ORIGINAL RESEARCH PAPER
Volume - 14 | Issue - 10 | October - 2025 | PRINT ISSN No. 2277 - 8179 | DOI : 10.36106/ijsr

INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH

DIAGNOSTIC ACCURACY OF POINT-OF-CARE ULTRASOUND FOR CONFIRMATION OF ENDOTRACHEAL INTUBATION IN THE EMERGENCY DEPARTMENT: A PROSPECTIVE OBSERVATIONAL STUDY

Emergency Medicine

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ABSTRACT

Background: The precise identification of the endotracheal tube placement is crucial in averting any grave complications as part of emergency airway management. The conventional methods like auscultation and chest radiography (CXR) is limited in terms of time, exposure to radiation, and transportation. Point-of-Care Ultrasound (POCUS) has become a possible fast, noninvasive alternative for bedside confirmation of position of the endotracheal tube. **Objectives:** To evaluate the diagnostic accuracy of upper airway Point-of-Care Ultrasound (POCUS) in confirming placement and depth of endotracheal tube, compared with auscultation and chest X-ray. **Methods:** This prospective observational study was conducted in the emergency department. A total of 100 intubated adult patients were assessed using auscultation, POCUS, and chest X-ray. POCUS signs included bullet sign, empty esophagus sign, and cuff visualization at suprasternal notch. **Patients:** A hundred adult patients who needed endotracheal intubation or were transported with a secured airway between January 2021 and January 2023 were considered. Those with a surgical airway, neck injuries, infants, or pregnant women were not included. **Results:** Auscultation identified malposition in 12% of cases, X-ray and POCUS identified it in 16% and 18% of cases, respectively. POCUS showed 100% sensitivity, 37.5% specificity, and 89.4% Positive Predictive Value, 100% Negative Predictive Value. Diagnostic accuracy was 90% with interobserver agreement ($\kappa = 0.92$). In comparison, auscultation showed 86% accuracy. **Conclusions:** POCUS has proven to be a rapid, radiation-free, reliable check method for endotracheal tube placement that can be expanded to depth checks. It can potentially replace CXR in emergency and low-resource settings, but the operator's proficiency is still needed. POCUS has potential to become first line for confirming correct endotracheal tube position in ED.

KEYWORDS

Auscultation, Chest Radiograph, Endotracheal Intubation, Emergency Airway Management, Point-of-Care Ultrasound, Tracheal Ultrasound, Tube Malposition

1. INTRODUCTION

Airway management is essential for resuscitating critically ill patients, especially in the emergency department (ED). Confirming the placement of the endotracheal tube is crucial for adequate ventilation and preventing serious complications like esophageal or main stem bronchial intubations. If the endotracheal tube is not correctly positioned, it can lead to poor oxygenation, gastric insufflation, lung injury, atelectasis, or even death if not quickly recognized and repositioned [1] Misplacement happens in up to 15% of cases, with the right main bronchus intubation being the most common malposition.[2]

Traditional methods for confirming endotracheal tube placement include direct laryngoscopy, auscultation, measuring end-tidal carbon dioxide levels ($ETCO_2$), and performing chest radiography. Each method has its own drawbacks. For example, capnography, despite being standard, can give false readings during cardiac arrest or low blood flow states. [3] Auscultation may miss unilateral intubations, and chest X-rays may take time, especially for unstable patients or during active cardiopulmonary resuscitation. [4] Moreover, radiation exposure and patient handling add concerns in critical care situations.[5]

Point-of-care ultrasound (POCUS) has become a non-invasive, portable, real-time option for confirming airway placement. Ultrasound of the upper airway can accurately tell the difference between tracheal and esophageal intubations and check tube depth by visualizing a saline or air-inflated cuff at the suprasternal notch. [6] It is instrumental in emergencies where other methods might be slow or impractical. Previous studies have found that POCUS has high sensitivity and specificity, with accuracy comparable to,or better than traditional methods.[7-9]

Even with increasing evidence, limited research directly compares POCUS with auscultation and chest X-rays to confirm endotracheal tube placement and depth in emergencies. Additionally, the consistency of POCUS results among different observers has not been thoroughly tested in real-time clinical settings.

 PRINT ISSN No. 2277 - 8179 | DOI : 10.36106/ijsr

This prospective observational study aims to evaluate the reliability of upper airway POCUS in confirming endotracheal intubation and tube depth compared to auscultation and chest X-rays in the emergency department.

2. METHODOLOGY

2.1. Study Design and Setting

A prospective observational hospital based comparative study on 100 patients presenting to emergency department of Yashoda Super Speciality Hospital, Malakpet between January 2021 to January 2023, requiring endotracheal intubations or who were transferred with a secured airway from an outside facility, satisfying the inclusion and exclusion criteria, obtaining hospital ethical committee approval and written informed consent. Functional outcome of the study has been evaluated using upper airway POCUS and compared with auscultation and chest radiographs.

2.2. Study Population

Adult patients (≥18 years) requiring endotracheal intubation in the emergency department (ED). This included patients undergoing in-hospital resuscitation and those transferred with a pre-secured airway. Patients were enrolled consecutively, depending on the availability of the ultrasound operator and functional imaging equipment.

2.3. Inclusion Criteria

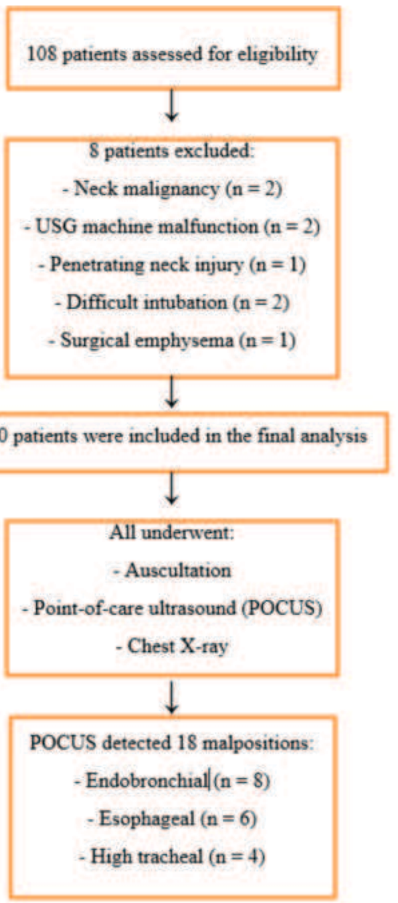
1. All cases requiring endotracheal intubation in the ED
2. All cases transferred with a secured airway from an outside facility
3. All cases requiring a switch from alternate airway devices to a standard endotracheal tube

2.4. Exclusion Criteria

1. Patients with pre-existing surgical airways
2. Patients requiring NIV or supraglottic airway devices
3. Patients having a penetrating injury in the neck region
4. Infants and Neonates
5. Pregnant females

Study Flowchart

Flowchart showing patient screening, exclusions, final inclusion, and the diagnostic pathway used in the study.



2.5. Sample Size

A total of 100 patients were included in the final analysis. The sample size was considered adequate to ensure the internal validity and statistical power for the sensitivity and specificity estimates, based on the effect sizes observed in prior studies evaluating ultrasonographic confirmation of endotracheal tube placement. It also allowed for meaningful subgroup analysis while accounting for potential exclusion or data loss.

2.6. Intubation Protocol

All intubations were performed by emergency medicine residents using direct laryngoscopy with a senior emergency physician directly supervising them. The procedure adhered to the hospital's standard operating procedure (SOP) based on Advanced Cardiac Life Support (ACLS) guidelines. Although the intubations were not video recorded, real-time clinical supervision ensured that the protocol was followed and the technique remained consistent.

After each procedure, we confirmed placement through three methods:
- Auscultation
- Point-of-Care Ultrasound (POCUS)
- Chest X-ray (AP view)

A senior emergency physician, with over four years of post-training experience, performed auscultation. POCUS was performed by the principal investigator, who received 12 hours of hands-on training under the guidance of an experienced radiologist with over 20 years of experience in the field. All POCUS examinations were supervised by a senior emergency physician who performed more than 150 supervised ultrasound scans.

2.7. POCUS Technique

We used a high-frequency linear array transducer (8–12 MHz) with a Philips HD11 ultrasound machine. The patient was placed supine in a sniffing position. [10-12]. Probe positions and scanning planes are illustrated in Figure 1.

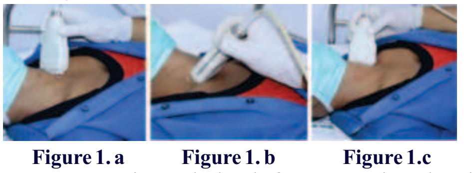


Figure 1. a **Figure 1. b** **Figure 1.c**

Figure 1.a Transverse view at the level of suprasternal notch and to the left of the trachea.
Figure 1.b Transverse view at the level of suprasternal notch.
Figure 1.c Parasagittal view at the level of suprasternal notch.

Airway Ultrasound Views:
We conducted a transverse scan at the suprasternal notch and to the left of midline to detect:
- Bullet sign (widening of vocal cord angle) [8] (Figure 2)
- Empty esophagus sign (non-visualization of ET Tube in Esophagus) [10] (Figure 2)
- Double lumen/trachea sign (indicating esophageal intubation) [11] (Figure 3)

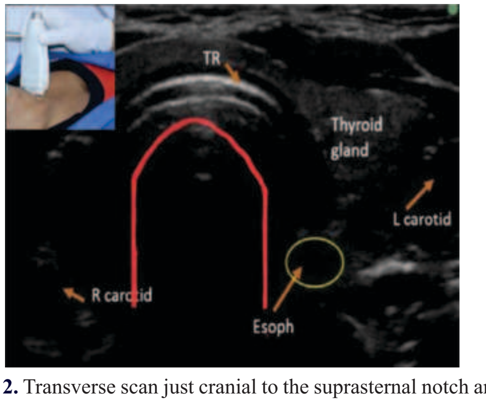


Figure 2. Transverse scan just cranial to the suprasternal notch and to the left side of the trachea showing BULLET SIGN (vocal cord angle widening) and EMPTY ESOPHAGUS SIGN, suggestive of endotracheal intubation.TR: Tracheal Rings

PRINT ISSN No. 2277 - 8179 | DOI : 10.36106/ijsr

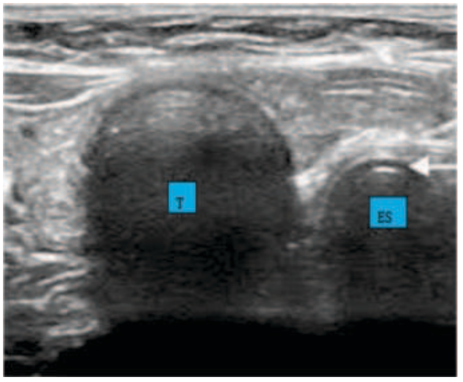


Figure 3. Transverse scan showing DOUBLE LUMEN SIGN or DOUBLE TRACHEA SIGN, suggestive of esophageal intubation T: Trachea, ES: Esophagus

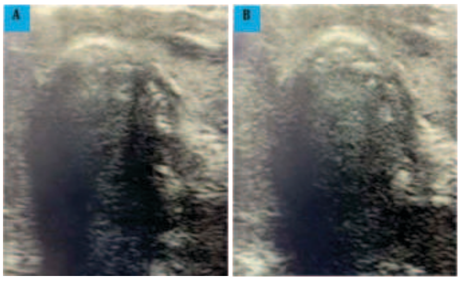


Figure 4. Transverse scan showing endotracheal intubation with visualization of the cuff at the suprasternal notch during inflation (A) and deflation (B) of the cuff as identified by widening and narrowing of tracheal shadow respectively.

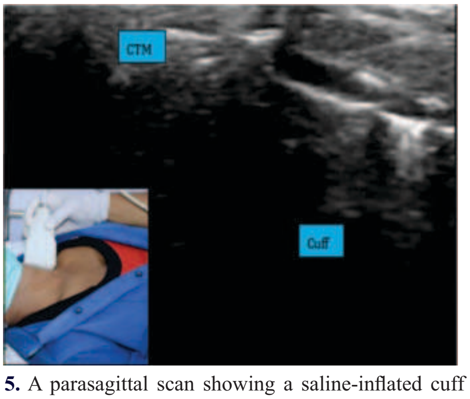


Figure 5. A parasagittal scan showing a saline-inflated cuff of the endotracheal tube at the level of the suprasternal notch, suggesting an appropriate depth of the endotracheal tube. CTM: Cricothyroid Membrane

We also took parasagittal and transverse views (Figure 4 and 5) to identify cuff of the endotracheal tube at the suprasternal notch during inflation and deflation and confirm the appropriate depth. [12] The cuff was properly checked prior to the procedure, 7ml saline inflated for performing POCUS. Immediately cuff was deflated and re-inflated with air after the procedure. Proper suctioning of mouth and oropharynx was strictly followed before altering the cuff to prevent the risk of aspiration of any secretions. POCUS was performed immediately after intubation, and before radiographic confirmation. We have documented and stored the POCUS findings.

2.8. Chest Radiography

Portable anteroposterior chest X-rays were obtained within 15 minutes of intubation while the patient was in a semi-recumbent position. Radiographs were interpreted by a senior experienced radiologist who was blinded to the ultrasound findings to minimize observer bias. Proper endotracheal tube position was defined as 2 to 6 cm above the carina or at the level of T3 to T4. [4] The chest X-ray interpretation served as the gold standard comparator for this study. Various malposition's found in CXR shown below in (Figure 6 and 7).

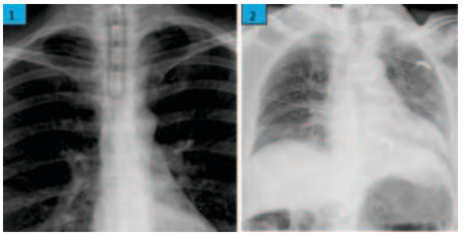
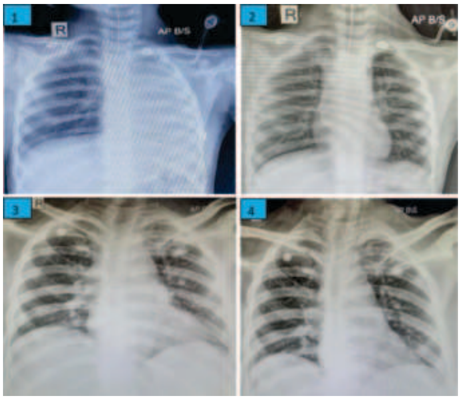


Figure 6.1. Correct endotracheal tube position in trachea (approximately 4 cms above the carina),
Figure 6.2. Esophageal intubation (endotracheal tube is seen projecting from the left side of the neck, outside the tracheal air column, in alignment with the nasogastric tube, associated with gaseous distension of the stomach.



- **Figure 7.1.** Right main bronchus intubation with atelectasis of the left lung.
- **Figure 7.2.** Corrected endotracheal tube with reexpansion of the left lung
- **Figure 7.3.** ET tube non-visualization in an intubated patient is caused by a position that is too high.
- **Figure 7.4.** Corrected endotracheal tube position.

2.9. Outcome Measures

Primary outcome was the diagnostic accuracy of POCUS in confirming both endotracheal tube placement and appropriate depth, compared with chest radiography.

Secondary outcomes included sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and interobserver agreement for POCUS, auscultation and X-ray findings, as assessed by the Kappa statistic, with $\kappa \geq 0.80$ considered excellent. [13]

2.10. Statistical Analysis

Data analysis was conducted using SPSS Version 19.0 (IBM, USA). Continuous variables are shown as mean ± standard deviation (SD) or median with interquartile range (IQR). Categorical data summarized with frequencies and percentages. We assessed proportional differences using the Chi-square test. We calculated diagnostic accuracy parameters, including sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV), using 2×2 contingency tables. Interobserver agreement was evaluated with the Kappa coefficient (κ).[14]

3. RESULTS

3.1. Study Population

Table 1 summarizes the baseline characteristics of the 100 patients who underwent endotracheal intubation during the study period. The median age was 53.5 years (IQR 53.5–82). Seventy-three patients (73%) were male. The mean body mass index (BMI) was 22.4 ± 2.9 kg/m². Most intubations took place within the hospital (88%). Twelve percent occurred outside the hospital and were referred with a secured airway.

The most common reasons for intubation were low Glasgow Coma Scale (GCS) (39%), impending respiratory failure (26%), and shock (17%). Other reasons included impending cardiopulmonary arrest (14%), status epilepticus (5%), and cardiac arrest (2%).

3.2. Procedural Characteristics

All patients had their endotracheal tube position confirmed using auscultation, point-of-care ultrasound (POCUS), and chest radiography (CXR). Auscultation found 12 malpositions (12%). POCUS detected 18 malpositions (18%), which included eight endobronchial placements (44.4%), six esophageal placements (33.3%), and four high tracheal placements (22.2%).

The principal investigator performed an ultrasound immediately after intubation, usually within 30 to 60 seconds. The cuff was visualized at the level of suprasternal notch in 82 patients (82%).

Key ultrasound signs were noted as follows:
- Bullet sign: 93 patients (93%)
- Empty esophagus sign: 94 patients (94%)
- Double trachea sign: 6 patients (6%)

All patients also had a portable AP chest X-ray as the reference standard for confirmation.

3.3. Outcomes
According to the CXR interpretation, 84 patients (84%) had correct endotracheal tube placement, while 16 patients (16%) were malpositioned.

POCUS showed strong diagnostic performance with a sensitivity of 100%, specificity of 37.5%, positive predictive value (PPV) of 89.4%, negative predictive value (NPV) of 100%, and an overall accuracy of 90%.

In comparison, auscultation had a sensitivity of 66.7%, specificity of 89.3%, PPV of 50%, NPV of 94.8%, and accuracy of 86%. The agreement between POCUS and chest radiography was almost perfect, with a Kappa value (κ) of 0.92.

Table 1: Patient Baseline Characteristics

Variables	Total (n = 100)
Patient demographics	
Age, median (IQR), yr	53.5 (53.5–82)
Male gender, n (%)	73 (73)
BMI, mean (SD), kg/m²	22.4 (2.9)
Place of intubation, n (%)	
In-hospital	88 (88)
Outside hospital	12 (12)
Indication for endotracheal intubation, n (%)	
Low Glasgow Coma Scale (GCS)	39 (39)
Impending respiratory failure	26 (26)
Shock	17 (17)
Impending cardiopulmonary arrest	14 (14)
Status epilepticus	5 (5)
Cardiac arrest	2 (2)
Others	2 (2)
Number of intubation attempts, n (%)	
Single attempt	97 (97)
Two or more attempts	3 (3)
Tracheal tube size, internal diameter, mm, n (%)	
7.0	9 (9)
7.5	66 (66)
8.0	25 (25)
Fixation point at lips, mean (SD), cm	22.6 (1.5)

IOR-Interquartile Range, SD-Standard Deviation, BMI-b=Body Mass Index

Table 2: Procedural Confirmation Findings and Diagnostic Outcomes

Variables	Patients (n = 100)
Tracheal and airway ultrasound, n (%)	
Bullet sign	93 (93)
Empty esophagus sign	94 (94)
Double trachea sign (esophageal intubation)	6 (6)
Cuff visualisation at the suprasternal notch	82 (82)
Malposition type identified by POCUS, n (%)	
Endobronchial	8 (8)
Esophageal	6 (6)
Too high (High Tracheal)	4 (4)
Overall POCUS interpretation, n (%)	
Correctly placed ETT	82 (82)
Malpositioned ETT	18 (18)
Chest X-ray (CXR), n (%)	
Performed	100 (100)
Correct ETT placement by CXR	84 (84)
Malposition by CXR	16 (16)
Auscultation, n (%)	
Correct placement	88 (88)
Malposition	12 (12)

CXR = chest radiography, ET = endotracheal tube, SD = standard deviation.

Table 3: Diagnostic Accuracy of POCUS and Auscultation Versus Chest X-ray

Modality	Diagnostic Metric (% unless stated)
POCUS	
Sensitivity	100
Specificity	37.5
Positive predictive value (PPV)	89.4
Negative predictive value (NPV)	100
Overall accuracy	90
Auscultation	
Sensitivity	66.7
Specificity	89.3
Positive predictive value (PPV)	50
Negative predictive value (NPV)	94.8
Overall accuracy	86

- POCUS = Point-of-care ultrasound
- PPV = Positive predictive value
- NPV = Negative predictive value
- CXR = Chest radiograph used as the diagnostic gold standard
- All values are percentages unless noted otherwise.
- We calculated diagnostic accuracy metrics using standard 2×2 contingency tables, with CXR-confirmed endotracheal tube position as the reference

4. DISCUSSION
Our study looked at 100 patients who needed emergency airway management. We assessed how accurately point-of-care ultrasound (POCUS) can diagnose compared to auscultation and chest X-rays. Besides confirming tracheal placement, POCUS also facilitated bedside assessment of depth of endotracheal tube.

Baseline Characteristics
Our cohort was mostly male (73%) with a median age of 53.5 years. The most common reasons for intubation were low Glasgow Coma Scale (39%) and impending respiratory failure (26%). These patterns are similar to those reported by Chou et al. [6] and Patil et al. [12], where neurological and respiratory causes were the main reasons for emergency intubation.

Diagnostic Accuracy Compared to Literature
The sensitivity of POCUS in our study (100%) matches with Senussi et al. [7], where they reported 100% sensitivity and 95% specificity in a multicenter analysis. Similarly, Gottlieb et al. [14] conducted a meta-analysis of 21 studies and found a pooled sensitivity of 98.7% and specificity of 97.1%, confirming the high reliability of POCUS. Abbasi et al. [8] noted slightly lower sensitivity (94.1%) and specificity (91.6%), which may reflect differences in operator training and ultrasound technique. Sim et al. [25] reported a sensitivity of 97% and specificity of 100%. Chou et al. [6], using the TRUE protocol, confirmed quick and accurate results in emergency intubations. Our lower specificity compared to these studies likely stems from our conservative approach, labeling high tracheal placements as malposition while others found them acceptable.

Comparison with Traditional Methods
Auscultation in our study achieved 66.7% sensitivity and 86% accuracy, which is much lower than POCUS. Abbasi et al. [19] found similar issues, noting that auscultation missed 21% of esophageal intubations. Milling et al. [25] also pointed out the unreliability of auscultation in cardiac arrest and noisy environments. In contrast, POCUS provided confirmation within about 60 seconds, similar to the TRUE protocol described by Chou et al. [6], which achieved confirmation within 15 seconds.

Depth Assessment and Additional Findings

Cuff visualization at the suprasternal notch was observed in 82% of our patients, closely linked to correct depth. Patil et al. [12] reported 94% accuracy for depth assessment using cuff visualization. Arafa et al. [10] and Das et al. [9], in their systematic review, supported the effectiveness of this method, showing pooled sensitivity and specificity of 93% and 96% for cuff localization.

Clinical Relevance

Unlike chest radiography, which is the reference standard but takes time and exposes patients to radiation, POCUS provides immediate bedside confirmation without these drawbacks [11]. These benefits are crucial in resource-limited settings or during cardiac arrest, where delays can negatively impact outcomes. While capnography is a gold standard in many protocols, its reliability decreases during low flow states or cardiac arrest, making POCUS a useful addition. [16,17]

Limitations

Our study was conducted at a single center with a modest sample size, which limits its generalizability. We did not formally record confirmation time, and a cost-effectiveness analysis was not part of the study. Future research should explore integrating POCUS into structured airway protocols across multiple centers and investigate its role in prehospital care.

5. CONCLUSION

Point-of-care ultrasound (POCUS) is a highly sensitive, non-invasive, and readily accessible solution for confirming endotracheal tube placement. It effectively distinguishes between tracheal and esophageal intubations and allows real-time depth assessment, minimizing the risk of misplacement.

Compared to traditional methods like auscultation and chest X-ray, POCUS shows superior diagnostic sensitivity and comparable overall accuracy, with added advantages of portability and immediate bedside use. Its practical value is especially evident in critically ill patients, during cardiac arrest situations, or whenever time and clarity are crucial. [8,14,15]POCUS has the potential to replace conventional repeated X-rays, especially in ICU's and pregnant patients.

Chest X-rays maintain their role in definitive depth confirmation and ongoing monitoring. However, this study along with others encourages the wider use of POCUS in standard airway-confirmation protocols. Given its high reliability (κ = 0.92), POCUS could improve patient safety and reduce delays in both emergency and prehospital care.

POCUS has the potential to become the first line for confirming correct endotracheal tube positions in the ED. POCUS is operator-dependent and requires structured training. Hence, Chest X-ray should be performed if there is high clinical suspicion of malposition of the endotracheal tube. As technology becomes more portable and accessible, ultrasound-based airway confirmation is increasingly positioned to become a routine standard of emergency practice.

Clinical Implications

Using POCUS as a standard tool in airway management can improve patient safety, reduced complications from malposition, and help with efficiency in critical situations.

Future Directions

More multicentre trials with larger groups are needed to confirm these findings, set standard training protocols, and look into cost-effectiveness and use in prehospital settings. [18,22,24]

6. Declaration

6.1. Funding

No external funding was received for this study.

6.2. Conflicts of Interest

The authors declare no conflicts of interest related to this work.

6.3. Author Contributions Statement

Author 1: Conceptualization, data collection, ultrasound examination, statistical analysis, manuscript drafting, and revision.
Author 2: Guidance on methodology, manuscript review, and final drafting.
Author 3: Study supervision, final approval.
Author 4: Evidence based guidance, manuscript review.
Author 5: Guidance on image acquisition, POCUS training.

6.4. Ethical Approval

This study was approved by the Institutional Ethics Committee of Yashoda Super Speciality Hospital in Malakpet, Hyderabad, India. Written informed consent was obtained from all participants or their legal representatives.

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