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Original Research Article

A Study to Compare Endotracheal Tube Position by Ultrasonography with Capnography

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Abstract

Introduction: Confirmation of correct endotracheal tube (ETT) placement is essential to prevent complications during airway management. Capnography is considered the gold standard; however, it may be unreliable in low perfusion states. Ultrasonography has emerged as a rapid bedside tool for airway assessment. This study aimed to compare ultrasonography with capnography for confirmation of ETT placement.

Materials and Methods: This prospective comparative study included 60 adult patients undergoing endotracheal intubation under general anesthesia. Patients were divided into two groups: ultrasonography (Group U) and capnography (Group C), with 30 patients in each group. The primary outcome was the time required to confirm ETT placement. Secondary outcomes included diagnostic accuracy, hemodynamic parameters, complications, and ease of procedure. Statistical analysis was performed with $p < 0.05$ considered significant.

Results: Demographic characteristics were comparable between groups. The median confirmation time was significantly shorter with ultrasonography than with capnography (4 seconds vs 7 seconds, $p < 0.001$). Both techniques showed 100% sensitivity and diagnostic accuracy. Hemodynamic parameters remained stable, and complication rates were minimal and comparable between groups.

Conclusion: Ultrasonography is a rapid and reliable method for confirming ETT placement with diagnostic accuracy comparable to capnography. It significantly reduces confirmation time and can serve as a useful adjunct in airway management.

Keywords: Endotracheal Tube, Ultrasonography, Capnography, Airway Management, Intubation Confirmation.

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Introduction

Airway management is a critical component of anaesthetic and emergency care, as securing a patent airway is essential for effective oxygenation and ventilation. Endotracheal intubation (ETI) is the most reliable method for airway control during surgical and critical care procedures. However, incorrect placement of the endotracheal tube (ETT), particularly oesophageal intubation, can result in severe complications such as hypoxia, aspiration, cardiac arrest, and death if not detected promptly. Therefore, rapid and accurate confirmation of ETT placement is essential after every intubation attempt [1].Conventional bedside methods used to confirm tube placement include visualization of the tube passing through the vocal cords, observation of chest rise, auscultation of bilateral breath sounds, and condensation within the ETT. Although these techniques are quick and widely practiced, they are subjective and may be unreliable in situations such as obesity, pneumothorax, or noisy emergency environments, potentially delaying detection of oesophageal intubation [2].Capnography is considered the gold standard for confirming tracheal intubation. It measures end-tidal carbon dioxide ($EtCO_2$) in exhaled air, and the presence of a consistent capnographic waveform indicates correct tracheal placement. However, capnography may produce false-negative results in conditions with reduced pulmonary perfusion such as cardiac arrest, severe hypotension, or massive pulmonary embolism, thereby limiting its reliability in low-flow states [3,4].Ultrasonography has recently emerged as a rapid, non-invasive bedside tool for confirming ETT placement. Using a high-frequency linear probe placed on the anterior neck, ultrasound allows direct visualization of the trachea and oesophagus.

Correct tracheal intubation typically shows a single air–mucosal interface within the trachea, whereas oesophageal intubation produces the characteristic “double tract sign” [5,6]. In addition, dynamic assessment of lung sliding and diaphragmatic movement can further support confirmation of correct tube placement. Previous studies have demonstrated that ultrasonography has high sensitivity and specificity for detecting correct ETT placement and can provide confirmation within a few seconds, independent of ventilation or circulatory status. These advantages make it particularly useful in emergency settings, trauma, and cardiopulmonary resuscitation [7–9].In view of these potential benefits, the present study was undertaken to compare endotracheal tube position assessment by ultrasonography with capnography, with the aim of evaluating the accuracy and time efficiency of ultrasonography as a method for confirming correct ETT placement in clinical practice [10].

Materials and Methods

This prospective observational comparative study was conducted in the Department of Anaesthesiology at Basaveshwara Teaching and General Hospital, attached to Mahadevappa Rampure Medical College, Kalaburagi. The study aimed to compare ultrasonography and capnography for confirmation of endotracheal tube (ETT) placement following intubation in patients undergoing elective surgeries under general anesthesia.The study was carried out over a period of 18 months, from July 2024 to December 2025.A total of 60 adult patients undergoing elective surgeries under general anesthesia were included in the study.

Inclusion Criteria

- Patients aged 18–75 years undergoing elective surgery under general anesthesia
- Patients belonging to American Society of Anesthesiologists (ASA) physical status I or II
- Patients who provided written informed consent

Exclusion Criteria

- Patients with ASA physical status III or higher
- Patients with anticipated difficult airway, congenital neck anomalies, or previous neck surgery
- Patients with restricted neck movement or short neck affecting ultrasonographic assessment
- Patients unwilling to participate in the study

Study Groups: Participants were randomly divided into two groups of 30 patients each.

Group A (Ultrasonography): ETT placement was confirmed using ultrasonography with a high-frequency linear probe placed transversely over the anterior neck between the cricoid cartilage and suprasternal notch. Visualization of a single air–mucosal interface within the trachea indicated correct placement. The time required for confirmation was recorded.

Group B (Capnography): ETT placement was confirmed using waveform capnography. The time interval between connection of the end-tidal CO_2 sensor and the appearance of a consistent capnographic waveform was documented.

Study Parameters

Primary Parameter: Time taken (in seconds) to confirm correct ETT placement.

Secondary Parameters

- Success rate of each confirmation method
- Detection of esophageal or mainstem intubation
- Hemodynamic parameters (heart rate, blood pressure, SpO_2)
- Any complications during intubation or confirmation.

Study Procedure: All patients underwent pre-anesthetic evaluation prior to surgery. Standard monitoring including electrocardiography, pulse oximetry, and non-invasive blood pressure was applied in the operating room. Baseline vital parameters were recorded.

General anesthesia was induced using intravenous glycopyrrolate (0.005 mg/kg), midazolam (0.05 mg/kg), fentanyl (2 mcg/kg), and propofol (2 mg/kg). Endotracheal intubation was facilitated with succinylcholine (1 mg/kg) using an appropriately sized cuffed ETT.

Immediately after intubation, ETT placement was confirmed according to the assigned group using either ultrasonography or capnography. The confirmation time was measured using a digital stopwatch.

Anesthesia was maintained with isoflurane (0.5–2%), oxygen (33%), and nitrous oxide (67%), with intermittent doses of vecuronium. At the end of surgery, neuromuscular blockade was reversed and patients were extubated as per standard practice.

Data Collection: Data were recorded prospectively using a structured proforma including demographic details, confirmation method, confirmation time, and perioperative observations. Hemodynamic parameters were documented at baseline, during intubation, and after confirmation. Data were entered into Microsoft Excel for tabulation and verification.

Statistical Analysis: Data analysis was performed using IBM SPSS version 25.0. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequency and percentage. The unpaired Student's t-test was used to compare mean values between groups, and the Chi-square test or Fisher's exact test was applied for categorical variables. A p-value < 0.05 was considered statistically significant.

Ethical Considerations: Ethical approval was obtained from the Institutional Ethics Committee of Mahadevappa Rampure Medical College, Kalaburagi prior to the study. Written informed consent was obtained from all participants. Confidentiality of patient information was maintained, and the study was conducted in accordance with the Declaration of Helsinki.

Results

A total of 60 patients were included in the study, with 30 patients in each group. The age distribution between the ultrasonography (USG) and capnography groups was comparable, and no statistically significant difference was observed ($\chi^2 = 2.66$, df = 4, p = 0.62). The majority of participants were in the 18–30 years (28.3%) and 31–40 years (26.7%) age groups, while older age groups were less represented. This balanced age distribution indicates that age was unlikely to influence the comparison between the two confirmation techniques (Table 1).

The overall study population consisted of 31 males (51.7%) and 29 females (48.3%), with a male-to-female ratio of 1.07:1. In the USG group, males constituted 63.3%, whereas females were more common in the capnography group (60.0%). However, the difference in gender distribution between the two groups was not statistically significant (p = 0.071), suggesting that gender was evenly distributed across both groups (Table 1).The mean BMI was similar between the two groups. The USG group had a mean BMI of 25.6 ± 2.5 kg/m^2, while the capnography group had a mean BMI of 25.2 ± 2.0 kg/m^2. The difference was not statistically significant (p = 0.51), indicating comparable body habitus in both groups (Table 1).Most patients belonged to ASA Grade I (58.3%), followed by ASA Grade II (41.7%). A higher proportion of ASA Grade I patients was observed in the USG group (73.3%) compared to the capnography group (43.3%). This difference was statistically significant (p = 0.018), indicating a greater proportion of relatively healthier patients in the USG group (Table 1).The types of surgeries performed were similar in both groups. General surgery accounted for 31.7%, orthopedic procedures for 21.7%, and ENT, gynecological, and urological procedures for 46.6% of cases. There was no statistically significant difference in the distribution of surgical procedures between groups (p = 0.92), suggesting comparable operative profiles in both groups (Table 2).Baseline physiological parameters were comparable between the two groups. The mean heart rate was 84.3 ± 10.4 bpm in the USG group and 85.9 ± 9.8 bpm in the capnography group (p = 0.56). Similarly, systolic blood pressure, diastolic blood pressure, and oxygen saturation showed no statistically significant differences between groups (p > 0.05 for all parameters). These findings indicate that both groups were physiologically comparable prior to intubation (Table 2).

Oxygen saturation remained stable and above 98% in both groups throughout the procedure. No statistically significant differences were observed at any stage including pre-intubation, during intubation, and after confirmation (p > 0.05), indicating that both ultrasonography and capnography were safe and did not result in oxygen desaturation during confirmation of endotracheal tube placement (Table 2).Mallampati grading was comparable between groups with no statistically significant difference ($\chi^2 = 0.485$, p = 0.785). Most patients had Mallampati Grade II (51.7%), followed by Grade I (31.7%) and Grade III (16.6%). This indicates that airway difficulty levels were similar between groups and unlikely to affect the comparison between the two confirmations methods (Table 1).

The time taken to confirm endotracheal tube placement differed significantly between the two techniques. The median confirmation time in the USG group was 4.0 seconds (IQR: 3–5 seconds), whereas in the capnography group it was 7.0 seconds (IQR: 6–8 seconds). Statistical analysis using the Mann–Whitney U test showed a highly significant difference (U = 34.0, Z = −6.264, p < 0.001), indicating that ultrasonography confirmed ETT placement significantly faster than capnography (Table 3).Both ultrasonography and capnography demonstrated 100% sensitivity and overall accuracy in detecting correct endotracheal tube placement. However, since no incorrect intubations occurred in the study sample, specificity and negative predictive value could not be calculated. The 95% confidence interval for sensitivity was 88.43–100%. These findings indicate that both techniques were highly reliable for confirming correct ETT placement (Table 3).No statistically significant differences were observed in hemodynamic parameters between the two groups during the confirmation process. Heart rate, blood pressure, mean arterial pressure, and oxygen saturation remained stable and comparable throughout the peri-intubation period ($p > 0.05$ for all parameters), indicating that both confirmation methods were hemodynamically well tolerated (Table 2).Complication rates were low in both groups, with no statistically significant differences observed. Desaturation occurred in 16.7% of patients in the USG group and 30.0% in the capnography group ($p = 0.222$). Esophageal intubation was noted in one patient in the USG group and none in the capnography group ($p = 0.313$). Other complications such as coughing or movement during intubation and postoperative sore throat were minimal and comparable between groups (Table 3).Most procedures were rated as easy by operators in both groups. In the USG group, 73.3% of procedures were rated easy compared with 66.7% in the capnography group. The difference was not statistically significant ($\chi^2 = 0.317$, $p = 0.573$), indicating that both techniques were similarly feasible to perform in routine clinical practice (Table 3). Correlation analysis showed no significant relationship between BMI and time required for ETT confirmation ($r = 0.042$, $p = 0.752$), suggesting that BMI did not influence confirmation time within the included patient population (Table 3).Postoperative satisfaction was high in both groups. Very satisfied ratings were reported by 83.3% of patients in the USG group and 76.7% in the capnography group, with no statistically significant difference ($p = 0.51$). This indicates that both techniques were acceptable to patients and did not negatively affect the perioperative experience (Table 3).Mean arterial pressure values remained comparable between groups at baseline, during intubation, and after confirmation. None of the differences were statistically significant ($p > 0.05$), indicating that both techniques maintained hemodynamic stability throughout the intubation process (Table 2).Overall, ultrasonography confirmed endotracheal tube placement significantly faster than capnography while demonstrating comparable diagnostic accuracy, safety, and operator ease. These findings suggest that ultrasonography can serve as a rapid and reliable adjunct for confirmation of endotracheal tube placement in clinical practice (Tables 1–3).

Table 1: Baseline Characteristics of Study Participants (n = 60)

Parameter	USG Group (n = 30)	Capnography Group (n = 30)	p-value
Age (years)	38.4 ± 11.2	39.1 ± 10.6	0.62
Male n (%)	19 (63.3)	12 (40.0)	0.071
Female n (%)	11 (36.7)	18 (60.0)	
BMI (kg/m²)	25.6 ± 2.5	25.2 ± 2.0	0.51
ASA I n (%)	22 (73.3)	13 (43.3)	0.018
ASA II n (%)	8 (26.7)	17 (56.7)	
Mallampati I n (%)	10 (33.3)	9 (30.0)	0.785
Mallampati II n (%)	16 (53.3)	15 (50.0)	
Mallampati III n (%)	4 (13.3)	6 (20.0)	

Table 2: Comparison of Time Taken to Confirm Endotracheal Tube Position

Parameter	USG	Capnography	p-value
Median time (seconds)	4 (3–5)	7 (6–8)	<0.001
Mean Rank	16.63	44.37	
Mann–Whitney U	34.0	–	
Z value	-6.264	–	

Table 3: Diagnostic Accuracy and Safety Outcomes

Parameter	USG	Capnography	p-value
Sensitivity (%)	100	100	–
Accuracy (%)	100	100	–
Desaturation n (%)	5 (16.7)	9 (30.0)	0.222
Esophageal intubation n (%)	1 (3.3)	0 (0.0)	0.313
Coughing/movement n (%)	2 (6.7)	3 (10.0)	0.64
Post-operative sore throat n (%)	4 (13.3)	3 (10.0)	0.688
Procedure rated easy n (%)	22 (73.3)	20 (66.7)	0.573

Discussion

The present study was conducted to compare ultrasonography with capnography for confirmation of endotracheal tube (ETT) placement in adult patients undergoing endotracheal intubation. The primary objective was to evaluate the time required for confirmation of ETT position, while secondary outcomes included diagnostic accuracy, hemodynamic stability, complications, procedural ease, and patient satisfaction. The findings demonstrated that ultrasonography confirmed ETT placement significantly faster than capnography while maintaining comparable diagnostic accuracy and safety.

The demographic characteristics of both groups were comparable. Age distribution showed no statistically significant difference between groups ($p = 0.616$), with most patients belonging to the 18–40 year age group. Similar demographic comparability has been reported in earlier studies comparing airway ultrasonography and capnography. Karacabey et al. reported high agreement between the two techniques with overall diagnostic accuracy of 97.18% [11]. Likewise, Abhishek et al. demonstrated high diagnostic performance of ultrasonography in adult patients undergoing general anesthesia with sensitivity of 96.84% and specificity of 100% [12].

Gender distribution in the present study was nearly equal, with males constituting 51.7% and females 48.3%. Although minor differences existed between groups, these were not statistically significant ($p = 0.071$). Similar balanced gender representation has been reported in studies evaluating airway ultrasonography. Reddy et al. demonstrated ultrasonography sensitivity of 98.63% and specificity of 100% in emergency intubations, confirming its reliability across heterogeneous patient populations [13]. Roy et al. also reported perfect diagnostic agreement between ultrasonography and capnography, with ultrasound providing faster confirmation (4.93 seconds vs 15.39 seconds) [7].

Body mass index (BMI) was also comparable between groups ($p = 0.51$), and no correlation was found between BMI and confirmation time ($r = 0.042$, $p = 0.752$). These findings indicate that BMI did not influence the performance of either confirmation method within the included population. Maskay et al. similarly reported high diagnostic accuracy for ultrasonography (96.84%) with reliable performance across varied patient morphologies [6]. However, obese patients and anticipated difficult airways were excluded from the present study, and therefore the findings cannot be generalized to those populations. Although ASA physical status distribution differed significantly between groups ($p = 0.018$), all participants belonged to ASA grades I or II, representing relatively stable surgical populations. Similar findings have been reported by Srikanth et al., who demonstrated ultrasonography sensitivity of 97.22% and specificity of 100% in elective surgical patients [14]. In contrast, Chou et al. demonstrated that in low pulmonary blood flow states such as cardiopulmonary resuscitation, capnography may misidentify correct ETT placements, whereas ultrasonography remained accurate [15].

Baseline hemodynamic parameters and oxygen saturation were comparable between groups and remained stable throughout the peri-intubation period. Oxygen saturation remained above 98% in both groups, indicating that both confirmation techniques are safe in controlled settings. Similar observations have been reported by Reddy et al., who showed that ultrasonography allows rapid confirmation without compromising physiological stability [13].

Mallampati grade distribution was also comparable between groups ($p = 0.785$), ensuring similar airway difficulty conditions. Abhishek et al. and Srikanth et al. similarly demonstrated reliable ultrasonographic confirmation of ETT placement in elective surgical patients with comparable airway characteristics [12,14].

The primary outcome of the study showed that ultrasonography confirmed ETT placement significantly faster than capnography. Median confirmation time was 4 seconds with ultrasonography compared with 7 seconds with capnography ($p < 0.001$), representing approximately a 43% reduction in confirmation time. These findings are consistent with previous studies. Roy et al. reported ultrasound confirmation in 4.93 seconds compared with 15.39 seconds for capnography [7]. Reddy et al. also reported significantly faster confirmation with ultrasonography (8.13 ± 1.27 seconds vs 17.86 ± 2.34 seconds) [13]. Maskay et al. similarly reported a significant time advantage with ultrasonography [6]. Rapid confirmation is clinically important, particularly in emergency airway management where delayed identification of misplaced tubes can have serious consequences.

Both ultrasonography and capnography demonstrated 100% sensitivity and diagnostic accuracy in the present study. However, specificity and negative predictive value could not be calculated because no incorrect intubations occurred in the study sample. Previous studies have also reported high diagnostic accuracy for ultrasonography. Roy et al. demonstrated 100% sensitivity and specificity [7], while Reddy et al. reported sensitivity of 98.63% and specificity of 100% [13]. Hemodynamic parameters remained stable throughout the study, and no significant differences were observed between groups. Heart rate, blood pressure, and mean arterial pressure showed only expected physiological changes during intubation. These findings are consistent with previous studies indicating that ultrasonography confirmation does not introduce additional hemodynamic stress [7,13].

Complication rates were low in both groups, with no statistically significant differences. Minor events such as desaturation, coughing, and postoperative sore throat were comparable between groups, confirming that both techniques have good safety profiles. Similar safety findings have been reported in previous comparative studies [6,7].Ease of procedure was comparable between groups, with most procedures rated as easy. Approximately 73.3% of ultrasonography procedures and 66.7% of capnography confirmations were rated easy ($p = 0.573$). Srikanth et al. similarly described airway ultrasonography as a feasible and reliable real-time method for confirming ETT placement [14].Postoperative patient satisfaction was high in both groups and did not differ significantly, indicating that the choice of confirmation technique did not influence overall patient perception of care.

Conclusion

Ultrasonography proved to be a rapid and reliable method for confirming endotracheal tube placement, demonstrating diagnostic accuracy comparable to capnography while significantly reducing confirmation time. Both techniques were safe and well tolerated. Therefore, ultrasonography can serve as an effective adjunct to capnography, particularly in emergency situations where rapid confirmation of airway placement is essential.

Limitations

The present study had certain limitations. The sample size was relatively small and conducted at a single center, which may limit the generalizability of the findings.

Only patients with anticipated normal airways and ASA Grade I–II were included, while obese patients and those with difficult airway conditions were excluded. In addition, all intubations were successful, preventing the calculation of specificity and negative predictive value. Ultrasonography is also operator-dependent, and the accuracy may vary based on the experience of the clinician performing the examination.

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