Comparison of Conventional Surgical Tracheostomy and Percutaneous Dilatational Tracheostomy in the Neurosurgical Intensive Care Unit

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ABSTRACT

Objective: Tracheostomy is a necessary procedure for patients admitted to the neurosurgery intensive care unit (ICU) with severe brain injury, because mechanical ventilation must be maintained for a long time following neurologic failure. The purpose of this study was to compare conventional surgical tracheostomy (CST) and percutaneous dilatational tracheostomy (PDT) performed at the bedside in critically ill neurosurgery patients requiring tracheostomy to determine which procedure has comparative advantages.

Methods: This retrospective study was conducted between January 2019 and December 2020. PDT was performed on 52 patients and CST was performed on 44 patients. The baseline characteristics, procedural characteristics, and clinical outcomes were recorded.

Results: The mean operative time in the CST group was 25.5±6.5 minutes and that in the PDT group was 15.1±2.5 minutes; the difference was statistically significant (p<0.01). Four patients in the CST group and none in the PDT group experienced bleeding requiring transfusion. However, there was no significant difference in total ICU mortality or length of hospital stay. There were no statistical differences in the individual complication categories between the 2 study groups.

Conclusion: There were fewer procedure-induced complications among patients receiving PDT than among those receiving CST. In addition, the treatment time for PDT was shorter than that for CST treatment.

Keywords: Brain injury; Tracheostomy; Neurosurgery; Intensive care unit; Retrospective study

INTRODUCTION

Tracheostomy is a necessary procedure for patients admitted to the neurosurgery intensive care unit (NSICU) with severe brain injury since mechanical ventilation must be maintained for a long time due to neurologic failure. If endotracheal intubation is maintained for a long time, it can cause subglottic stenosis, vocal cord injury, or ventilator-associated pneumonia. Tracheostomy facilitates the weaning off of mechanical ventilation and has advantages in secretion management in the lower airway.
In addition, as ventilator weaning is performed after tracheostomy, sedative drugs can be reduced, neurologic examination necessary for brain injury patients can be confirmed, and cardiopulmonary function can be restored by reducing atelectasis and pneumonia.\textsuperscript{14}

Regarding the method of tracheostomy, conventional surgical tracheostomy (CST) was the gold standard until the mid-2000s.\textsuperscript{14} However, since percutaneous dilatational tracheostomy (PDT) was first introduced in 1985 by Ciaglia et al.,\textsuperscript{6} it can be performed directly from the bedside, can reduce the risks associated with transporting patients, and has the advantages of a reduced cost and relatively simple operation.\textsuperscript{4}

NSICU patients often suffer from severe brain injury and their general condition is not good. In particular, if they are infected with a multidrug-resistant pathogen, tracheostomy in the intensive care unit (ICU) is often required to prevent the spread of nosocomial infection.\textsuperscript{18}

The purpose of this study was to compare CST and PDT performed at the bedside on critically ill neurosurgery patients requiring tracheostomy to determine which procedure has comparative advantages.

**MATERIALS AND METHODS**

**Study design**

This is a retrospective review of ICU patients who underwent a tracheostomy in the NSICU of Gyeongsang National University Changwon Hospital (GNUCH) and Gyeongsang National University Hospital (GNUH). The Institutional Review Board was conducted at GNUCH (approval No. GNUCH 2022-02-021).

In the ICU of GNUCH, PDT was performed on 52 patients from January 2019 to December 2020 and CST was performed on 44 patients during the same period in the ICU of GNUH. All procedures were performed at the bedside due to concerns about the risk of patient movement and nosocomial infection caused by multidrug-resistant bacteria.\textsuperscript{19}

Indications for tracheostomy are defined as cases where ventilator weaning is difficult when intubation maintenance is expected for patients who experience slow recovery of consciousness, for airway protection in patients with high aspiration potential, and airway toilets for patients with high respiratory secretion.\textsuperscript{12}

Among the absolute contraindications of PDT, there were a cervical spine instability and infection at the planned insertion site.\textsuperscript{7} Therefore, we excluded patients who received traumatic cervical spine injury. Additionally, patients under the age of 18 years old, and patients who were discharged less than 14 days after surgery were excluded because there were not sufficient medical records.

**Technique**

CST was performed at the bedside in the same manner as it is performed in the operating room.

Modified PDT was performed using the Ciaglia Blue Rhino Percutaneous Dilatational Tracheostomy Kit (Cook Critical Care, Bloomington, IN, USA); however, unlike the conventional method, the 2nd & 3rd tracheal ring and surrounding blood vessels were checked by ultrasound instead of bronchoscopy (FIGURE 1).\textsuperscript{17}
The patient was under intravenous anesthesia using propofol and a neuromuscular blocker, and the ventilator mode was switched to the P-CMV mode. Anatomic landmarks were identified by palpation and ultrasonography was used to identify and avoid large blood vessels near the tracheostomy. After exposing the trachea by making a skin incision 1 cm below the cricoid cartilage, a dissection was performed, and the existing endotracheal tube was withdrawn to a depth of 13 cm. After dilatation of the insertion site using a guidewire and a dilator, tracheal tube insertion and ventilator application were performed to confirm that the tidal volume was intact and the procedure was terminated (FIGURE 2).
Statistical analysis
All analyses were performed in R version 4.1.0 (R Foundation, Vienna, Austria) under the significance level $p=0.05$. To compare the differences between the groups, quantitative data and qualitative data were divided and analysis of variance, t-tests, and $\chi^2$ tests were performed.

RESULTS

Baseline characteristics
Among 96 patients, CST was performed in 44 patients and PDT in 52 patients; all procedures were performed by neurosurgeons and trainees.

For ICU admission reasons, intracranial hemorrhage was the most common among the PDT group, followed by traumatic brain injury, subarachnoid hemorrhage, and cerebral infarct. Among the baseline characteristics, statistically significant differences between the PDT group and CST group were identified as age, traumatic brain injury, and Glasgow Coma Scale (GCS) at the time of admission to ICU. This difference was related to the population distribution of cities to which GNUCH and GNUH belong. In particular, GNUH is a hospital with a regional trauma center, which is thought to be the reason for the relatively high proportion of trauma patients. In both comparison groups, GCS was lower in the PDT group, confirming that the patients’ severity at the time of first admission was higher (TABLE 1).

The reasons for performing tracheostomy were similar between the 2 groups in the order of difficulty in ventilator weaning, continuous intubation, and prevention of aspiration risk.

### TABLE 1. Baseline characteristics

| Characteristics                  | PDT (n=52)   | CST (n=44)   | p-value |
|----------------------------------|--------------|--------------|---------|
| Age (years)                      | 59.3±14.4    | 65.9±15.5    | 0.014*  |
| Sex                              |              |              |         |
| Female                           | 22 (42.3)    | 23 (52.3)    | 0.442   |
| Male                             | 30 (58.8)    | 21 (47.7)    |         |
| BMI (kg/m$^2$)                   | 24.1±3.7     | 22.8±3.6     | 0.091   |
| Obese (BMI >30 kg/m$^2$)         |              |              |         |
| Comorbidities                    |              |              |         |
| Hypertension                     | 18 (34.6)    | 8 (18.2)     | 0.115   |
| Diabetes mellitus                | 4 (7.6)      | 7 (15.9)     | 0.348   |
| Dyslipidemia                     | 7 (13.4)     | 5 (11.3)     | 1.000   |
| Malignancy                       | 1 (1.9)      | 0 (0)        | 1.000   |
| Coronary artery disease          | 5 (9.6)      | 4 (9.1)      | 1.000   |
| Chronic kidney disease           | 2 (3.8)      | 2 (4.5)      | 0.498   |
| Chronic liver disease            | 5 (9.6)      | 1 (2.3)      | 0.214   |
| Cerebrovascular accident history  | 6 (11.5)     | 3 (6.8)      | 0.501   |
| Reason for admission             |              |              |         |
| Brain tumor                      | 0 (0)        | 1 (2.3)      | 0.458   |
| Intracranial hemorrhage          | 25 (48)      | 13 (31)      | 0.101   |
| Traumatic brain injury           | 12 (23.1)    | 21 (50.0)    | 0.020*  |
| Subarachnoid hemorrhage          | 12 (23.1)    | 8 (19.0)     | 0.737   |
| Cerebral infarction              | 2 (3.8)      | 1 (2.3)      | 1.000   |
| Others                           | 1 (1.9)      | 0 (0)        | 1.000   |
| GCS on ICU admission             | 5.0±3.1      | 7.6±3.3      | <0.001* |

Data are present as mean ± SD or number (%).
PDT: percutaneous dilatational tracheostomy, CST: conventional surgical tracheostomy, BMI: body mass index, GCS: Glasgow Coma Scale, ICU: intensive care unit.
*The p-values <0.05 are considered statistically significant.
Except for this slightly longer point, there was no significant difference in lab or ventilator settings (TABLE 2).

Although the PDT group failed only 1 case of the initial success of tracheostomy, there was no significant difference between the 2 groups. However, the procedure time of CST (mean value 25.5±6.5) was statistically significantly longer than that of PDT (mean value 15.1±2.5) \((p<0.001)\). The PDT group had fewer incidences of major complications compared to the CST group, including hemoglobin levels decreased by more than 2 g/dL compared to before surgery, requiring transfusion (PDT group n=0, 0% vs. CST group n=4, 9.1%) \((p=0.041)\). Although it is not statistically significant, the difference identified such as respiratory arrest (PDT group n=0, 0% vs. CST group n=1, 2.3%), stomatal infection requiring antibiotics (PDT group n=0, 0% vs. CST group n=2, 4.5%). However, tracheal stenosis & granulation (PDT group n=3, 5.8% vs. CST group n=2, 4.5%) were more common complications in the PDT group (TABLE 3).

**TABLE 2. Procedural characteristic**

| Characteristics                  | PDT (n=52) | CST (n=44) | p-value |
|----------------------------------|------------|------------|---------|
| Reason for tracheostomy          |            |            |         |
| Difficult ventilator weaning or prolonged intubation | 34 (65.4)  | 31 (70.5)  | 0.756   |
| Airway protection                | 0 (0.0)    | 5 (11.4)   | 0.018*  |
| Airway toilet                    | 8 (15.4)   | 6 (13.6)   | 1.000   |
| Difficult airway                 | 2 (3.8)    | 2 (4.5)    | 1.000   |
| GCS on procedure                 | 5.4±2.2    | 6.3±2.4    | 0.079   |
| Duration before tracheostomy (days) | 13.4±5.0   | 10.3±3.0   | 0.001*  |
| Lab result on the procedure day  |            |            |         |
| Platelet count \((×10^3/\mu L)\) | 272.1±152.7| 273.2±113.6| 0.591   |
| PT (INR)                         | 14.3±1.4   | 14.1±0.9   | 0.868   |
| aPTT (seconds)                   | 38.3±7.2   | 36.9±7.1   | 0.307   |
| Ventilator setting               |            |            |         |
| \( \text{FiO}_2 \) (%)           | 48.0±21.9  | 34.0±14.5  | <0.001* |
| PEEP                             | 5.0±2.3    | 5.6±1.3    | 0.326   |
| Vasopressor requirement          | 3 (5.8)    | 1 (2.3)    | 0.622   |

Data are presented as mean ± SD or number (%).  
PDT: percutaneous dilatational tracheostomy, CST: conventional surgical tracheostomy, GCS: Glasgow Coma Scale, PT: prothrombin time, aPTT: activated partial thromboplastin time, INR: international normalized ratio, \( \text{FiO}_2 \): fraction of inspired oxygen, PEEP: positive end-expiratory pressure.  
*The \( p \)-values <0.05 are considered statistically significant.

**TABLE 3. Clinical outcome**

| Characteristics                  | PDT (n=52) | CST (n=44) | p-value |
|----------------------------------|------------|------------|---------|
| Procedural data                  |            |            |         |
| Initial success of tracheostomy  | 51 (98.1)  | 44 (100.0) | 1.000   |
| Procedure time (Minutes)         | 15.1±2.5   | 25.5±6.5   | <0.001* |
| Complication                     |            |            |         |
| Major bleeding                    | 0 (0.0)    | 4 (9.1)    | 0.041*  |
| Lost airway or respiratory arrest| 0 (0.0)    | 1 (2.3)    | 0.458   |
| Subcutaneous emphysema            | 0 (0.0)    | 0 (0.0)    | -       |
| Stoma infection                   | 0 (0.0)    | 2 (4.5)    | 0.207   |
| Tracheal stenosis & granulation   | 3 (5.8)    | 2 (4.5)    | 1.000   |
| Outcomes                          |            |            |         |
| ICU mortality                     | 12 (23.1)  | 3 (6.8)    | 0.057   |
| Hospital mortality                | 0 (0.0)    | 0 (0.0)    | -       |
| Length of stay in hospital        | 42.6±27.5  | 33.7±18.9  | 0.142   |

Data are shown as mean ± SD or number (%).  
PDT: percutaneous dilatational tracheostomy, CST: conventional surgical tracheostomy, ICU: intensive care unit.  
*The \( p \)-values <0.05 are considered statistically significant.
DISCUSSION

Tracheostomies are performed in the neurosurgical ICU to protect the airway from aspiration pneumonia and pulmonary toileting and to secure the airway in cases requiring prolonged mechanical ventilation. CST has been widely accepted but still has many complications, with an overall incidence of 36%–41%, including pneumothorax, subcutaneous emphysema, bleeding, stoma infections, and less commonly, mortality.

The safety and feasibility of PDT has already been proven in previous prospective study and meta-analysis, however, absolute or relative contraindications in PDT were controversial. According to other studies, cervical spinal injury, pediatric age, coagulopathy and emergency airway necessity and anomaly of the aortic arch branches were considered absolute contraindications. On the other hand, difficult anatomy such as short neck, obesity, minimal neck extension and tracheal deviation and severe respiratory disease were relative contraindication.

In this study, we compared PDT and CST techniques in terms of ICU mortality, hospital mortality, and length of hospital stay. The mean duration of hospital stay was 42.6±27.5 for PDT and 33.7±18.9 for CST; there was no statistically significant difference between the 2 groups (p=0.142). We suggest that this is because the initial GCS score was significantly lower in the PDT group (5.0±2.1) than in the CST group (7.6±3.3) and the patients’ conditions were more serious.

We investigated the safety and feasibility of PDT compared to CST in critically ill neurosurgery patients. First, procedure-related complications, including bleeding, stoma infection, and respiratory arrest were more common in the CST group than in the PDT group. Second, the procedure time was longer in the CST group than in the PDT group. This finding was consistent with similar previous studies.

We noted that the overall complication rate was lower in the PDT group (1, 5.8%) than in the CST group (9, 20.3%). Thus, PDT is a relatively safer procedure than CST. Many authors even suggested that the complications and clinical outcomes were not of significant statistical difference between trainees and experienced surgeons. In addition, PDT can be performed at the ICU bedside, which is safer regarding the risk of patient transport. Recently, PDT has been recognized as a reliable alternative to CST.

Intraoperative and post-operative major bleeding requiring a transfusion was seen in both the PDT and CST groups. The reported incidence of hemorrhages in the CST group was up to 3%–37% and was very variable due to the incision and dissection of paratracheal tissue, retraction or division of the isthmus, and proximity of the vessels supplying the thyroid, which lie near the pre-tracheal tissue. However, PDT reportedly has a lesser incidence of hemorrhage, mostly owing to small incisions that avoid surrounding vessels.

Recently, the use of PDT has increased due to fewer complications such as bleeding and wound infection compared to CST. In this study, procedure-induced complications were lower among patients receiving PDT than among patients receiving CST. In particular, fibrotic bronchoscopy can cause increased intracranial pressure in patients with a head injury; thus, we performed ultrasound-guided PDT to decrease this risk. Complications in PDT can be further reduced by having an experienced surgeon perform the procedure and by using preoperative ultrasound to rule out any abnormal course of vessels at the site of the cannula puncture as well as enlarged thyroid lobes, isthmus, or any neck masses.
It is important to perform PDT in patients with brain injuries who require neurointensive care because, unlike other patients, patients with acute neurologic conditions such as traumatic brain injury, stroke, and hypoxic-ischemic encephalopathy have hypoventilation, bowed posture, hypoxia, and hypotension. It is necessary to appropriately deal with subtle risks such as elevated intracranial pressure and the use of less sedative drugs than general CST. However, no patient transport, short procedure time, and low procedure-induced complications are all advantages over CST.

Several limitations were identified in our study. First, it is a retrospective study and the number of patients in the population is small. Second, since PDT and CST were performed in different centers, it was difficult to reflect the average age of patients according to region and the characteristics of diseases in the results. Additionally, there was a difference in the ICU care method for each center. Third, all procedures were performed by trainees, not by a specialist. Therefore, there may be a difference in postoperative complication if procedures were performed by a specialist. However, we believe it will be meaningful as a study of neurosurgery patients. And more case analysis and prospective research will confirm the usefulness of PDT, and it will be possible to safely perform it in more patients.

CONCLUSION

PDT is as safe and effective as conventional tracheostomy and is associated with a lower incidence of overall complications and a faster procedure time. Procedure-related hemorrhages and infections are statistically insignificant and are less common with PDT. It can be a better option in a critical care setup where tracheostomy is required and can also be performed at the bedside. Therefore, PDT performed by neurosurgeons is safer and more feasible than CST in the NSICU.

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