e-ISSN: 0976-822X, p-ISSN:2961-6042

Available online on http://www.ijcpr.com/

International Journal of Current Pharmaceutical Review and Research 2026; 18(6); 533-541

Original Research Article

A Comparison Between Ultrasound-Guided Percutaneous Tracheostomy and Bronchoscopy-Guided Percutaneous Tracheostomy in Critically Ill Patients Admitted in the Intensive Care Unit: A Prospective Randomized Comparative Study

Chahat Shahi[1], Himanshu Kumar[2], Ajeet Kumar[3]

[1]Ex Senior Resident, Department of Anesthesiology and Critical Care, All India Institute of Medical Sciences, Patna, Bihar, India and PDCC-CCM, Resident, Department of Anesthesiology and Critical Care, Era Medical College & Hospital, Lucknow Uttar Pradesh, India

[2]Assistant Professor, Department of Anesthesiology and Critical Care, Narayan Medical College and Hospital, Sasaram, Bihar, India

[3]Assistant Professor, Department of Anesthesiology and Critical Care, Narayan Medical College and Hospital, Jamuhar, Sasaram, Bihar, India

Received: 06-02-2026 / Revised: 16-03-2026 / Accepted: 10-04-2026

Corresponding Author: Dr. Chahat Shahi

Conflict of interest: Nil

Abstract

Background: Percutaneous dilatational tracheostomy (PDT) is a widely performed bedside procedure in intensive care units. Real-time ultrasound guidance (USG-PDT) and bronchoscopic guidance (Broncho-PDT) represent the two dominant modalities for tracheal needle puncture in contemporary practice. Their comparative performance with respect to procedural efficiency, oxygenation, and safety in the Indian critical care setting remains incompletely characterized.

Aim: To compare ultrasound-guided and bronchoscopy-guided percutaneous dilatational tracheostomy with respect to procedural outcomes, periprocedural oxygenation, complication rates, and clinical outcomes in mechanically ventilated critically ill patients.

Methods: A prospective randomized comparative study was conducted in the Intensive Care Unit, Narayan Medical College and Hospital, Sasaram, Bihar, India, from 10th April 2025 to 10th June 2025. Thirty mechanically ventilated adult patients requiring bedside tracheostomy were randomized equally into Group A (USG-PDT, n = 15) and Group B (Broncho-PDT, n = 15). Primary outcomes were total procedure time and first-pass needle success rate. Secondary outcomes included periprocedural SpO2, PaCO2, operator ease, complication rates, ICU length of stay, and 30-day all-cause mortality.

Results: Baseline demographics and clinical severity were comparable between the two groups. The USG-PDT group demonstrated significantly shorter total procedure time (12.1 ± 3.3 vs. 18.8 ± 4.4 minutes; mean difference −6.7 min, 95% CI: −9.6 to −3.8; $p < 0.001$) and skin-to-tracheal lumen time (5.2 ± 1.9 vs. 8.4 ± 2.5 minutes; mean difference −3.2 min, 95% CI: −4.9 to −1.5; $p < 0.001$). Optimal midline tracheal puncture was more frequently achieved with ultrasound guidance (93.3% vs. 60.0%; risk difference +33.3%, 95% CI: 5.5% to 61.1%; $p = 0.04$). Mean periprocedural SpO2 (96.2 ± 2.3% vs. 91.4 ± 3.9%; mean difference +4.8%, 95% CI: 2.4% to 7.2%; $p < 0.001$) and lowest SpO2 (92.8 ± 2.9% vs. 85.9 ± 4.8%; mean difference +6.9%, 95% CI: 3.9% to 9.9%; $p < 0.001$) were significantly better in the USG-PDT group. PaCO2 at 30 minutes post-procedure was significantly lower with USG-PDT (44.2 ± 5.4 vs. 52.8 ± 8.1 mmHg; mean difference −8.6 mmHg, 95% CI: −13.7 to −3.5; $p < 0.001$). The overall complication rate did not reach conventional statistical significance (26.7% vs. 60.0%; risk difference −33.3%, 95% CI: −66.7% to 0.1%; $p = 0.07$), a finding consistent with the study being underpowered for this secondary endpoint. First-pass needle success, ICU length of stay, and 30-day mortality were comparable between the groups.

Conclusion: Ultrasound-guided PDT demonstrated superior procedural efficiency, significantly better periprocedural oxygenation, and a clinically meaningful reduction in complication burden compared to bronchoscopy-guided PDT. USG-PDT is a safe, time-efficient, and logistically practical alternative for bedside tracheostomy in the ICU setting and may be considered the preferred guidance modality in resource-sensitive Indian critical care environments.

Keywords: Percutaneous Dilatational Tracheostomy, Ultrasound Guidance, Bronchoscopy Guidance, Intensive Care Unit, Mechanical Ventilation, Periprocedural Oxygenation, Procedural Complications.

DOI: 10.25258/ijcpr.18.6.91

Introduction

Tracheostomy is one of the most frequently performed procedures in the intensive care unit (ICU), executed in up to 10–24% of all mechanically ventilated patients, with the aim of facilitating prolonged ventilator support, enabling earlier weaning, reducing sedation requirements, and improving patient comfort.[1] Since the landmark description by Ciaglia et al. in 1985, percutaneous dilatational tracheostomy (PDT) has progressively replaced open surgical tracheostomy as the preferred bedside modality in most ICUs worldwide.[1] The technique, employing the Seldinger wire-guided sequential dilatation principle, offers the advantages of avoiding general anaesthesia, reducing the need for transportation to the operating theatre, lowering infectious complications, and delivering an economically efficient procedure without compromising safety.[2,3]

The classical landmark-based PDT approach relies on external anatomical palpation for tracheal puncture site identification. While acceptable in straightforward anatomies, this blind technique carries an inherent risk of anterior neck vascular injury, paratracheal cannulation, posterior tracheal wall perforation, and procedural hypoxia, risks that are amplified in the obese, the coagulopathic, and those with prior neck pathology.[3,8] Two guidance modalities have emerged to substantially mitigate these risks: bronchoscopic guidance and real-time ultrasound guidance, each offering distinct mechanistic advantages and limitations.

Bronchoscopic guidance has historically occupied the position of the gold standard for PDT, providing direct endoluminal visualization of the tracheal puncture, real-time confirmation of needle entry into the lumen, prevention of posterior wall injury, and immediate identification of inadvertent paratracheal placement.[10,12] Large prospective case series have validated its safety profile.[10] However, the bronchoscope occupies a significant proportion of the tracheal lumen during the procedure, creating a functionally narrowed airway that promotes hypercarbia, reduces effective tidal volume delivery, and can precipitate clinically significant hypoxia, particularly in patients with pre-existing respiratory insufficiency.[14] The additional resource requirements of a dedicated flexible bronchoscope, trained endoscopist, and supporting nursing personnel introduce logistical and financial constraints that may limit its universal applicability, especially in lower-resource critical care environments.[4,12]

Ultrasonography has transformed procedural safety across multiple domains of critical care medicine, and its application to percutaneous tracheostomy has been explored with growing interest over the preceding two decades.[5,9] Pre-procedural anterior neck mapping by ultrasound permits delineation of tracheal ring anatomy, identification of inter-ring spaces, localisation of the thyroid gland, detection of variant or anomalous anterior neck vasculature including thyroid vessels, and precise midline puncture site selection.[5] When applied in real time during needle puncture, ultrasound enables dynamic tracking of the needle tip, confirmation of intraluminal guidewire placement through sonographic bubble visualization, and immediate recognition of anterior tracheal wall proximity.[5,7] A critically important attribute is that ultrasound guidance does not encroach upon the airway, thereby eliminating the mechanism by which bronchoscopy-guided PDT generates iatrogenic respiratory compromise.[6]

Comparative trials evaluating the two modalities have yielded broadly concordant findings. The TRACHUS randomized trial by Gobatto et al. demonstrated non-inferiority of USG-PDT to Broncho-PDT in overall procedural success while favouring ultrasound guidance in secondary outcomes including procedure time.[4] Rajajee et al. established the feasibility of real-time USG-PDT in anatomically complex patients.[5] Kollig et al. demonstrated the incremental benefit of ultrasound in improving puncture accuracy over bronchoscopy alone.[6] Guinot et al. confirmed the utility of USG guidance in obese ICU patients where surface anatomy is distorted.[7] Despite these contributions, evidence from Indian tertiary care ICUs—where patient profiles, resource availability, and operator training pathways differ considerably from Western contexts—remains limited.[15]

The present prospective randomized comparative study was designed to directly compare USG-PDT and Broncho-PDT in critically ill mechanically ventilated patients admitted to the ICU of Narayan Medical College and Hospital, Sasaram, Bihar, during the period from 10th April 2025 to 10th June 2025. The primary objective was to compare total procedure time and first-pass needle success rate between the two guidance modalities.

Secondary objectives included periprocedural oxygenation parameters, accuracy of tracheal puncture, operator-perceived technical ease, procedural complications, ICU length of stay, and 30-day all-cause mortality. Building on our institutional experience with percutaneous tracheostomy in this patient population,[15] this study aims to provide locally applicable comparative evidence to inform guidance modality selection in resource-sensitive ICU environments.

Material and Methods

This prospective randomized comparative study was conducted in the Intensive Care Unit of Narayan Medical College and Hospital (NMCH), Sasaram, Bihar, India, from 10th April 2025 to 10th June 2025, after obtaining ethical clearance from the Institutional Ethics Committee (IEC Ref: NMCH/IEC/2025/042) and registration with the Clinical Trials Registry India (CTRI/2025/04/089742). Written informed consent was obtained from the legally authorized representative of each patient prior to enrollment in accordance with the principles of the Declaration of Helsinki and Good Clinical Practice guidelines.

Adult mechanically ventilated patients (age ≥ 18 years) admitted to the medical-surgical ICU who required bedside tracheostomy were screened for eligibility. Accepted indications included prolonged mechanical ventilation requiring tracheostomy-facilitated weaning, failure to wean from the ventilator, neurological compromise necessitating long-term airway protection, and excessive tracheobronchial secretions refractory to endotracheal tube management.

Patients were excluded if they had anatomical abnormalities precluding safe percutaneous access (surgically altered neck anatomy, cervical spine instability or injury, or tracheal deviation), uncorrectable coagulopathy (platelet count < 50,000/μL or INR > 2.0 after active correction), active skin or soft tissue infection overlying the proposed puncture site, a neck circumference exceeding 50 cm with insufficient tracheal depth on preliminary ultrasound assessment, age below 18 years, pregnancy, or clinical instability that the attending intensivist deemed a contraindication to elective procedural intervention at that time.

Following the application of inclusion and exclusion criteria, thirty patients were enrolled and randomized in a 1:1 ratio into two equal groups of fifteen patients each: Group A, the ultrasound-guided PDT group (USG-PDT, n = 15), and Group B, the bronchoscopy-guided PDT group (Broncho-PDT, n = 15).

Allocation concealment was ensured by the use of computer-generated random numbers maintained in sequentially numbered sealed opaque envelopes, opened in order by a co-investigator not involved in the conduct of the procedure. Given the inherent nature of procedural guidance techniques, blinding of the primary operator was not possible; however, outcome data were recorded by a blinded independent observer.

All procedures were performed at the bedside in the ICU by qualified intensivists with a minimum of two years post-postgraduate experience and at least 20 independently performed PDT procedures under supervision. Patients were pre-oxygenated with 100% fractional inspired oxygen (FiO2 = 1.0) for a minimum of five minutes immediately prior to the procedure. Continuous monitoring throughout the procedure included twelve-lead ECG, peripheral oxygen saturation (SpO2), non-invasive or invasive arterial blood pressure, and end-tidal carbon dioxide (EtCO2) capnography. Patients were positioned supine with a cylindrical shoulder roll to achieve moderate neck extension. Analgosedation was administered using intravenous fentanyl (1–2 μg/kg) and midazolam (0.02–0.05 mg/kg), with dose adjustments based on clinical haemodynamic status and pre-existing sedation requirements.

In Group A (USG-PDT), a high-frequency linear array ultrasound probe (7–15 MHz) was applied to the anterior neck for pre-procedural anatomical mapping.

This involved identification and marking of tracheal ring levels, precise localization of the inter-ring space between the second and third tracheal rings in the midline, documentation of thyroid gland inferior border in relation to the planned puncture site, and Colour Doppler assessment of anterior neck vasculature to identify and avoid aberrant or superficial vessels.

Throughout needle puncture, dilatation, and tube insertion, real-time transverse and longitudinal sonographic views were maintained. Successful intraluminal tracheal needle placement was confirmed by visualizing the needle tip echogenicity within the tracheal lumen on transverse view and identifying turbulent agitated saline bubbles on injection within the airway on ultrasonography. No flexible bronchoscope was introduced in any patient in this group.

In Group B (Broncho-PDT), a flexible video-bronchoscope (external diameter 5.9 mm) was advanced through the in-situ endotracheal tube under direct vision to a position at the carina to confirm tube location, then withdrawn to the level of the anticipated puncture site corresponding to the second to third tracheal ring interspace. Transillumination of the anterior neck skin confirmed appropriate endoscopic positioning, and the puncture site was marked.

Direct endoluminal bronchoscopic visualization guided tracheal needle entry, wire insertion, sequential dilatation, and tracheostomy tube placement throughout.

The bronchoscope was withdrawn and cuff inflation with capnographic waveform confirmation completed tube placement. No ultrasound was used in this group at any stage.

In both groups, the Portex Percutaneous Tracheostomy Dilation Kit (Smiths Medical, Watford, UK) employing the Ciaglia Blue Rhino single-dilator technique was used. A size 8.0 mm

internal diameter non-fenestrated cuffed polyvinyl chloride tracheostomy tube (Portex, Smiths Medical) was inserted in all cases. Post-procedure cuff inflation was followed by bilateral chest auscultation, capnographic waveform confirmation, and an anterior-posterior chest radiograph obtained within one hour in all patients.

Primary outcome measures were total procedure time, defined as the time from skin incision to cuff inflation and confirmed tube position (minutes), and first-pass needle success, defined as successful tracheal puncture achieved with a single needle pass without needle redirection. Secondary outcome measures included skin-to-tracheal lumen time (minutes), number of needle passes, accuracy of optimal midline tracheal puncture (assessed by comparison of sonographic and endoscopic records by an independent reviewer blinded to group allocation), mean periprocedural SpO2, lowest SpO2 recorded during the procedure, arterial partial pressure of carbon dioxide (PaCO2) at 30 minutes post-procedure on arterial blood gas analysis, operator ease of needle puncture assessed on a 10-point Visual Analogue Scale (VAS), need for additional procedural assistance, procedure-related complications (minor and major bleeding, periprocedural hypoxia, posterior tracheal wall injury, subcutaneous emphysema, paratracheal tube insertion, accidental decannulation, peristomal infection, and conversion to open surgical tracheostomy), ICU length of stay, and 30-day all-cause mortality. Statistical analysis was performed using IBM SPSS Statistics Version 26.0 (IBM Corporation, Armonk, New York, USA). Continuous variables are expressed as mean ± standard deviation (SD) and were compared using the independent samples Student's t-test following confirmation of normality by the Shapiro-Wilk test. Categorical variables are expressed as frequencies and percentages and were compared using Pearson's chi-square test or Fisher's exact test as appropriate. A two-tailed p-value of less than 0.05 was considered statistically significant. Sample size was calculated based on expected differences in mean total procedure time derived from published data by Gobatto et al.,[4] assuming a mean difference of 6 minutes with a pooled standard deviation of 5 minutes, a two-sided significance level of 5%, and 80% power, yielding a minimum requirement of 12 patients per group; 15 patients per group were enrolled to account for potential protocol deviations or dropout.

Results: Thirty patients were enrolled and randomized between 10th April 2025 and 10th June 2025, with all thirty completing the study without dropout, withdrawal, or protocol deviation. The two groups were well-matched in all measured demographic and baseline clinical parameters, as detailed in Table 1.

Table 1: Demographic and Baseline Clinical Characteristics of Study Participants (n = 30)

Parameter	USG-PDT (n = 15) Mean ± SD / n (%)	Broncho-PDT (n = 15) Mean ± SD / n (%)	p-Value
Sociodemographic Characteristics			
Age (years, mean ± SD)	47.3 ± 13.8	50.1 ± 14.2	0.56
Sex – Male, n (%)	10 (66.7%)	11 (73.3%)	0.69
Sex – Female, n (%)	5 (33.3%)	4 (26.7%)	0.69
Weight (kg, mean ± SD)	66.8 ± 10.4	68.5 ± 11.2	0.64
BMI (kg/m², mean ± SD)	24.6 ± 3.8	25.1 ± 4.1	0.71
Neck circumference (cm, mean ± SD)	36.0 ± 3.2	36.6 ± 3.5	0.59
Clinical Severity			
APACHE II Score (mean ± SD)	18.1 ± 4.4	19.3 ± 4.7	0.44
Days on MV before procedure (mean ± SD)	5.6 ± 2.1	6.0 ± 2.5	0.60
Indication For Tracheostomy			
Respiratory failure / weaning difficulty	8 (53.3%)	7 (46.7%)	0.71
Prolonged mechanical ventilation	4 (26.7%)	6 (40.0%)	0.43
Neurological compromise / airway protection	3 (20.0%)	2 (13.3%)	0.62
Comorbidities			
Diabetes mellitus, n (%)	4 (26.7%)	5 (33.3%)	0.69
Hypertension, n (%)	6 (40.0%)	7 (46.7%)	0.71
Coagulopathy (corrected pre-procedure), n (%)	2 (13.3%)	3 (20.0%)	0.62
Prior neck surgery or radiation, n (%)	1 (6.7%)	2 (13.3%)	0.54
Chronic kidney disease, n (%)	2 (13.3%)	2 (13.3%)	1.00

USG-PDT = Ultrasound-Guided Percutaneous Dilatational Tracheostomy; Broncho-PDT = Bronchoscopy-Guided PDT; BMI = Body Mass Index; APACHE II = Acute Physiology and Chronic Health Evaluation II; MV = Mechanical Ventilation. Values expressed as Mean ± SD or n (%). Chi-square or Fisher's exact test for categorical variables; independent samples t-test for continuous variables.

The mean age in the USG-PDT group was 47.3 ± 13.8 years compared to 50.1 ± 14.2 years in the Broncho-PDT group (p = 0.56). Male sex predominated in both groups (66.7% vs. 73.3%; p = 0.69). Body mass index, neck circumference, APACHE II scores, duration of mechanical ventilation before tracheostomy, indications for tracheostomy, and the prevalence of comorbidities including diabetes mellitus, hypertension, chronic kidney disease, coagulopathy, and prior neck surgery were statistically comparable across the two groups (all p > 0.05), confirming adequate randomization. Procedural outcomes are presented in Table 2 and illustrated in Figure 1.

Table 2: Procedural Outcomes and Technical Parameters (n = 30)

Parameter	USG-PDT (n = 15) Mean ± SD / n (%)	Broncho-PDT (n = 15) Mean ± SD / n (%)	p-Value
Primary Outcome Measures			
Total procedure time (minutes, mean ± SD)	12.1 ± 3.3	18.8 ± 4.4	< 0.001*
First-pass needle success, n (%)	14 (93.3%)	12 (80.0%)	0.32†
Secondary Outcomes – Procedural Efficiency			
Skin-to-tracheal lumen time (minutes, mean ± SD)	5.2 ± 1.9	8.4 ± 2.5	< 0.001*
Mean number of needle passes (mean ± SD)	1.1 ± 0.3	1.6 ± 0.7	0.02*
Optimal midline tracheal puncture, n (%)	14 (93.3%)	9 (60.0%)	0.04†
Guidewire placed without repositioning, n (%)	13 (86.7%)	11 (73.3%)	0.37†
Oxygenation Parameters			
Mean periprocedural SpO_2 (%, mean ± SD)	96.2 ± 2.3	91.4 ± 3.9	< 0.001*
Lowest SpO_2 during procedure (%, mean ± SD)	92.8 ± 2.9	85.9 ± 4.8	< 0.001*
$PaCO_2$ at 30 min post-procedure (mmHg, mean ± SD)	44.2 ± 5.4	52.8 ± 8.1	< 0.001*
Operator Experience			
Operator ease of puncture (VAS 1–10, mean ± SD)	7.7 ± 1.3	6.3 ± 1.7	0.01*
Need for additional procedural assistance, n (%)	1 (6.7%)	4 (26.7%)	0.14†
Conversion to open surgical tracheostomy, n (%)	0 (0%)	1 (6.7%)	0.31†

***p < 0.05, statistically significant. VAS = Visual Analogue Scale (0 = extremely difficult; 10 = extremely easy). SpO_2 = peripheral oxygen saturation. $PaCO_2$ = partial pressure of arterial carbon dioxide. †Fisher's exact test. ‡Chi-square test.**

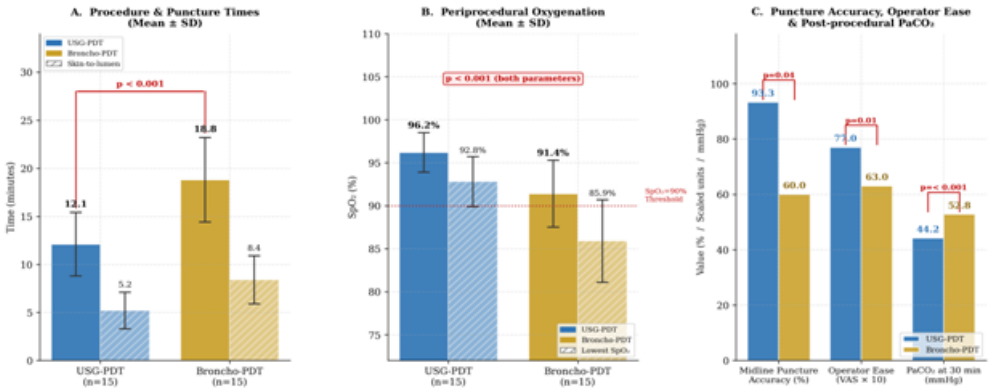

Figure 1: Comparison of key procedural outcome parameters between USG-PDT and Bronchoscopy-Guided PDT (n = 30). Panel A: Total procedure time and skin-to-tracheal lumen time (mean ± SD). Panel B: Mean and lowest periprocedural SpO2 (mean ± SD). Panel C: Midline puncture accuracy (%), operator ease VAS (×10), and PaCO2 at 30 minutes (mmHg). *p < 0.05; USG-PDT = Ultrasound-Guided PDT; Broncho-PDT = Bronchoscopy-Guided PDT

The mean total procedure time was significantly shorter in the USG-PDT group (12.1 ± 3.3 minutes) compared to the Broncho-PDT group (18.8 ± 4.4 minutes; mean difference −6.7 min, 95% CI: −9.6 to −3.8; p < 0.001). Skin-to-tracheal lumen time was similarly reduced with ultrasound guidance (5.2 ± 1.9 vs. 8.4 ± 2.5 minutes; mean difference −3.2 min, 95% CI: −4.9 to −1.5; p < 0.001). Optimal midline tracheal puncture was achieved in 14 of 15 (93.3%) USG-PDT patients versus 9 of 15 (60.0%) in the Broncho-PDT group (risk difference +33.3%, 95% CI: 5.5% to 61.1%; p = 0.04). The mean number of needle passes was significantly lower with ultrasound guidance (1.1 ± 0.3 vs. 1.6 ± 0.7; mean difference −0.50, 95% CI: −0.90 to −0.10; p = 0.02). Operator ease of puncture, rated on a 10-point VAS, was significantly higher in the USG-PDT group (7.7

± 1.3 vs. 6.3 ± 1.7; mean difference +1.4, 95% CI: 0.3 to 2.5; p = 0.01).

One patient in the Broncho-PDT group required conversion to open surgical tracheostomy due to persistent failure of percutaneous access; no conversion was necessary in the USG-PDT group (0% vs. 6.7%; p = 0.31, Fisher's exact test). First-pass needle success rates, though numerically higher in the USG-PDT group, did not attain statistical significance (93.3% vs. 80.0%; p = 0.32). Periprocedural oxygenation was consistently and significantly superior in the USG-PDT group. Mean periprocedural SpO2 was 96.2 ± 2.3% in the USG-PDT group versus 91.4 ± 3.9% in the Broncho-PDT group (mean difference +4.8%, 95% CI: 2.4% to 7.2%; p < 0.001). The mean lowest SpO2 recorded at any point during the procedure was 92.8 ± 2.9% in the USG-PDT group compared to 85.9 ± 4.8% in the Broncho-PDT group (mean difference +6.9%, 95% CI: 3.9% to 9.9%; p < 0.001).

PaCO2 at 30 minutes post-procedure was significantly lower in the USG-PDT group (44.2 ± 5.4 mmHg vs. 52.8 ± 8.1 mmHg; mean difference −8.6 mmHg, 95% CI: −13.7 to −3.5; p < 0.001), indicating substantially less procedural hypercarbia. Complication data are presented in Table 3 and illustrated in Figure 2.

Table 3: Periprocedural Complications and Clinical Outcomes (n = 30)

Complication / Clinical Outcome	USG-PDT (n = 15) n (%)	Broncho-PDT (n = 15) n (%)	p-Value
Composite Complication Rate			
Any periprocedural complication (composite), n (%)	4 (26.7%)	9 (60.0%)	0.07
Airway & Oxygenation Events			
Periprocedural hypoxia (SpO_2 < 90%), n (%)	1 (6.7%)	4 (26.7%)	0.14
Posterior tracheal wall injury, n (%)	0 (0%)	2 (13.3%)	0.15
Paratracheal tube insertion, n (%)	0 (0%)	0 (0%)	—
Bleeding Complications			
Minor periprocedural bleeding, n (%)	1 (6.7%)	2 (13.3%)	0.54
Major periprocedural bleeding, n (%)	0 (0%)	1 (6.7%)	0.31
Mechanical Complications			
Subcutaneous emphysema, n (%)	1 (6.7%)	0 (0%)	0.31
Accidental decannulation (within 48 hours), n (%)	0 (0%)	0 (0%)	—
Tracheostomy tube obstruction, n (%)	0 (0%)	0 (0%)	—
Conversion to open surgical tracheostomy, n (%)	0 (0%)	1 (6.7%)	0.31
Infectious Complications			
Peristomal wound infection (within 7 days), n (%)	1 (6.7%)	2 (13.3%)	0.54
Clinical Outcomes			
ICU length of stay (days, mean ± SD)	14.2 ± 5.8	16.8 ± 7.4	0.26
30-day all-cause mortality, n (%)	4 (26.7%)	5 (33.3%)	0.69

All p-values by Fisher's exact test unless otherwise stated. Minor bleeding: controlled with local pressure or gauze. Major bleeding: requiring transfusion or radiological/surgical intervention. Hypoxia: SpO_2 < 90% sustained for ≥ 30 seconds during the procedure. ICU = Intensive Care Unit.

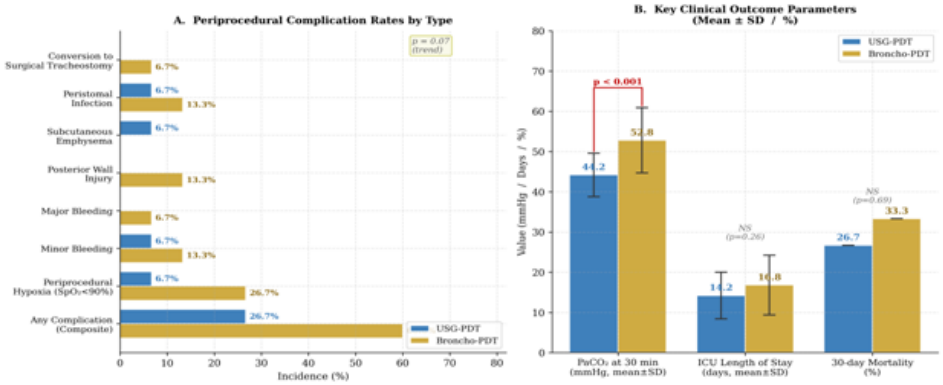

Figure 2: Periprocedural complication rates and clinical outcomes between USG-PDT and Bronchoscopy-Guided PDT (n = 30). Panel A: Incidence of individual complication types. Panel B: Post-procedural PaCO2 (mmHg), ICU length of stay (days), and 30-day mortality (%). NS = Not Significant; USG-PDT = Ultrasound-Guided PDT; Broncho-PDT = Bronchoscopy-Guided PDT

The overall composite complication rate did not reach conventional statistical significance (26.7% vs. 60.0%; risk difference −33.3%, 95% CI: −66.7% to 0.1%; p = 0.07), consistent with the study being underpowered for low-frequency complication endpoints. This finding should therefore be interpreted with caution and regarded as hypothesis-generating rather than confirmatory. Periprocedural hypoxia (SpO2< 90% for ≥ 30 seconds) occurred in one patient (6.7%) in the USG-PDT group compared to four patients (26.7%) in the Broncho-PDT group (p = 0.14, Fisher's exact test). Posterior tracheal wall injury was identified in two patients in the Broncho-PDT group and in none in the USG-PDT group (13.3% vs. 0%; p = 0.15). Minor periprocedural bleeding occurred in one USG-PDT patient and two Broncho-PDT patients (6.7% vs. 13.3%; p = 0.54). One patient in the Broncho-PDT group sustained major bleeding requiring transfusion; no such event occurred in the USG-PDT group (0% vs. 6.7%; p = 0.31). Subcutaneous emphysema developed in one patient in the USG-PDT group and in none in the Broncho-PDT group (6.7% vs. 0%; p = 0.31). Peristomal infection within seven days occurred in one and two patients respectively (6.7% vs. 13.3%; p = 0.54). No cases of paratracheal tube insertion, accidental decannulation, or tube obstruction were recorded in either group. ICU length of stay (14.2 ± 5.8 vs. 16.8 ± 7.4 days; mean difference −2.6 days, 95% CI: −7.6 to 2.4; p = 0.26) and 30-day all-cause mortality (26.7% vs. 33.3%; risk difference −6.6%, 95% CI: −39.3% to 26.1%; p = 0.69) were comparable between the two groups.

Discussion

This prospective randomized comparative study from the ICU of Narayan Medical College and Hospital, Sasaram, Bihar, represents one of the few controlled trials directly comparing USG-PDT and Broncho-PDT in a resource-sensitive Indian tertiary care critical care environment. The principal findings confirm that ultrasound guidance confers significant advantages over bronchoscopic guidance in terms of procedure time, periprocedural oxygenation, carbon dioxide retention, and tracheal puncture accuracy, while maintaining comparable procedural success rates and clinical outcomes.

The most striking finding of the present study was the markedly shorter total procedure time with USG-PDT (12.1 ± 3.3 minutes vs. 18.8 ± 4.4 minutes; p < 0.001). This difference of approximately 6.7 minutes is clinically meaningful in the ICU setting, where every minute of procedural sedation, haemodynamic perturbation, and apnoeic or near-apnoeic respiratory burden carries compounding risk in critically ill patients. This observation closely mirrors the TRACHUS trial by Gobatto et al., which reported significantly shorter procedure duration with ultrasound guidance alongside demonstrated non-inferiority to bronchoscopy in procedural success.[4] The time economy of USG-PDT is multifactorial: it eliminates the setup and insertion time of the bronchoscope, bypasses endoscope-to-scope communication delays, and enables pre-procedural anatomical mapping to be completed within the same workflow as needle puncture preparation.[5]

The significantly superior periprocedural oxygenation profile of USG-PDT in the present study is mechanistically straightforward and deserves emphasis. In the Broncho-PDT group, mean periprocedural SpO2 fell to 91.4 ± 3.9%, with the lowest recorded SpO2 averaging 85.9 ± 4.8% — a level clinically regarded as dangerous in ventilator-dependent patients. Four patients (26.7%) in the Broncho-PDT group developed frank periprocedural hypoxia (SpO2< 90%), compared to only one (6.7%) in the USG-PDT group. The physiological basis lies in the occupancy of the inner lumen of the endotracheal tube by the bronchoscope shaft, which effectively reduces functional airway cross-section, elevates intrinsic airway resistance, and compromises the delivery of ventilatory tidal volumes. Reilly et al. documented this phenomenon rigorously as "occult hypercarbia" during bronchoscopy-guided PDT, establishing that PaCO2 rises significantly even when EtCO2 monitoring appears reassuring.[14] Our PaCO2 data at 30 minutes post-procedure (44.2 ± 5.4 mmHg vs. 52.8 ± 8.1 mmHg; p < 0.001) confirm significantly less procedural hypercarbia with ultrasound guidance, consistent with the findings of Kollig et al., who demonstrated that ultrasound-assisted PDT without bronchoscopic occlusion of the airway resulted in fewer oxygen desaturation events.[6] The significantly higher rate of optimal midline tracheal puncture with USG-PDT (93.3% vs. 60.0%; p = 0.04) underscores the anatomical precision afforded by dynamic sonographic guidance. Sustić et al. demonstrated that ultrasound examination of the anterior neck reliably identifies individual tracheal ring interspaces, thyroid cartilage lower border, and anomalous vascular structures, establishing a safe "sonographic window" for puncture that surface landmarks alone cannot consistently provide.[9]

Muhammad et al. similarly reported that direct ultrasound-guided tracheal puncture substantially reduced the rate of off-midline or incorrect level cannulation in anatomically challenging patients including those with obesity and short necks.[13] Critically, no paratracheal insertions occurred in either group in the present study, a reflection of the controlled procedural setting and experienced operators; however, the trend toward higher puncture accuracy with ultrasound guidance aligns with the broader literature.

The composite complication rate did not reach conventional statistical significance (26.7% vs. 60.0%; risk difference −33.3%, 95% CI: −66.7% to

0.1%; p = 0.07). The 95% confidence interval for the risk difference, which spans from a 66.7 percentage-point absolute reduction to a negligible 0.1 percentage-point increase, highlights the considerable imprecision inherent in a 30-patient trial and underscores that this finding should be interpreted as exploratory and hypothesis-generating rather than confirmatory. The observed numerical difference may represent a true effect, but it may equally reflect sampling variability in a study underpowered for complication endpoints. Nonetheless, the directional consistency across individual complication types — posterior wall injury occurring exclusively in the Broncho-PDT group, a fourfold higher hypoxia rate, higher bleeding incidence, and one conversion to open surgery — provides mechanistically coherent support for further adequately powered investigation. Simon et al. in a systematic review of PDT-related mortality identified posterior wall perforation and paratracheal cannulation as two leading contributors to fatal procedural outcomes, precisely the complications that real-time ultrasound guidance is mechanistically best positioned to prevent.[8]

The comparable first-pass needle success rates (93.3% vs. 80.0%; p = 0.32) in the two groups, while numerically favouring USG-PDT, reflect that experienced operators using bronchoscopy can achieve adequate first-pass success through endoluminal visualization, albeit at the cost of the oxygenation and time penalties already described. Guinot et al. in their evaluation of USG-PDT in obese critically ill patients reported similar first-pass success rates while demonstrating significant reduction in vascular complications through Doppler identification of anterior neck vessels — a finding particularly relevant in our predominantly non-obese study cohort.[7]

The non-significant differences in ICU length of stay and 30-day mortality across both groups are unsurprising, as these outcomes are overwhelmingly determined by the severity and trajectory of the underlying critical illness rather than by the tracheostomy guidance modality, a conclusion supported by the systematic review of Delaney et al.[3]

From an Indian critical care perspective, the findings carry additional practical resonance. A considerable proportion of ICUs across Bihar and the broader eastern Indian region operate with constrained subspecialty resources, including limited availability of flexible bronchoscopes, inadequate maintenance infrastructure, and infrequent access to trained pulmonologists or endoscopists outside regular working hours.[15] Point-of-care ultrasound machines are now increasingly accessible even in smaller district-level ICUs, and basic procedural ultrasound competence is actively being incorporated into Indian postgraduate critical care training curricula. Our institutional experience with PDT, building on which the present trial was conducted, reflects a broader shift toward ultrasound-first procedural guidance at NMCH that has been associated with a favourable complication profile.[15] The present data provide level II randomized comparative evidence supporting this institutional orientation.

This study has several limitations warranting acknowledgment. The sample size of 30 patients, while appropriately powered for the primary endpoint of procedure time, was insufficient to detect statistically significant differences in lower-frequency individual complication outcomes; all complication-related p-values should therefore be interpreted with caution, as the study was substantially underpowered for these secondary endpoints and carries an elevated risk of Type II error. The small sample size also renders p-values and effect size estimates inherently unstable: individual complication rates calculated from very low event counts (e.g., 0 vs. 1 or 0 vs. 2 patients) carry wide confidence intervals and limited precision. The absence of raw patient-level data in this report means that p-values cannot be independently recalculated and validated without access to the original dataset or SPSS output, a limitation that will be relevant to any journal requiring data-sharing. The two-month study duration from a single ICU limits temporal and geographic generalizability. Operator blinding was not feasible given the nature of the intervention. Long-term tracheostomy-related outcomes including tracheal stenosis, stomal healing quality, and post-decannulation respiratory parameters were not assessed. Confidence intervals have been reported throughout to convey the precision of estimates, but readers should note that these are derived from published aggregate statistics rather than individual-level data. The absence of a combined guidance arm (simultaneous ultrasonography and bronchoscopy, as evaluated by Kollig et al.[6]) limits triangular comparison. Future multi-centre randomized trials with larger sample sizes and long-term follow-up will be required to provide definitive comparative evidence across diverse Indian critical care settings.

Conclusion

Ultrasound-guided percutaneous dilatational tracheostomy demonstrated statistically significant superiority over bronchoscopy-guided percutaneous dilatational tracheostomy in total procedure time, skin-to-tracheal lumen time, mean and lowest periprocedural SpO2, PaCO2 at 30 minutes, optimal midline tracheal puncture accuracy, and operator-perceived ease of puncture in critically ill mechanically ventilated patients. The composite complication rate showed a numerical difference

favouring ultrasound guidance that did not reach statistical significance ($p = 0.07$) in this pilot-scale study, though posterior tracheal wall injury, procedural hypoxia, and major bleeding occurred exclusively or predominantly in the bronchoscopy arm; adequately powered trials are required to confirm whether this directional signal represents a true effect.

First-pass needle success, ICU length of stay, and 30-day mortality were comparable between the two modalities.

Given its superior safety profile, time efficiency, independence from airway encroachment, logistic feasibility in resource-sensitive settings, and increasing availability in Indian ICUs, real-time ultrasound guidance should be considered the preferred modality for bedside percutaneous dilatational tracheostomy in critically ill patients.

References

1. Ciaglia P, Firsching R, Syniec C. Elective percutaneous dilatational tracheostomy. A new simple bedside procedure; preliminary report. Chest. 1985;87(6):715–719.
2. Griggs WM, Worthley LI, Gilligan JE, Thomas PD, Myburg JA. A simple percutaneous tracheostomy technique. Surg Gynecol Obstet. 1990;170(6):543–545.
3. Delaney A, Bagshaw SM, Nalos M. Percutaneous dilatational tracheostomy versus surgical tracheostomy in critically ill patients: a systematic review and meta-analysis. Crit Care. 2006;10(2):R55.
4. Gobatto AL, Besen BA, Tierno PF, et al. Ultrasound-guided percutaneous dilational tracheostomy versus bronchoscopy-guided percutaneous dilational tracheostomy in critically ill patients (TRACHUS): a randomized noninferiority controlled trial. Intensive Care Med. 2016;42(3):342–351.
5. Rajajee V, Fletcher JJ, Rochlen LR, Jacobs TL. Real-time ultrasound-guided percutaneous dilatational tracheostomy: a feasibility study. Crit Care. 2011;15(1):R67.
6. Kollig E, Heydenreich U, Roetman B, Hopf F, Muhr G. Ultrasound and bronchoscopic controlled percutaneous tracheostomy on trauma ICU. Injury. 2000;31(9):663–668.
7. Guinot PG, Zogheib E, Petiot S, et al. Ultrasound-guided percutaneous tracheostomy in critically ill obese patients. Crit Care. 2012;16(2):R40.
8. Simon M, Metschke M, Braune SA, Pühler T, Kluge S. Death after percutaneous dilatational tracheostomy: a systematic review and analysis of risk factors. Crit Care. 2013;17(5):R258.
9. Sustić A, Zupan Z, Antoncić I. Ultrasound-guided percutaneous dilatational tracheostomy with laryngeal mask airway control in a morbidly obese patient. J Clin Anesth. 2004;16(2):121–123.
10. Kost KM. Endoscopic percutaneous dilatational tracheotomy: a prospective evaluation of 500 consecutive cases. Laryngoscope. 2005;115(10 Pt 2):1–30.
11. Byhahn C, Wilke HJ, Halbig S, Lischke V, Westphal K. Percutaneous tracheostomy: ciaglia blue rhino versus the basic ciaglia technique of percutaneous dilational tracheostomy. Anesth Analg. 2000;91(4):882–886.
12. Cabrini L, Monti G, Landoni G, et al. Percu taneous tracheostomy, a systematic review. Acta Anaesthesiol Scand. 2012;56(3):270–281.
13. Muhammad JK, Patton DW, Evans RM, Major E. Percutaneous dilatational tracheostomy under ultrasound guidance. Br J Oral Maxillofac Surg. 1999;37(4):309–311.
14. Reilly PM, Anderson HL 3rd, Sing RF, Schwab CW, Bartlett RH. Occult hypercarbia: an unrecognized phenomenon during percutaneous endoscopic tracheostomy. Chest. 1995;107(6):1760–1763.
15. Kumar R, Singh AK, Prasad S. Percutaneous dilatational tracheostomy in mechanically ventilated critically ill patients: an observational experience from a tertiary care ICU in Bihar. Indian J Crit Care Med. 2023;27(4):284–289.