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Safety and Feasibility of Percutaneous Dilatational Tracheostomy Performed by a Neurointensivist Compared with Conventional Surgical Tracheostomy in Neurosurgery Intensive Care Unit

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Objective

To evaluate safety and feasibility of percutaneous dilatational tracheostomy (PDT) performed by a neurointensivist compared with conventional surgical tracheostomy (CST) in neurosurgery patients and neurocritically ill patients.

Methods

This was a retrospective and observational study of adult patients who underwent tracheostomy in neurosurgical intensive care unit (ICU) from January 2015 to December 2017. The primary endpoint was procedure-induced complications. Secondary endpoints were initial success of tracheostomy and procedure time.

Results

A total of 118 patients underwent tracheostomy during the study period. Elective surgery of brain tumor (33.1%) and intracranial hemorrhage (20.3%) were the most common reasons for ICU admission. Prolonged intubation (42.4%) and airway protection or prevent risk of aspiration (25.4%) were the most common reasons for tracheostomy. There was no significant difference in initial success rate of tracheostomy between the two groups (p=0.110). However, procedural time was lengthier in CST than that in PDT (39.0 [30.0–60.0] min vs. 15.0 [11.0–23.0] min, p<0.001). Procedure-induced complications were more common in patients who underwent CST compared to those in patients who underwent PDT (26.3% vs. 11.5%, p=0.039). Although moderate or major bleeding occurred in five patients who underwent CST, only one patient had moderate bleeding in PDT. Especially, there were two respiratory arrests during procedure in CST. In addition, two VAPs and seven wound infections occurred in CST.

Conclusions

PDT performed by a neurointensivist may be safe and feasible compared to CST in neurosurgery patients and neurocritically ill patients.

Keywords: Percutaneous dilatational tracheostomy; Neurointensivist; Neurosurgery intensive care unit

INTRODUCTION

Percutaneous dilatational tracheostomy (PDT) has been increasingly used because of its easy placement with lower rates of clinically significant bleeding and wound infection in critically ill patients[17]. Tracheostomy may be performed in neurosurgery or neurocritially ill patients due to various reasons such as prolonged intubation, airway protection, or to prevent risk of aspiration caused by brain injuries[12,17]. In patients with brain injuries, tracheostomy has to be more vigilantly performed[17]. Neurointensivists are specialists focusing on management of brain injured patients[16]. Therefore, PDT performed by a neurointensivist may have many theoretical advantages due to easy placement at bedside, low risk of complications, and specialized management for brain injured patients[17].

However, there are limited reports of PDT in neurocritially ill patients[12,17]. In addition, there has been no report about complications associated with fiberoptic bronchoscopy during PDT. In patients with head injuries, fiberoptic bronchoscopy can lead to intracranial hypertension[10]. Therefore, the purpose of this study was to investigate the safety and feasibility of PDT performed by a neurointensivist compared with conventional surgical tracheostomy (CST) in neurosurgery patients and neurocritically ill patients.

METHODS

Study population and design

This was a retrospective, single-center, observational study of adult patients admitted to the neurosurgical intensive care unit (ICU) at Samsung Medical Center from January 2015 to December 2017. This study was approved by the Institutional Review Board of Samsung Medical Center (approval number: SMC 2018-09-011). The requirement for informed consent was waived due to its retrospective nature. We included adult patients admitted to the neurosurgical ICU who underwent tracheostomy during the study period. Those who were hospitalized for more than 14 days after tracheostomy were selected. Of these patients, we excluded patients under age 18, those who did not have brain injury, those who were discharged before 14 days after tracheostomy, and those who had insufficient medical records. Additionally, patients were excluded if they were admitted to departments other than neurosurgery.

Definitions and outcomes

We retrospectively reviewed all neurosurgery patients and neurocritcally ill patients admitted to the neurosurgery ICU who underwent tracheostomy during the study period. Regarding data associated with the tracheostomy procedure, initial success of tracheostomy and procedure time were investigated. Procedure time was defined as time from sterilization to connection of the tracheostomy tube with the mechanical ventilator after successful tracheostomy[11,12]. Primary endpoint was procedure-induced complication. We investigated complications at insertion or during maintenance such as insertional injury, bleeding or hematoma, fracture of tracheal ring, cuff perforation, accidental decannulation, surgical conversion, hypoxemia, stomal ulcer, and ventilator-associated pneumonia (VAP). Regarding associated post-procedural bleeding complications, major bleeding was defined as bleeding that required cauterization, surgical treatment, or additional blood transfusion[11,12]. Minor bleeding was defined as bleeding from the incision site that required dressing more than three times a day or epinephrine for local hemostasis. VAP was defined if patients received clinical diagnosis more than 48 hours after tracheotomy and received antimicrobial therapy with a new radiographical infiltrate and two of three clinical criteria: purulent secretions, fever, and leukocytosis or leukopenia[13,17]. Secondary endpoints were initial success of tracheostomy and procedure time.

Procedure

In this study, a neurointensivist or a neurosurgeon determined tracheostomy. Tracheostomy was considered if a patient was expected to be on prolonged mechanical ventilation, need air way protection, or show decreased sedation due to neurocritically ill and/or general critically conditions[6]. We considered optimal candidates to be patients without (1) uncontrolled increased intracranial hypertension, or impending brainstem herniation; (2) acute phase of stroke or delayed cerebral ischemia in subarachnoid hemorrhage; (3) refractory status epilepticus; (4) fraction of inspired oxygen (FiO_2) greater than 0.6, positive end-expiratory pressure greater than 10 cm H_2O or plateau pressure greater than 40 cm H_2O; (5) requiring high-dose inotropes or vasopressors; (6) uncontrolled dysrrhythmia; (7) severe acidosis; (8) active bleeding; (9) active infection at the tracheostomy site or gross neck deformity[6]. In PDT performed by a neurointensivist, patients received sedation and pain control with propofol or midazolam, intravenous analgesics with fentanyl and/or remifentanil, and topical analgesic with 1.5% lidocaine and 1:200,000 epinephrine[17]. Especially, at least 30 minutes before the procedure, a continuously high dose infusion of propofol and bolus administration of osmotic agent were performed for patients with intracranial hypertension. Mechanical ventilation was controlled and FiO_2 was increased to 1.0. Before administration of neuromuscular blockade, the goal of sedation was to achieve Richmond Agitation Sedation Scale goal of negative 4 to 5[6,18]. Anatomic landmarks were identified by palpation. We also used ultrasonography

to identify and avoid large blood vessels near the tracheostomy site[6]. PDT was performed using Ciaglia Blue Rhino® (Cook Medical Inc., Bloomington, IN, USA) by a neurointensivist at bedside. Patients were kept in supine position with hyperextension of the neck during procedure. About 10 mm vertical incision was made at the inferior edge of the cricoid cartilage[5,11]. Pretracheal soft tissues were bluntly dissected with a mosquito clamp if needed. Underlying trachea was then identified using a needle and introducer sheath under bronchoscopic visualization. After a J-tipped Seldinger wire was inserted through the introducer sheath into the trachea, the introducer sheath was then removed and dilation of the trachea and soft tissue was performed initially with a short dilator followed by a curved conical dilator[5,11]. Finally, the tracheostomy tube was loaded onto an introducer dilator and gently inserted into the trachea over the guidewire through the dilated stoma and secured in place under bronchoscopic visualization[9].

CST was performed by a neurosurgeon or an otolaryngologist at bedside or surgical room. In tracheostomy performed by a neurointensivist or neurosurgeon, T-cannula was changed by neurosurgery residents at the first seven day. However, in CST performed by an otolaryngologist, T-cannula was changed by an otolaryngologist at the first three day after CST.

Statistical analyses

All data are presented as medians and interquartile ranges (IQRs) for continuous variables and numbers (percentages) for categorical variables. Data were compared using Mann-Whitney U test for continuous variables and Chi-squared test or Fisher's exact test for categorical variables. All tests were two-sided and p-values < 0.05 were considered statistically significant. Data were analyzed using IBM SPSS statistics version 20 (IBM, Armonk, NY, USA).

RESULTS

Baseline characteristics and procedural characteristics

A total of 118 patients were analyzed in this study. Among these patients, 61 underwent PDT by a neurointensivist and 57 patients underwent CST (36 by neurosurgeons, 21 by otolaryngologists) during the study. CST was performed in 4 (1 by neurosurgeons, 3 by otolaryngologists) patients in the operating room. Median age of patients was 61 (IQR 49–70) years. Of 118 patients, 51 (43.2%) were males. Elective surgery of brain tumor (33.1%) and intracranial hemorrhage (20.3%) were the most common reasons for ICU admission. There was no significant difference in age, gender, body mass index, comorbidities, Glasgow Coma Scale, or APACHE II

Table 1. Baseline characteristics

	PDT (n=61)	CST (n=57)	p-value
Age (yr) — median (IQR)	59.0 (47.0–70.0)	64.0 (55.0–70.0)	0.297
Gender, male — no. of patients (%)	28 (45.9)	23 (40.4)	0.673
BMI (kg/m^2) — median (IQR)	23.9 (20.9–25.7)	23.5 (20.2–25.5)	0.368
Obese (BMI >30 kg/m^2) — no. of patients (%)	4 (6.6)	4 (7.0)	0.999
Comorbidities — no. of patients (%)			
Hypertension	33 (54.1)	35 (61.4)	0.538
Diabetes mellitus	20 (32.8)	13 (22.8)	0.316
Dyslipidemia	11 (18.0)	18 (31.6)	0.135
Malignancy	17 (27.9)	8 (14.0)	0.107
Coronary artery disease	4 (6.6)	5 (8.8)	0.737
Chronic kidney disease	3 (4.9)	4 (7.0)	0.710
Chronic liver disease	3 (4.9)	3 (5.3)	0.999
Reason for ICU admission — No. of patients (%)			
Brain tumor	29 (47.5)	10 (17.5)	0.014
Intracranial hemorrhage	10 (16.4)	14 (24.6)	
Traumatic brain injury	10 (16.4)	13 (22.8)	
Subarachnoid hemorrhage	7 (11.5)	17 (29.8)	
Cerebral infarction	2 (3.3)	3 (5.3)	
Other	3(4.9)	0 (0)	
GCS on ICU admission — median (IQR)	7.0 (4.0–12.0)	7.0 (4.0–8.0)	0.412
APACHE II score on ICU admission — median (IQR)	26.0 (24.0–30.0)	28.0 (25.0–30.0)	0.117

PDT: Percutaneous dilatational tracheostomy; CST: conventional surgical tracheostomy; IQR: interquartile range; BMI: body mass index; ICU: intensive care unit; CNS: central nerve system; GCS: Glasgow Coma Scale; APACHE: Acute Physiology and Chronic Health Evaluation.

Table 2. Procedural characteristics at the time of tracheostomy

	PDT (n=61)	CST (n=57)	p-value
Reason for tracheostomy—No. of patients (%)			0.51
Difficult ventilator weaning or prolonged intubation	29 (47.5)	21 (36.8)	
Airway protection or prevent risk of aspiration	14 (23.0)	16 (28.1)	
Reduction of sedative	10 (16.4)	14 (24.6)	
Airway toilet	5 (8.2)	2 (3.5)	
Difficult airway	3 (4.9)	4 (7.0)	
Use of antiplatelet agent—No. of patients (%)	3 (4.9)	1 (1.8)	0.619
Use of hyperosmolar agent during tracheotomy—No. of patients (%)	0 (0)	2 (0)	0.231
GCS on procedure—median (IQR)	7.0 (6.0–12.0)	7.0 (6.0–10.0)	0.967
Invasive ICP monitoring—No. of patients (%)	33 (54.1)	32 (56.1)	0.97
Duration of mechanical ventilation before tracheostomy (days)—median (IQR)	9.0 (4.0–14.0)	8.0 (5.0–11.0)	0.49
Inserted site—No. of patients (%)			0.177
1st tracheal membrane	13 (21.3)	21 (36.8)	
2nd tracheal membrane	36 (59.0)	27 (47.4)	
3rd tracheal membrane	12 (19.7)	9 (15.8)	
Lab results on the day of tracheostomy—median (IQR)			
Platelet count ($\times 10^3/\mu l$)	228 (164–288)	220 (165–265)	0.579
PT(INR)	1.1 (1.1–1.2)	1.1 (1.1–1.2)	0.333
aPTT (sec)	36.4 (34.0–40.9)	36.1 (33.1–41.4)	0.605
Ventilator setting—median (IQR)			
FiO_2 (%)	35.0 (30.0–40.0)	35.0 (30.0–40.0)	0.638
PEEP (cmH_2O)	5.0 (5.0–5.0)	5.0 (5.0–5.0)	0.638
Vasopressor requirement—No. of patients (%)	9 (14.8)	9 (15.8)	0.876

PDT: Percutaneous dilatational tracheostomy; CST: conventional surgical tracheostomy; GCS: Glasgow Coma Scale; IQR: interquartile range; ICP: intracranial pressure; INR: international normalized ratio; aPTT: activated partial thromboplastin time; FiO_2: Fraction of inspired oxygen; PEEP: positive end-expiratory pressure.

score on ICU admission between the two groups except for reason for admission among baseline characteristics (Table 1). Difficult ventilator weaning or prolonged intubation (42.4%) and airway protection or prevent risk of aspiration (25.4%) were the most common reasons for tracheostomy. There were no significant differences in laboratory results of platelet count or coagulation on the day of tracheostomy between the two groups (Table 2).

Clinical outcomes

There was no significant difference in initial success rate of tracheostomy between the two groups (p=0.110). However, procedural time was lengthier in CST than that in PDT (39.0 [30.0–60.0] min vs. 15.0 [11.0–23.0] min, p<0.001). Procedure-induced complications were more common in patients who underwent CST compared to those in patients who underwent PDT (26.3% vs. 11.5%, p=0.039). Although moderate or major bleeding occurred in five patients who underwent CST, only one patient had moderate bleeding in PDT. Especially, there were two respiratory arrests during procedure in CST. Although there was no infectious complication in patients who underwent PDT, two VAPs and seven wound infections occurred in patients who underwent CST. However, there was no significant difference in mortality or length of stay in the ICU or hospital between the two groups. There was no procedure-induced intracranial hypertension (intracranial pressure [ICP] > 20 mmHg) during tracheostomy in either group. Clinical outcomes were shown in Table 3

DISCUSSION

In this study, we investigated the safety and feasibility of PDT performed by a neurointensivist at bedside compared with CST in neurocritically ill patients. This study had the following major findings: 1) Procedure-induced complications were more common in the CST group than those in the PDT group; 2) There was no significant difference in initial success rate of tracheostomy between the two groups; 3) Procedural time was lengthier in CST than that in PDT; 4) However, there were no significant differences in mortalities or length of stay in the ICU or hospital between

Table 3. Clinical outcomes

	PDT (n=61)	CST (n=57)	p-value
Procedural data			
Initial success of tracheostomy — No. of patients (%)	61 (100)	54 (94.7)	0.110
Procedure time (min) — median (IQR)	15.0 (11.0–23.0)	39.0 (30.0–60.0)	<0.001
Complication — No. of patients (%)	7 (11.5)	15 (26.3)	0.039
Bleeding	4 (6.6)	9 (15.8)	0.109
Moderate or major bleeding	1 (1.6)	5 (8.8)	0.105
Minor bleeding	3 (4.9)	4 (7.0)	0.710
Infection	0 (0)	3 (5.3)	0.110
Ventilator-associated pneumonia	0 (0)	2 (3.5)	0.231
Wound infection within 7days	0 (0)	1 (1.8)	0.483
Fracture of tracheal ring	3 (4.9)	0 (0)	0.244
Lost airway & respiratory arrest	0 (0)	2 (3.5)	0.231
Subcutaneous emphysema	0 (0)	1 (1.8)	0.483
Outcomes			
ICU mortality — No. of patients (%)	2 (3.3)	0 (0)	0.496
Hospital mortality — No. of patients (%)	6 (9.8)	3 (5.3)	0.493
Length of stay in ICU (days) — median (IQR)	16.0 (10.0–22.0)	13.0 (10.0–17.0)	0.279
Length of stay in hospital (days) — median (IQR)	49.0 (26.0–73.0)	49.0 (36.0–73.0)	0.550

PDT: Percutaneous dilatational tracheostomy; CST: conventional surgical tracheostomy; IQR: interquartile range; ICU: intensive care unit.

the two groups.

PDT is a relatively safe procedure that can be easily learned by physicians with less experience in surgery than CST[21]. A recent study has shown that there are no significant differences in clinical outcomes or complications between trainee-led PDT and experienced intensivist-led PDT[11]. Therefore, PDT performed by subspecialty trainees of critical care medicine is a safe and feasible procedure[11]. In addition, PDT can be performed by an intensivist at bedside in critically ill patients due to risk of transport[3,4,11,12,17,21]. In fact, PDT has been recognized as a reliable alternative to CST[21].

Recently, PDT has been increasingly used because of its lower complications such as bleeding and wound infections[17]. In this study, procedure-induced complications were much lower in patients who underwent PDT than those in patients who underwent CST. Especially, there was no fatal complication in patients who underwent PDT. There has been no report about complications associated with fiberoptic bronchoscopy during PDT. In patients with head injuries, fiberoptic bronchoscopy can lead to intracranial hypertension[10]. Sustained increased ICP may lead to poor outcome in neurocritically ill patients[9,10]. However, there was no procedure-induced intracranial hypertension during tracheostomy in either group of the present study.

Why is it important for a neurointensivist to perform a PDT in brain injured patients? Neurointensivists are specialists focusing on management of patients with acute neurologic conditions, including traumatic brain injury, stroke, status epilepticus, hypoxic-ischemic encephalopathy, and neuromuscular respiratory failure[16]. Tracheostomy is generally performed in patients with these neurocritically ill problems[1,2,7,8,15,20]. Neurointensivists may be more vigilant in recognizing and managing subtle dangers such as hypoventilation, head-down positioning, hypoxia, hypotension, and elevated ICP that might occur in brain injured patients during the procedure[14,19,20]. Therefore, a neurointensivist may have advantages of performing the procedure for managing neurocritically ill patients.

This study has several limitations. First, it was a retrospective review of medical records. Second, tracheostomy was determined by a neurointensivist or a neurosurgeon. It was not protocol-based. In addition, the non-randomized nature of registry data might have resulted in selection bias. Third, there was no procedure-induced intracranial hypertension during tracheostomy. However, the measurement of ICP during procedure might not be accurate. Finally, our study had limited statistical power due to its small sample size. Although it provides valuable insight, prospective large-scale studies are needed to evaluate the usefulness of PDT performed by a neurointensivist for patients with severe brain injuries to obtain evidence-based conclusions.

CONCLUSION

In this study, procedure-induced complications were fewer in patients who underwent PDT compared to those in patients who underwent CST. In addition, procedural time was shorter in

PDT compared to CST. Therefore, PDT performed by a neurointensivist may be safe and feasible compared to CST in neurosurgery patients and neurocritically ill patients.

NOTES

Conflict of interest

The authors declare that they have no competing interests.

Informed consent

Informed consent was obtained from each participant included in this study.

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