologist with over 5 years of clinical experience and proficient in airway management.
2. Sonographer: Another anesthesiologist with more than 5 years of clinical experience, skilled in using USG.
3. Observer.

Capnography was monitored using a mainstream capnography device positioned away from the sonographer's view who performed USG before intubation using the high-frequency linear probe (5–10 MHz) of the SonoSite M-Turbo ultrasound machine to identify anatomical structures and confirm visualization of the trachea and esophagus. During laryngoscopy, the transducer was positioned just above the sternal notch in a transverse orientation with minimal pressure, and then slightly shifted to the left. Post-intubation, the correct placement of the ET tube was confirmed if the sonographer visualized a single air-mucosal (A-M) interface with reverberation artefact in the trachea. There was no direct communication between the laryngoscopist and sonographer during the procedure.

The observer recorded two timings on a stopwatch:

(i) Time from the removal of the face mask to the appearance of the sixth continuous capnographic waveform, with mechanical ventilation set at 14 breaths/min.
(ii) Time from the removal of the face mask to visualization of the "comet-tail" artefact in the trachea on the ultrasound monitor, confirmed by a non-verbal signal from the sonographer to the observer.

Secondary confirmation of ET tube placement was conducted by bilateral chest auscultation in all cases. The only allowed communication between the sonographer and laryngoscopist was if the sonographer observed the entry of the ET tube into the esophagus as a "double tract" sign on ultrasound, prompting redirection of the tube into the trachea to prevent accidental esophageal intubation.

Ethics

The study was approved by the Institutional Ethics Committee of St. John's Medical College, Bengaluru (Ref. No.: 342/2020), and was registered with the Clinical Trials Registry - India (CTRI/2021/12/038505) before its commencement. All procedures followed were in accordance with the prevailing ethical standards for clinical research in human subjects.

Statistical analysis

Data were entered and managed on Epi Info v.7.2 and statistical analysis was conducted using IBM SPSS Statistics 28.0. Baseline demographic characteristics were analyzed using descriptive statistics and presented in tables and graphs. The mean time durations for confirming proper tube placement using both techniques were compared using a paired samples t-test. A $P<0.05$ was considered significant for all statistical tests.

RESULTS

The mean age of the 112 participants included in the study was 40.1 (±12) years, 59 (52.6%) of whom were females. Demographic details have been summarized in Table 1.

A comprehensive airway assessment was conducted for all participants in the pre-operative holding area, and their modified Mallampati classification was recorded. The LEON score, which is based on specific predictors of a difficult airway, was calculated and documented for each patient. Patients were also categorized according to their presenting clinical conditions and comorbidities using the ASA physical status classification. Only individuals classified as ASA I–III were included in the study. The distribution of the study population following these assessments is represented in Figure 1.

The time required to confirm ET tube placement using both transtracheal USG and capnography was recorded for all 112 participants, with the mean (±standard deviation [SD]) calculated for each technique. There were 27 instances of unanticipated difficult airway (UDA) intubations, which resulted in an approximate 10-s increase in the mean confirmation time across both methods. Excluding UDA cases, the time to confirm tube placement

Table 1: Participant demographics

Parameters	Mean (±SD), distribution (%)
Age (years)	40.1 (±12)
<40	48.3
≥40	51.7
Sex	–
Males	47.4
Females	52.6
BMI (kg/m^2)	23.8 (±3.1)
≤24.9	66.1
>25	33.9

BMI: Body mass index, SD: Standard deviation

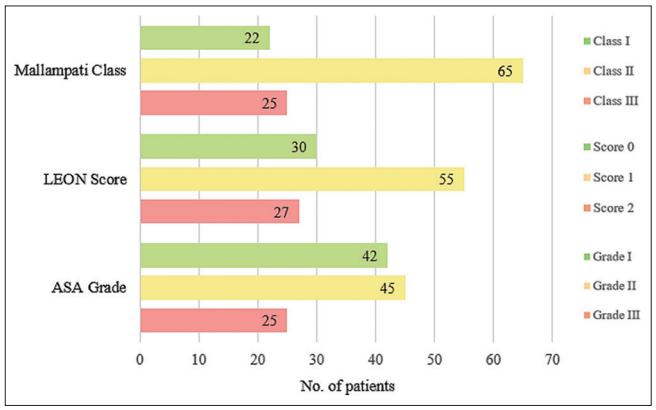

Figure 1: Airway and physical status assessment

through transtracheal USG (35.8±9.8 s) was significantly shorter than that for capnography (67.4±13.7 s).

The mean confirmation times for both methods, with and without UDA cases, were compared using a paired samples t-test (Table 2). The difference in mean times was found to be statistically significant ($P<0.001$) in both scenarios. These findings demonstrate that transtracheal USG is a significantly faster method for confirming tube placement compared to capnography, regardless of the occurrence of UDA.

There were six instances in which the sonographer observed that the ET tube was inadvertently entering the esophagus instead of the trachea. This was immediately communicated to the laryngoscopist, and the tube was promptly redirected into the trachea, thereby preventing esophageal intubation.

DISCUSSION

Confirmation of proper ET tube placement immediately after intubation is a critical aspect of airway management, and if overlooked, it can significantly contribute to patient morbidity and mortality. Multiple airway associations recommend continuous waveform capnography as the gold standard for confirming tube placement. However,

Table 2: Time taken for confirmation of ET tube placement

Study population	Capno (s)	USG (s)	Mean diff. (s)	t-test	P-value
Including UDA, n=112	78.0±24.7	47.4±23.6	30.8±8.4	38.4	<0.001
Excluding UDA, n=85	67.4±13.7	35.8±9.8	31.6±7.8	37.3	<0.001

USG: Ultrasonography, UDA: Unanticipated difficult airway, ET: Endotracheal

recent literature has highlighted the potential advantages of transtracheal USG in confirming intubation. This study aimed to evaluate whether transtracheal USG could serve as a faster method for confirming proper tracheal intubation compared to the current benchmark technique of capnography.

Our pre-operative airway assessment included the Modified Mallampati classification and the LEON method of evaluation. The LEON score, introduced by Reed et al., has been validated by multiple studies as an effective clinical tool for identifying predictors of difficult airway.[13-15] Despite the exclusion of participants with predictors of a difficult airway, our team encountered 27 cases (24.1%) of UDA within the study population. These cases were characterized by intubation times exceeding 60 s or the need for an airway adjunct, such as a bougie.

USG versus capnography

After reviewing the data collected in our study, the mean (±SD) time taken to confirm ET tube placement using both transtracheal USG and capnography was calculated, excluding the 27 cases of UDA. We found that the time taken for intubation confirmation through USG was 35.8±9.8 s, which was shorter when compared to capnography (67.4±13.7 s). The mean time difference between the two methods was 31.6±7.8 s. We then recalculated the results, including the UDA incidents, and found that the mean time for confirmation using USG was 47.4±23.6 s, while capnography took 78.0±24.7 s, with a mean time difference of 30.8±8.4 s. In both scenarios, USG was the faster method. This finding can be attributed to the fact that USG provides real-time confirmation, allowing direct visualization of the tube entering the trachea on the ultrasound monitor. In contrast, capnography involves a delay, as it requires connecting the circuit to the ET tube and waiting for the appearance of six waveforms on the monitor before confirming correct placement and conclusively ruling out esophageal intubation.

We analyzed the results using a paired samples t-test and found that the mean time difference in both scenarios was statistically significant, with a $P<0.001$. Based on this analysis, we concluded that transtracheal USG is the faster method for confirming proper ET tube placement compared to waveform capnography, and this holds true even during the management of unanticipated difficult airways.

Although these results favor USG, there were certain limitations encountered during its use. To visualize intubation in real-time, the probe needed to be transversely positioned just above the suprasternal notch during the intubation attempt. This occasionally interfered with laryngoscopy, requiring the probe to be temporarily lifted off until the laryngoscope could be properly positioned in the oral cavity. In addition, in cases of an anteriorly positioned larynx where external laryngeal manipulation (ELM) was required, the presence of the probe posed a challenge while the ultrasound jelly hindered the maneuver by making the field slippery. These challenges were particularly evident when encountering UDA.

A 2020 study led by Chowdhury et al., at AIIMS, New Delhi, which included 120 patients undergoing elective surgery under general anesthesia, reported a mean time of 36.5±15.1 s for ultrasonographic confirmation of ET intubation from mask removal, compared to a mean time of 61.7±15.9 s for confirmation using waveform capnography. These results were consistent with our findings. Furthermore, the mean time difference of 25.2±4.4 s between the two techniques in their study was statistically significant, thus reinforcing the conclusion that USG is a faster method for confirming ET intubation.[1]

Another study by Thomas et al., in Thrissur, involving 100 patients requiring emergency intubation, found that the time taken for ultrasound confirmation was 8.3±1.5 s from the moment the airway provider confirmed the completion of intubation, whereas the meantime for capnographic confirmation was 18.06±2.6 s. A statistically significant time difference of 12.5 s was observed in favor of USG.[7] Similarly, Roy et al., concluded that USG (4.9±1.09 s) was significantly faster than both capnography (15.3±1.6 s) and clinical confirmation (17.8±1.7 s) in the intensive care unit (ICU) setting.[11]

A few studies, however, have reported contradictory findings. Shebl and Said conducted a study on 200 respiratory ICU patients in 2019 and concluded that USG confirmation took a significantly longer time than capnography (15.13 vs. 12.9 s).[8] Similarly, Abhishek et al., conducted a study in an operating room setting and found that the time spent on capnography for confirming correct

ET tube placement was 8.99±1.04 s, whereas upper airway USG took 12.0±1.3 s. The 3-s time delay was found to be statistically significant.[12]

Esophageal intubation

During the conduct of our study, the ultrasonographer observed the "double tract" sign indicating ET tube entry into the esophagus on six separate occasions. In these cases, patient safety necessitated verbal communication between the ultrasonographer and the laryngoscopist, who successfully redirected the tube into the trachea once alerted. This highlights a key advantage of USG over capnography, as esophageal intubation can lead to dire consequences if not promptly recognized and averted.

Although some studies have compared the sensitivity and specificity of ultrasound and capnography in detecting esophageal intubation,[11,12] we did not include this comparison in our objectives. This decision was based on the fact that capnography requires ventilation to confirm intubation. Ventilating a patient after esophageal intubation poses risks such as gastric insufflation and pulmonary aspiration. In fact, in any case that esophageal tube misplacement was detected by the ultrasonographer; ventilation was withheld until correct tracheal placement was confirmed to ensure patient safety.

Limitations of the study

The findings of this study are limited in their applicability to patients with predictors of a difficult airway; as such individuals were intentionally excluded during recruitment in alignment with our aim of determining the quickest confirmation technique. Prolonged intubation time, a direct consequence of difficult airway management, would have had the potential to distort our results. In spite of these exclusions, we still observed UDA in 24.1% of the study population. Nonetheless, our study results remained unchanged, that is, USG consistently demonstrated faster tube placement confirmation, regardless of UDA occurrence. Sonography was performed by a single anesthesiologist with sufficient airway ultrasound expertise to maintain consistency throughout the study. The same study involving trainees or inexperienced sonographers may have produced different results.

CONCLUSION

The study highlights the effectiveness of transtracheal USG as a faster and more reliable method for confirming the proper placement of an ET tube during intubation, in comparison to the more widely used continuous waveform capnography. A key insight from the study is that transtracheal USG allows for the early detection of accidental misdirection of the ET tube into the esophagus. This is a significant advantage, as it can prevent undetected esophageal intubation, a dangerous situation that can lead to severe complications if not addressed promptly. The study emphasizes the role of USG in improving patient safety during intubation by ensuring rapid confirmation of accurate tube placement.

REFERENCES

1. Chowdhury AR, Punj J, Pandey R, Darlong V, Sinha R and Bhoi D. Ultrasound is a reliable and faster tool for confirmation of endotracheal intubation compared to chest auscultation and capnography when performed by novice anaesthesia residents-a prospective controlled clinical trial. Saudi J Anaesth. 2020;14(1):15-21.
   https://doi.org/10.4103/sja.SJA_180_19
2. Alonso Quintela P, Oulego Erroz I, Mora Matilla M, Rodríguez Blanco S, Mata Zubillaga D and Regueras Santos L. [Usefulness of bedside ultrasound compared to capnography and X-ray for tracheal intubation]. An Pediatr (Barc). 2014;81(5):283-288.
   https://doi.org/10.1016/j.anpedi.2014.01.004
3. Karacabey S, Sanrı E, Gencer EG and Guneysel O. Tracheal ultrasonography and ultrasonographic lung sliding for confirming endotracheal tube placement: Speed and reliability. Am J Emerg Med. 2016;34(6):953-956.
   https://doi.org/10.1016/j.ajem.2016.01.027
4. Panchal AR, Bartos JA, Cabañas JG, Donnino MW, Drennan IR, Hirsch KG, et al. Part 3: Adult basic and advanced life support: 2020 American heart association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. Circulation. 20200;142(16 Suppl 2):S366-S468.
   https://doi.org/10.1161/CIR.0000000000000916
5. Das SK, Choupoo NS, Haldar R and Lahkar A. Transtracheal ultrasound for verification of endotracheal tube placement: A systematic review and meta-analysis. Can J Anaesth J Can Anesth. 2015;62(4):413-423.
   https:///doi.org/10.1007/s12630-014-0301-z
6. Bansal P. Comparison of upper airway ultrasonography with standard waveform capnography and auscultation to verify correct placement of endotracheal tube after intubation. Int J Contemp Med Res. 2018;5(9):11-15.
   https://doi.org/10.21276/ijcmr.2018.5.9.7
7. Thomas VK, Paul C, Rajeev PC and Palatty BU. Reliability of ultrasonography in confirming endotracheal tube placement in an emergency setting. Indian J Crit Care Med Peer. 2017;21(5):257-261.
   https://doi.org/10.4103/ijccm.ijccm_417_16
8. Shebl E and Said AM. The role of tracheal ultrasonography in confirming endotracheal tube placement in respiratory intensive-care unit patients. Egypt J Chest Dis Tuberc. 2019;68(3):351.
   https://doi.org/10.4103/ejcdt.ejcdt_192_18
9. Kerslake I and Kelly F. Uses of capnography in the critical care unit. BJA Educ. 2017;17(5):178-183.
10. Aminiahidashti H, Shafiee S, Zamani Kiasari A and Sazgar M. Applications of end-tidal carbon dioxide (ETCO2) monitoring in emergency department; a narrative review. Emerg (Tehran). 2018;6(1):e5.
11. Roy PS, Joshi N, Garg M, Meena R and Bhati S. Comparison of ultrasonography, clinical method and capnography for detecting correct endotracheal tube placement- A prospective,

observational study. Indian J Anaesth. 2022;66(12):826.
https://doi.org/10.4103/ija.ija_240_22

12. Abhishek C, Munta K, Rao SM and Chandrasekhar CN. End-tidal capnography and upper airway ultrasonography in the rapid confirmation of endotracheal tube placement in patients requiring intubation for general anaesthesia. Indian J Anaesth. 2017;61(6):486-489.
https://doi.org/10.4103/ija.IJA_544_16
13. Reed MJ, Rennie LM, Dunn MJ, Gray AJ, Robertson CE and McKeown DW. Is the "LEMON" method an easily applied emergency airway assessment tool? Eur J Emerg Med Off J Eur Soc Emerg Med. 2004;11(3):154-157.
https://doi.org/10.1097/01.mej.0000127645.46457.b9
14. Ji SM, Moon EJ, Kim TJ, Yi JW, Seo H and Lee BJ. Correlation between modified LEMON score and intubation difficulty in adult trauma patients undergoing emergency surgery. World J Emerg Surg. 2018;13(1):33.
https://doi.org/10.1186/s13017-018-0195-0
15. Hagiwara Y, Watase H, Okamoto H, Goto T, Hasegawa K and Japanese Emergency Medicine Network Investigators. Prospective validation of the modified LEMON criteria to predict difficult intubation in the ED. Am J Emerg Med. 2015;33(10):1492-1496.
https://doi.org/10.1016/j.ajem.2015.06.038

Authors' Contributions:
SR- Prepared first draft of manuscript, implementation of study protocol, data collection, data analysis, literature review, manuscript preparation and article submission; **ND**- Selection of study, planning of study design and methodology, manuscript editing and final revision; **PR**- Literature review, statistical analysis, preparation of figures and tables, manuscript writing, manuscript review and editing; **TV**- Data collection, manuscript review and editing; **NJ**- Manuscript review and editing; **SS**- Data collection.

Work attributed to:
St. John's Medical College Hospital, Bengaluru, India.

Orcid ID:
Shruthi Rioniz - https://orcid.org/0009-0005-5956-8770
Nischala Dixit - https://orcid.org/0000-0001-6690-2400
Preethi Rioniz - https://orcid.org/0009-0009-0836-059X
Thomas T Vellapally - https://orcid.org/0000-0001-7311-9860
Nayanthara Joachim - https://orcid.org/0000-0002-9530-4423
Siddhanth Suresh - https://orcid.org/0000-0002-7345-050X

Source of Support: Nil, **Conflicts of Interest:** None declared.