RESEARCH PAPER

Ultrasonography Versus Conventional Chest Radiography for Confirmation of Endotracheal Tube Placement in Mechanically Ventilated Adults: A Randomized Controlled Trial

Dr. Priya Manjunath Shetty[1], Dr. Shivanand L Karigar[2], Dr. Akshay Kuchanur[3], Dr. Basavaraj Patil[4], Dr. Kotian Harshita Damodar Sudha[5]

[1]Junior Resident, Department of Anaesthesiology, Shri B. M. Patil Medical College Hospital and Research Centre, BLDE (Deemed to be University), Vijayapura, Karnataka, India.

[2]Professor, Department of Anaesthesiology, Shri B. M. Patil Medical College Hospital and Research Centre, BLDE (Deemed to be University), Vijayapura, Karnataka, India.

[3]Assistant Professor & Intensivist, Department of Medicine, Shri B. M. Patil Medical College Hospital and Research Centre, BLDE (Deemed to be University), Vijayapura, Karnataka, India.

[4]Associate Professor, Department of Anaesthesiology, Shri B. M. Patil Medical College Hospital and Research Centre, BLDE (Deemed to be University), Vijayapura, Karnataka, India.

[5]Junior Resident, Department of Anaesthesiology, Shri B. M. Patil Medical College Hospital and Research Centre, BLDE (Deemed to be University), Vijayapura, Karnataka, India.

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ABSTRACT

Background: Rapid, accurate confirmation of endotracheal tube (ETT) placement is critical in intensive care units (ICUs). Chest radiography (CXR) is commonly used but can be slow and resource-intensive. Upper-airway ultrasonography (USG) is a rapid, radiation-free alternative; however, comparative data from Indian ICUs are limited. The present study aimed to evaluate the effectiveness of ultrasonography in confirming ETT placement and position compared with conventional methods in adult ICU patients.

Materials and Methods: This prospective randomized study was done on 180 adult patients requiring endotracheal intubation. Ultrasonography was performed using a high-frequency linear probe to identify characteristic signs of tracheal intubation and to assess ETT depth using the saline-filled cuff technique. Conventional confirmation methods included clinical examination, capnography, and chest radiography.

Results: The mean age was 49.5 ± 18.1 years, with male predominance (67.8%). Ultrasonography confirmed ETT placement significantly faster than conventional methods (1.3 ± 1.7 minutes vs 21.9 ± 13.6 minutes; $p < 0.001$). The mean ETT position from the carina was comparable between groups (4.04 ± 0.6 cm vs 4.1 ± 0.3 cm; $p = 0.39$). The ultrasound group required fewer radiographs and had significantly lower imaging costs (₹400 ± 402 vs ₹927.78 ± 503.5).

Conclusion: USG is a rapid, reliable, cost-effective modality in confirming endotracheal tube placement and position in critically ill patients, reducing confirmation time and radiographic dependence while maintaining comparable accuracy to conventional methods.

Keywords: Endotracheal intubation, Ultrasonography, Point-of-care ultrasound, Intensive care unit, Airway management.

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INTRODUCTION

Patients in ICU often have limited physiological reserves, making airway management a high-risk procedure.[1]

Corresponding Author: Dr. Shivanand L Karigar, Shivanandkarigar82@gmail.com

Endotracheal intubation is a lifesaving intervention, but failure to promptly recognize esophageal intubation may cause severe complications and increased mortality.[2] Emergency intubation carries an increased risk of inadvertent esophageal intubation and delayed identification of improper tube placement.[2] Traditionally, verification of correct endotracheal tube (ETT) positioning has depended on monitoring end-tidal carbon dioxide ($EtCO_2$) levels.[3]

According to the Royal College of Anaesthetists' National Audit Project (NAP), approximately 25% of airway-related complications occur in the ICU.[4] Waveform capnography is widely regarded as the most reliable method for confirming correct ETT placement, given its excellent sensitivity and specificity.[5] However, capnography may provide unreliable results and requires several ventilatory cycles to confirm tube placement.[3] In addition, technical malfunction of gas analyzers may affect measurement accuracy, highlighting the need for rapid and reliable alternative methods.[6,7]

Apart from confirming tracheal placement, correct positioning of the ETT within the trachea is equally important.[8] Improper tube depth can cause endobronchial intubation, carinal stimulation, accidental extubation.[9] Conventional methods used to determine ETT position include clinical examination, cuff palpation at the suprasternal notch, estimation based on patient height, chest radiography, and fibreoptic bronchoscopy (FOB).[10] Although FOB is most reliable technique, its availability in many ICUs is limited, and procedures such as chest radiography are time-consuming, costly, and associated with radiation exposure.[11]

Point-of-care ultrasonography (POCUS) has recently gained prominence as a quick, non-invasive bedside modality for assessing the airway and verifying correct ETT placement.[12] Several studies in adult and pediatric populations have demonstrated high sensitivity and specificity of ultrasonography in confirming ETT placement.[13] The saline-filled cuff technique allows visualization of the cuff and helps determine appropriate tube depth without requiring patient repositioning.[14] Ultrasonography may therefore serve as a useful adjunct or alternative to conventional methods such as capnography and chest radiography.[5] However, limited literature exists comparing ultrasonography with conventional techniques in ICU settings. Hence, this study was aimed to evaluate the use of USG in confirming endotracheal intubation and determining ETT position in comparison with conventional methods in adult patients admitted to the ICU.

MATERIALS AND METHODS

This prospective randomized controlled single-centre study was conducted in the Intensive Care Units at a tertiary care centre, from June 2024 to November 2025. Institutional Ethics Committee approval was obtained prior to commencement of the study (IEC No: BLDE(DU)/IEC-SBMPMC/067/2023-24). The study was registered with the Clinical Trials Registry of India (CTRI No: CTRI/2025/05/087797). The study methodology and reporting followed CONSORT guidelines for randomized controlled trials.

The sample size was calculated using G*Power software version 3.1.9.4. The calculation was based on a two-tailed t-test for the difference between two independent means, with an effect size (d) of 0.42, alpha error probability of 0.05, and power ($1-\beta$) of 0.80. Based on these parameters, the minimum required sample size was 90 per group, resulting in 180 participants.

Adult patients aged > 18 years admitted to the ICU who required endotracheal intubation were included in the study. Patients with BMI > 30 kg/m², those with cervical spine immobilization or unsafe neck conditions, and patients intubated with uncuffed endotracheal tubes were excluded. Baseline data, clinical parameters, ventilatory parameters, and relevant comorbidities were noted.

Participants were randomly allocated into two groups using a computer-generated sequence in a 1:1 ratio: Group U (ultrasonography group) and Group C (conventional confirmation group), with 90 patients in each group. Allocation concealment was maintained using sequentially numbered, sealed opaque envelopes, which were opened only after enrolment of the participant.

Upper airway ultrasonography was performed by a trained intensivist using a high-frequency linear probe (13–6 MHz). The probe was placed transversely between the suprasternal notch and the cricothyroid membrane to visualize the trachea and adjacent structures. Specific sonographic signs were assessed to confirm the placement of the endotracheal tube (ETT). The "snowstorm sign" represented transient change of the air-mucosa interface with comet-tail artifacts indicating entry of the tube into the trachea. The "double-track sign" indicated the presence of a second air–mucosa interface suggestive of esophageal intubation. To assess the depth of the tube, the ETT cuff was inflated with approximately 10 mL of normal saline to produce an anechoic rounded cuff shadow. The cephalad border of the saline-filled cuff was localized relative to the tracheal rings, with the ideal position corresponding to the level of the third to fourth tracheal rings, indicating appropriate tube depth. If the cuff shadow was absent or displaced suggesting malposition, the tube position was reassessed and re-evaluated. The saline volume of 10 mL was selected to improve cuff visibility without increasing cuff pressure clinically.

In Group U (ultrasonography group), confirmation of endotracheal tube placement and assessment of tube position were performed using ultrasonography. In Group C (conventional group), confirmation of ETT placement was performed using conventional methods according to ICU protocol.

Conventional methods were also used to confirm ETT placement according to ICU protocol. These included clinical assessment with observation of bilateral chest expansion and auscultation, waveform capnography, and chest radiography. For radiographic confirmation, an anteroposterior chest X-ray was obtained and the ideal tube position was considered to be approximately 4 cm above the carina, corresponding to the mid-tracheal position.

Radiographic interpretation and data analysis were performed by investigators who were blinded to the group allocation in order to reduce observer bias.

The primary outcomes assessed were the time taken to confirm ETT placement and the accuracy of ETT tip position relative to the carina. Secondary outcomes included the cost of imaging, number of imaging procedures required, incidence of accidental extubation or displacement of the ETT due to patient movement, and any procedure-related complications.

Data was entered into Microsoft Excel and analysed using Statistical Package for Social Sciences (SPSS) version 26. Continuous variables were expressed as mean ± standard deviation (SD) and analysed using Mann-Whitney U test, while categorical variables were presented as frequencies and percentages and analysed using Chi-square test. A p-value of <0.05 was considered statistically significant.

RESULTS

The mean age of the participants was 49.5 ± 18.1 years with majority patients belonging to the 30–60 years age group. Regarding indications for mechanical ventilation, airway protection was the most common cause (Table 1).

Table 1. Baseline characteristics (n=180)

Variable		Frequency (n)	Percentage (%)
Age distribution	**<30 years**	35	19.4
	30–60 years	86	47.8
	>60 years	59	32.8
Gender	**Male**	122	67.8
	Female	58	32.2
Indication	**Airway protection**	108	60.0
	Type I respiratory failure	28	15.6
	Type II respiratory failure	44	24.4

The distribution of the number of chest X-rays required for confirmation of endotracheal tube placement differed significantly between Group U and Group C. A considerable proportion of patients in Group U required no radiographs, while all patients in Group C required at least one chest X-ray, with some needing multiple radiographs. Overall, Group U demonstrated significantly reduced radiographic utilization compared with Group C (Table 2).

Table 2: Number of chest X-rays required

Number of X-rays	Group U (Ultrasonography) n (%)	Group C (Conventional) n (%)	χ^2 value	p value
0	40 (44.3)	0 (0)	**84.7**	**<0.001**
1	28 (31.4)	45 (50.0)		

2	22 (24.3)	21 (23.3)		
3	0 (0)	16 (17.7)		
4	0 (0)	8 (9.0)		

Comparison of clinical outcomes showed that Group U confirmed endotracheal tube placement significantly faster than Group C. Additionally, the cost associated with imaging was substantially lower in Group U. However, the mean distance of the endotracheal tube tip from the carina was comparable between the two groups, indicating similar accuracy in tube positioning (Table 3).

Table 3: Clinical outcomes

Parameter	Group U (Ultrasonography) (Mean ± SD)	Group C (Conventional) (Mean ± SD)	Test value	p value
Time for confirmation (minutes)	1.3 ± 1.7	21.9 ± 13.6	**U = 204.6**	**<0.001**
ETT position from carina (cm)	4.04 ± 0.6	4.10 ± 0.3	U = 0.86	0.39
Cost of imaging (₹)	400 ± 402	927.78 ± 503.5	**U = 6.52**	**<0.001**

The incidence of accidental extubation was slightly lower in the Group U than group C (Table 4).

Table 4: Incidence of accidental extubation

Accidental extubation	Group U (Ultrasonography)	Group C (Conventional)	χ^2 value	p value
Yes	13 (14.4)	16 (17.8)	**1.21**	**0.27**
No	77 (85.6)	74 (82.2)		

DISCUSSION

The present study evaluated the role of USG in confirming ETT placement and position in comparison with conventional methods in critically ill patients. The mean age of the participants was 49.5 ± 18.1 years with majority patients belonging to the 30–60 years age group, with male predominance. Similar demographic patterns was showed by Sahana et al. and Senussi et al., who observed that middle-aged and elderly individuals frequently require mechanical ventilation due to underlying comorbidities and respiratory compromise.[15,16] Male predominance is also comparable with Vijaya Patil et al. and Roy P. et al., which have been attributed to higher prevalence of cardiopulmonary disease, smoking, and occupational exposures among men.[10,17]

In the present study, ultrasonography significantly reduced the time required for confirmation of endotracheal tube placement compared with conventional methods (1.3 ± 1.7 minutes vs 21.9 ± 13.6 minutes; $p < 0.001$). Rapid confirmation is critical in emergency airway management, as delays can lead to complications such as hypoxia or unrecognized esophageal intubation. Similar findings were reported by Sarangi et al., who demonstrated that ultrasound confirmed tracheal intubation significantly faster than capnography.[18] These findings highlight the advantage of point-of-care ultrasonography as a rapid bedside tool that can improve efficiency in ICU settings.

USG reduced the requirement for radiographic investigations and associated costs. Patients in Group U required fewer chest radiographs, resulting in significantly lower imaging costs compared with Group C (₹400 ± 402 vs ₹927.78 ± 503.5; $p < 0.001$). Patil V et al. and Congedi et al. also highlighted the economic benefits and reduced dependence on radiology services when ultrasound is used for airway confirmation.[10,19]

Regarding the accuracy of tube positioning, the mean distance of the endotracheal tube tip from the carina was comparable between ultrasonography and conventional methods, indicating similar reliability in assessing tube depth. Senussi et al. and Gottlieb et al., also showed that ultrasonography can accurately determine both placement and depth of the endotracheal tube.[16,20] Additionally, the incidence of accidental extubation was slightly lower in the Group U, consistent with the observations of Sayed et al., supporting the reliability of ultrasound for airway confirmation in critically ill patients.[21]

The present study has several strengths, including an adequate sample size determined through a priori power calculation, a prospective randomized controlled design, and inclusion of a real-world ICU patient population, which enhances the clinical relevance of the findings. Objective parameters such as time taken for confirmation and distance of the endotracheal tube from the carina were also systematically measured, improving the reliability of the results. However, certain limitations are there. Ultrasonography is operator-dependent, and its accuracy may vary depending on the training and experience of the clinician, although recent studies suggest that focused training can achieve competent performance in airway ultrasound. Fiberoptic bronchoscopy, considered a gold standard for ETT confirmation, was not used due to ethical and logistical constraints, and comparisons were instead made with conventional methods such as chest radiography and capnography according to unit protocols. Furthermore, specific patient subgroups such as obese individuals and those with neck trauma were excluded.

CONCLUSION

USG is rapid, reliable, cost-effective modality for confirming endotracheal tube placement and assessing tube position in critically ill patients. In this prospective randomized controlled study, ultrasound significantly reduced the time required for confirmation and minimized the need for repeated radiographic investigations, thereby lowering healthcare costs and radiation exposure, while maintaining comparable accuracy to conventional methods in determining the endotracheal tube position relative to the carina. These findings support the integration of point-of-care ultrasonography as a valuable bedside tool for airway confirmation in intensive care settings, particularly where rapid decision-making and resource optimization are essential.

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