

Safety of Fiberoptic Bronchoscopy-Guided Percutaneous Dilatational Tracheostomy in Critically Ill Patients: A Single-Center Prospective Study

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Abstract

Background:

Percutaneous dilatational tracheostomy (PDT) is widely used in intensive care units (ICUs) as an alternative to surgical tracheostomy. However, procedure-related complications remain a concern. Fiberoptic bronchoscopy (FFB) has been proposed as a guidance technique to improve procedural safety. This study aimed to evaluate the safety and clinical outcomes of bronchoscopy-guided percutaneous dilatational tracheostomy in critically ill patients.

Methods:

This prospective observational study was conducted in the Emergency Intensive Care Unit of a tertiary university hospital between January 2014 and December 2016. A total of 40 adult patients who required prolonged mechanical ventilation and tracheostomy were included. All tracheostomy procedures were performed using the Griggs technique under fiberoptic bronchoscopy guidance. Demographic data, Sequential Organ Failure Assessment (SOFA) scores, laboratory parameters, arterial blood gas measurements, and procedural complications were recorded. Hematological and coagulation parameters before and after the procedure were compared, and complication rates were analyzed.

Results:

Forty patients (20 female, 20 male) with a mean age of 72.7 ± 14.7 years were included. The mean duration of intubation before PDT was 15.4 ± 9.4 days. No major complications such as pneumothorax, posterior tracheal wall injury, false passage, or massive hemorrhage were observed. Minor complications occurred in nine patients (22.5%), most commonly minor bleeding around the stoma. Hematocrit levels showed a small but statistically significant decrease after the procedure ($p = 0.035$). Arterial blood gas parameters did not show significant changes across measurements performed before, during, and after the procedure ($p > 0.05$).

Conclusion:

Bronchoscopy-guided percutaneous dilatational tracheostomy appears to be a feasible bedside procedure in critically ill patients and was associated with a low rate of mostly minor complications in this cohort. Real-time bronchoscopic visualization may contribute

to procedural safety by facilitating accurate cannula placement. However, larger prospective multicenter studies are needed to confirm these findings.

1. Introduction

Providing a safe and effective airway is critical for the management of patients requiring long-term mechanical ventilation support in intensive care units (ICUs) for both duration and quality of life. Prolonged endotracheal intubation time may cause serious complications such as tracheal stenosis, laryngeal edema, vocal cord paralysis, and subglottic tracheal injury [1, 2]. In order to prevent these complications, tracheostomy is increasingly preferred earlier and more widely [2]. Tracheostomy not only maintains airway patency but also facilitates the weaning process from the ventilator by reducing the patient's respiratory workload, reduces dead space volume, provides more effective clearance of secretions, and supports the patient's return to basic life activities such as oral feeding and communication [3, 4].

Percutaneous dilatational tracheostomy (PDT), developed as an alternative to surgical tracheostomy, was first described by Ciaglia in 1985 and has become a standard practice in intensive care practice over time [5]. PDT offers significant advantages, especially compared to surgical tracheostomy, such as shorter procedure time, lower risk of infection, less tissue trauma, and the ability to be applied at the bedside [6–8]. The Griggs method, which is widely used among PDT techniques, is based on dilating the trachea with modified forceps and is frequently preferred in emergency rooms and intensive care units due to its applicability [9]. However, all percutaneous tracheostomy methods, including the Griggs technique, carry risks for complications such as posterior tracheal wall injury, uncontrolled bleeding, paratracheal placement, pneumothorax and long-term tracheal stenosis [10]. These complications are more common in patients with anatomical variations, edema on the anterior neck surface, infection, or a history of previous surgery. In addition, the risk of bleeding during the procedure poses a significant problem in patients with coagulopathy, which necessitates careful patient selection before the procedure. Therefore, the use of techniques that provide additional visual guidance during the procedure is recommended to reduce the risk of complications and increase procedural safety. To prevent these complications and increase procedural safety, the use of auxiliary imaging methods such as flexible fiberoptic bronchoscopy (FFB) is recommended. Bronchoscopy-guided tracheostomy procedures facilitate cannula placement in the center of the anterior tracheal wall and at the correct depth, thereby reducing the risk of complications such as paratracheal passage, posterior wall perforation, and subcutaneous emphysema. In addition, the use of FFB allows real-time monitoring of the endotracheal tube cuff and the advancement of the guidewire, enabling the operator to make immediate corrections during the procedure. These technical advantages may contribute to improved procedural safety, particularly for less

experienced operators [10, 11]. Furthermore, bronchoscopy has been reported to be useful in the early detection of complications such as endobronchial bleeding, paratracheal placement, and tracheal perforation [12, 13].

The aim of this study was to evaluate the safety and clinical outcomes of percutaneous dilatational tracheostomy performed with flexible fiberoptic bronchoscopy guidance in critically ill patients.

2. Materials and methods

2. 1. Study Design and Ethical Approval

This single-center prospective observational study was conducted in the Emergency Intensive Care Unit of a tertiary university hospital between January 2014 and December 2016. The study protocol was approved by the Clinical Research Ethics Committee of Abant Izzet Baysal University Faculty of Medicine (Decision No: 2014/59-138). The study was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all patients or their legal representatives before the procedure and study inclusion.

2. 2. Study Population

A total of 40 adult patients (aged ≥ 18 years) who were intubated for various clinical indications, required prolonged mechanical ventilation, and were considered candidates for tracheostomy during ICU follow-up were included in the study.

Exclusion criteria were determined by taking into consideration the conditions that may increase the risk of complications during the tracheostomy procedure. In this context, patients with the following characteristics were not included in the study:

- Those with coagulopathy (platelet count $< 100,000/\text{mm}^3$, INR > 1.8)
- Those with active infection on the tracheostomy region
- Those with severe distortion of tracheal anatomy (e.g., cervical vertebra anomaly)
- Those with a history of goiter or previous larynx surgery in the anterior neck region
- Patients who do not need tracheostomy or are cured without intubation
- Individuals who cannot give informed consent or whose legal representatives cannot obtain consent

Due to the observational design of the study and the limited number of eligible patients during the study period, a formal sample size calculation was not performed. All consecutive patients who met the inclusion criteria during the study period were included in the analysis.

2. 3. Collection of Data

Within the scope of the study, the following clinical and laboratory data for each patient were recorded.

Patients' demographic data (age, gender, etc.), Sequential Organ Failure Assessment (SOFA) score and expected mortality rate (EMR) information were recorded in a standard patient follow-up form.

Blood tests were taken twice, before the procedure and 24 hours after the procedure, and complete blood count, Prothrombin Time (PT), Activated Partial Thromboplastin Time (aPTT) and International Normalized Ratio (INR) values were examined.

In addition, arterial blood gas analysis was performed three times: 24 hours before the procedure, on the morning of the procedure, and 24 hours after the procedure; In these analyses, pH, partial oxygen pressure (PaO₂), partial carbon dioxide pressure (PaCO₂) and bicarbonate (HCO₃⁻) values were evaluated.

Data regarding complications during and after the procedure, bleeding amounts, percutaneous dilatation status, and cannula placement were also recorded in the same form.

2. 4. Pre-Procedure Preparation

The tracheostomy procedure was performed by an experienced clinician and the operating team under standard sterile surgical conditions. Enteral nutrition and medications that could increase the risk of bleeding were discontinued prior to the procedure according to standard ICU protocols. The patient's head was placed in a hyperextended position with a pillow positioned between the scapulae to facilitate exposure of the anterior neck. Preoxygenation was performed before the procedure to maintain oxygen saturation (SpO₂) above 94%.

2. 5. Percutaneous Dilatational Tracheostomy (PDT)

All tracheostomy procedures were performed under the supervision of an experienced faculty member and assistants. Before the procedure, the endotracheal tube was partially

withdrawn under bronchoscopic visualization, and sedation, analgesia, and neuromuscular blockade (fentanyl 1–2 µg/kg, midazolam 0.05–0.2 mg/kg, and rocuronium 0.5–1 mg/kg) were administered intravenously.

Patient Preparation

The patients' heads were hyperextended with a support placed under the shoulder. Before the procedure, preoxygenation was performed to ensure oxygen saturation (%SpO₂) above 94% with pulse oximetry. Continuous ECG, non-invasive blood pressure, and peripheral oxygen saturation (SpO₂) monitoring were performed throughout the procedure.

Use of Bronchoscopy

The patients' heads were maintained in a hyperextended position with support placed under the shoulders. Continuous ECG, non-invasive blood pressure, and peripheral oxygen saturation (SpO₂) monitoring were performed throughout the procedure. The procedure site, located between the 2nd and 3rd tracheal rings, was disinfected with povidone-iodine solution under sterile conditions.

Tracheal Puncture and Guidewire Placement

The cricoid cartilage and suprasternal notch were palpated, and the interspace between the 1st and 2nd tracheal rings was identified. Local anesthesia was administered using 2% lidocaine. Under fiberoptic bronchoscopy (FFB) guidance, the trachea was punctured through the identified interspace using a 14-G intravenous catheter. After confirming correct intratracheal placement with FFB, the needle was removed, and the guidewire was advanced toward the carina under continuous bronchoscopic visualization.

Dilation and Cannula Placement

A small skin incision was made with a scalpel at the point where the guidewire entered, and the dilator was advanced under bronchoscopic visualization while avoiding injury to the posterior tracheal wall. Following dilatation, the tracheal opening was enlarged with blunt-ended forceps, and the tracheostomy cannula was placed over the guidewire under bronchoscopic guidance.

Post-Procedure Control and Imaging

The correct position of the cannula was confirmed with FFB, ventilation was checked with lung auscultation, and the intubation tube was removed. After checking the presence of subcutaneous emphysema by palpation, bleeding was controlled by entering the cannula with FFB and aspiration was performed. For all patients, antero-posterior (A-P) chest

radiograph was taken at the bedside after the procedure, and cannula position and potential complications such as pneumothorax were evaluated radiologically.

2.6. Statistical analysis

Statistical analyses were performed using SPSS version 22.0 (IBM Corp., Armonk, NY, USA). The distribution of continuous variables was evaluated using the Shapiro-Wilk test. Normally distributed variables were presented as mean $\pm$ standard deviation (SD), whereas non-normally distributed variables were expressed as median and interquartile range (IQR). Comparisons between two independent groups were performed using the Student's t-test for normally distributed variables and the Mann-Whitney U test for non-normally distributed variables. Changes in repeated measurements were analyzed using repeated measures ANOVA for normally distributed variables and the Wilcoxon signed-rank test for non-normally distributed variables. Categorical variables were compared using the Chi-square test. A p value < 0.05 was considered statistically significant.

3. Results

A total of 40 patients (20 females and 20 males) with a mean age of 72.7 ± 14.7 years (73.9 ± 15.0 for females and 71.5 ± 14.8 for males) were included in the study. The mean duration of intubation before PDT was 15.4 ± 9.4 days. There was no statistically significant difference in intubation duration according to discharge or exitus status ($p = 0.479$). Pre-procedural SOFA scores of the patients were estimated as 14.05 ± 2.83 , and the predicted mortality rate was $59.1 \pm 22.3\%$ according to the SOFA scoring system.

There was a statistically significant association between SOFA scores and discharge or exitus status after tracheostomy ($p = 0.007$). A statistically significant relationship was also observed between SOFA scores and the development of complications ($p = 0.012$). In addition, a statistically significant association was found between predicted mortality rates based on SOFA scores and discharge or exitus status after tracheostomy ($p = 0.005$).

The data obtained from pre-procedural and post-procedural hemogram and coagulation examinations are shown in the Table 1. When hematocrit measurements were analyzed, a statistically significant difference was found between hematocrit value measured before tracheostomy and the value measured after procedure ($p = 0.035$). Accordingly, a decrease in hematocrit values was observed.

Table 1

Complete blood count and coagulation parameters before and after tracheostomy

Variable	Before PDT Median (IQR)	After PDT Median (IQR)	p value
Hemoglobin (g/dL)	9.2 (8.2–10.7)	9.2 (8.0–10.3)	0.070
Hematocrit (%)	29.8 (25.7–33.4)	28.9 (25.4–32.9)	0.035
Platelet ($\times 10^3/\text{mm}^3$)	229 (149.2–318.2)	203.5 (155–303)	0.131
aPTT (s)	29.9 (27.5–37.9)	29.5 (25.9–33.8)	0.261
PT (s)	15.7 (14.6–17.0)	16.1 (14.4–17.6)	0.027
INR	1.28 (1.17–1.43)	1.34 (1.19–1.53)	0.015
Data are presented as median (interquartile range). Comparisons between pre- and post-procedure measurements were performed using the Wilcoxon signed-rank test. Abbreviations: Hgb , hemoglobin; Hct , hematocrit; Plt , platelet count; PT , prothrombin time; aPTT , activated partial thromboplastin time; INR , international normalized ratio.			

There was no statistically significant difference in the arterial blood gas examinations performed on the day before, the day of and the day after the procedure (Table 2).

Table 2

Arterial blood gas parameters before, on the day of, and after the tracheostomy procedure

Variable	Day before procedure	Day of procedure	Day after procedure	p value
pH	7.43 $\pm$ 0.12	7.45 $\pm$ 0.10	7.48 $\pm$ 0.12	0.151
PaCO ₂ (mmHg)	47.6 $\pm$ 21.1	44.0 $\pm$ 17.9	40.3 $\pm$ 13.6	0.413
PaO ₂ (mmHg)	99.8 $\pm$ 58.8	100.0 $\pm$ 36.1	111.9 $\pm$ 42.8	0.488
HCO ₃ ⁻ (mmol/L)	31.0 $\pm$ 8.5	30.6 $\pm$ 8.3	30.3 $\pm$ 8.5	0.928
Data are presented as mean $\pm$ standard deviation. Comparisons between repeated measurements were performed using repeated measures ANOVA. Abbreviations: PaCO ₂ , partial pressure of carbon dioxide; PaO ₂ , partial pressure of oxygen; HCO ₃ ⁻ , bicarbonate.				

Data are presented as mean $\pm$ standard deviation. Comparisons between repeated measurements were performed using repeated measures ANOVA. Abbreviations: PaCO₂, partial pressure of carbon dioxide; PaO₂, partial pressure of oxygen; HCO₃⁻, bicarbonate.

The severe life-threatening complications including bleeding during procedure and tracheal aspiration, and minor bleeding that is not life threatening, cannula insertion, percutaneous dilatation status and blood value data were shown in Table 3.

Table 3
Table 3. Procedural characteristics and complications of
percutaneous dilatational tracheostomy

Variable	Number	%
Complications		
No complications	31	77.5
Minor bleeding around the stoma	6	15.0
Bleeding into the trachea	2	5.0
Tracheostomy tube cuff rupture	1	2.5
Bleeding during procedure		
Controlled with sponge compression	39	97.5
Controlled with pressure	1	2.5
Percutaneous dilatation		
Effortless	31	77.5
With slight force	9	22.5
Cannula insertion		
Effortless	31	77.5
With slight force	8	20.0
Very difficult but successful	1	2.5
Post-procedural bleeding		
Bleeding soaking one sponge	39	97.5
Sponge replacement required every 30 minutes	1	2.5
Aspirated blood		
Mild (0–20 mL in the first hour)	31	77.5
Moderate (20–50 mL in the first two hours)	9	22.5
Data are presented as number (percentage).		
mL: milliliter.		

No complications developed in 31 out of 40 patients who underwent intervention. In one of the patients who developed complications, the cuff of tracheostomy tube was ruptured due to very difficult cannula insertion. In the other eight patients, there was difficulty in

performing percutaneous dilatation, resulting in difficulties in cannula insertion and minor bleeding. The amounts of bleeding during and after procedure were minor bleeding (less than 50 ml) and none of the patients developed massive bleeding requiring transfusion. None of the patients developed major complications such as posterior tracheal wall injury, subcutaneous false passage, emphysema and pneumothorax.

4. Discussion

In this prospective study, the effectiveness of flexible fiberoptic bronchoscopy (FFB) in preventing possible complications during percutaneous dilatational tracheostomy (PDT) using the Griggs method in the Emergency Intensive Care Unit (ICU) was evaluated. The findings of our study suggest that bronchoscopy-guided percutaneous dilatational tracheostomy appears to be a safe technique with a low rate of complications. These findings are consistent with previous studies reported in the literature [14, 15].

Although the complication rates observed in our study are consistent with previously reported data, our findings contribute additional evidence regarding the safety of bronchoscopy-guided percutaneous tracheostomy in critically ill patients in a real-world clinical setting. In particular, the prospective design of the study and the standardized use of fiberoptic bronchoscopy during all procedures provide further support for the feasibility and safety of this technique in intensive care practice.

The relationship between SOFA score and mortality and complication development after tracheostomy is parallel to the findings of other studies in the literature. The increased mortality and morbidity rates in patients with high SOFA scores support the idea that this score is an important tool in determining prognosis in critically ill patients [16, 17]. These results indicate that our study reflects the expected clinical course of the patient population.

One of the most important findings of our study is that the use of FFB effectively prevents the development of major complications. One of the most frequently reported complications of percutaneous tracheostomy with a high incidence is pneumothorax [18]. However, there was no incidence of pneumothorax in our study. Similarly, complications such as incorrect placement of the cannula and false passage formation, which are reported to be more common in percutaneous tracheostomies in the literature, were not encountered in our study [19, 20]. Fiberoptic bronchoscopy guidance may help facilitate correct cannula placement and visualization of the tracheal lumen during the procedure. In fact, complications that are universally considered fatal, such as posterior tracheal wall injury and tracheoesophageal fistula (TEF), were not detected in any patient in our study [21, 22]. These findings suggest that the visual control provided by FFB during the tracheostomy procedure is of vital importance in preventing such serious complications.

In a meta-analysis conducted by Freeman et al. [23], complications such as difficulty in cannula placement, incorrect positioning and hypoxia, which were more common in percutaneous tracheostomy than in surgical tracheostomy, were not observed in our study. In our study, major complication rates, including major postoperative bleeding, were found to be zero, unlike the rate reported in the literature. This situation highlights the reliability of the procedure performed with FFB. Our minor complication rate (22.5%) is similar to that reported in previous single-step dilatation studies [24, 25]. None of these complications were fatal, and the use of FFB was also found to be effective in detecting and managing early minor bleeding.

Regarding the timing of tracheostomy, some studies such as Rumbark et al. [26] suggested that early tracheostomy (within the first 48 hours) reduces mortality, while a study by Terragni et al. [27] stated that early tracheostomy had no significant effect on the total hospital stay and survival. Kirca et al. reported a mean tracheostomy timing of 8.65 ± 5.97 days [28]. In the study conducted by Vargas et al., the most common application time of PDT was determined to be between 7 and 15 days (54.4%) after admission to the intensive care unit [29]. There is no widely accepted recommendation regarding the timing of tracheostomy. In our study, the average tracheostomy opening time was determined as 15 days, and no significant relationship was found between tracheostomy time and mortality. This suggests that the impact of tracheostomy timing on patient prognosis may vary depending on the patient population and other factors.

The cost-effectiveness of using flexible fiberoptic bronchoscopy is also a matter of considerable debate [30, 31]. However, in the ICU, FFB is routinely used in many diagnostic and therapeutic procedures such as airway obstruction, pulmonary hemorrhage and atelectasis [32, 33]. Therefore, rather than being an additional cost element for the PDT procedure, it is considered an already existing tool for airway management and patient monitoring in the ICU. The fact that social health institutions in our country cover such procedures also eliminates the cost barrier. The versatility and safety advantages offered by FFB contribute positively to the quality of patient care by increasing cost-effectiveness.

In addition, the absence of major complications in our cohort and the low rate of minor complications support the practical applicability of bronchoscopy-guided percutaneous tracheostomy in daily ICU practice. These findings may be particularly relevant for centers where procedural safety and operator training are important considerations.

5. Limitations

There are some limitations to our study. One of these limitations is the exclusion of patients who were decided to undergo tracheostomy and whose relatives could not give

informed consent. This resulted in a decrease in sample size and limitation of patient heterogeneity. This reduced the comprehensiveness of the study and limited its generalizability. The second limitation is that only percutaneous dilatational tracheostomy (PDT) procedures performed with FFB were evaluated in the study. Before starting the study, it was not deemed necessary to create a control group that was performed with the classical Griggs method and not using FFB, assuming that major complications would be less common in procedures performed with FFB guidance. However, this situation prevented comparative analysis from a methodological perspective and limited the evaluation of the impact of FFB at a numerically comparable level. Additionally, the number of patients included in the study is a limitation. Larger-scale, multicenter and prospective studies are needed. Another limitation is the short follow-up period. Complications after tracheostomy can develop not only in the early period but also over weeks and months. Longer-term follow-up data are needed to detect late complications, especially tracheal stenosis.

6. Future Directions

In future studies, complication rates can be directly compared between GYPDT procedures performed with and without FFB using comparative, randomized, and prospective methodologies. Thus, the statistical significance of FFB use can be demonstrated with stronger evidence. Additionally, studies comparing FFB with other imaging modalities, such as ultrasonography, may reveal the comparative effectiveness of pre- and intraprocedural guidance techniques. Since ultrasound is a method that can be widely used at the bedside and has low operator dependency, the complication prevention capacity of combined techniques can be investigated.

Another suggestion is to evaluate the impact of FFB use on the learning curve. By examining the extent to which FFB affects complication rates in tracheostomy procedures performed by operators with different experience levels, the potential contribution that FFB can provide, especially for physicians in the early stages of training, can be more clearly understood. However, qualitative studies on how the use of FFB affects the perceptions of patients and their relatives about the procedure may also shed light on future research. The effects of FFB on patient safety, consent process and healthcare professional satisfaction should be considered from a holistic perspective.

7. Conclusion

In conclusion, bronchoscopy-guided percutaneous dilatational tracheostomy appears to be a safe and feasible bedside procedure in critically ill patients, with a low rate of complications. Our findings support its use as a practical technique in intensive care units, although larger multicenter studies are needed to further confirm these results.

Abbreviations

PDT	Percutaneous Dilatational Tracheostomy
FFB	Flexible Fiberoptic Bronchoscopy
ICU	Intensive Care Unit
SOFA	Sequential Organ Failure Assessment
EMR	Expected Mortality Rate
ECG	Electrocardiography
SpO ₂	Peripheral Oxygen Saturation
PT	Prothrombin Time
aPTT	Activated Partial Thromboplastin Time
INR	International Normalized Ratio
PaO ₂	Partial Pressure of Oxygen
PaCO ₂	Partial Pressure of Carbon Dioxide
HCO ₃ ⁻	Bicarbonate
IQR	Interquartile Range
SD	Standard Deviation.

Declarations

9. 1. Ethics approval and consent to participate

This study was approved by the Clinical Research Ethics Committee of Abant Izzet Baysal University Faculty of Medicine (Decision No: 2014/59-138). The study was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all patients or their legal representatives prior to study inclusion.

9. 2. Consent for publication

Not applicable.

9. 3. Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

9. 4. Competing interests

The authors declare that they have no competing interests.

9. 5. Funding

The authors declare that no specific funding was received for this study.

9. 6. Authors' contributions

BBK designed the study and drafted the manuscript. HG supervised the research process. BBK, TO, MED, AA, and FT collected the data. MMO performed the statistical analysis. HG and BBK critically revised the manuscript. All authors read and approved the final manuscript.

9. 7. Acknowledgements

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9.8. Clinical trial number

Not applicable.

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