Original Article

Clinical implications of differentiating between types of post-tracheostomy tracheal stenosis

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Background: Post-tracheostomy tracheal stenosis (PTTS) can be divided into four types according to stenosis mechanism and site: subglottic, stoma, cuff, and tip granuloma. However, there is little information available regarding clinical differences among types of PTTS; therefore, we evaluated the clinical differences between these types.

Methods: We retrospectively evaluated 99 PTTS patients who underwent interventional bronchoscopy between 2004 and 2014. Patients were divided into two groups according to pathophysiological similarities as follows: subglottic or stoma type (n=59) and cuff or tip type (n=40).

Results: There were no differences in baseline characteristics between groups. However, silicone stents were more frequently needed in patients with subglottic or stoma type stenosis (76%) than those with cuff or tip type stenosis (55%, P=0.031) to maintain airway patency. On the contrary, permanent tracheostomy was more frequently performed in patients with cuff or tip type stenosis (50%) than those with subglottic or stoma type stenosis (19%, P=0.002). Finally, successful removal of the tracheostomy tube without surgery and procedure- or disease-related mortality were more frequently achieved in patients with subglottic or stoma type stenosis (71%) than those with cuff or tip type stenosis (45%, P=0.012).

Conclusions: Although there were no significant differences in baseline characteristics between PTTS types, patients with subglottic or stoma type stenosis had more favorable outcomes than those with cuff or tip type stenosis. Therefore, it could be important to distinguish between types of PTTS when assessing prognosis.

Keywords: Post-tracheostomy tracheal stenosis (PTTS); interventional bronchoscopy; airway stent; treatment outcome

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Introduction

Tracheal stenosis following tracheostomy is a well-established type of acquired benign stenosis in critically ill patients (1,2). Post-tracheostomy tracheal stenosis (PTTS) occurs in approximately 1–2% of patients as a late complication of tracheostomy (3,4). Although tracheal resection and end-to-end anastomosis is the treatment of choice for this type of lesion, postoperative complications were significantly increased in association with poor general

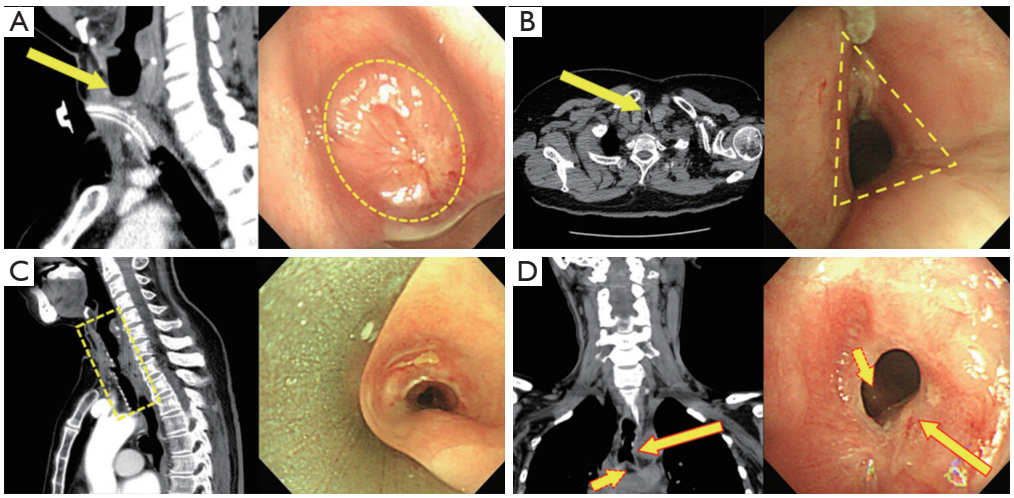

Figure 1 CT and bronchoscopic findings according to PTTS type. (A) Subglottic type. Subglottic area was completely obstructed by fibrotic stricture (arrow and circle); (B) stoma type. Upper trachea at the tracheostomy stoma was narrowed by cartilage fracture and fibrosis (arrow). Tracheal stenosis of triangular shape was observed during the bronchoscopy (dotted triangle); (C) cuff type. Mid-trachea at the cuff level was narrowed by fibrotic bands (dotted square); (D) tip granuloma type. Distal trachea just above the carina was narrowed by fibrosis (long solid arrow: fibrotic band; short dotted arrow: carina). CT, computed tomography; PTTS, post-tracheostomy tracheal stenosis.

health and comorbidities (5,6). Interventional bronchoscopy is an acceptable alternative to surgery for many inoperable patients, considering the high comorbidities of patients with PTTS (7,8).

PTTS can be subdivided into four types in accordance with stenosis site and pathophysiology as follows: subglottic, stoma, cuff, and tip types (9). PTTS occurs at subglottic or stomal sites, caused by inadequate incisions during tracheostomy procedures. In addition, PTTS sometimes occurs at the cuff or tip of the tracheostomy tube, caused by inadequate management of problems such as high cuff pressure and excessive irritation by the suction tip.

Each type of PTTS may have different clinical characteristics and optimal management may require different practices. However, there have been few studies comparing types of PTTS. Therefore, we investigated the clinical characteristics of patients with each type of PTTS who underwent interventional bronchoscopy.

Methods

Patients

We reviewed all 1,064 consecutive patients with airway stenosis who underwent interventional bronchoscopy at Samsung Medical Center (a 1,979-bed, university-affiliated, tertiary care referral hospital in Seoul, South Korea) between January 2004 and December 2014. Of these patients, 99 were identified to have tracheal stenosis after tracheostomy. Some patients who were reported in a previous study were re-evaluated in terms of clinical outcomes for extension of follow-up duration (10). Patients with PTTS were classified into two groups, "subglottic or stoma" and "cuff or tip," based on clinical, bronchoscopic, and radiological findings, which were thoroughly reviewed by three of the authors (B Shin, K Kim, and BH Jeong). Each type is detailed in *Figure 1*.

This retrospective observational study received Institutional Review Board of Samsung Medical Center approval (IRB No. 2016-08-139). The need for informed consent was waived because patient information was anonymized and de-identified prior to analysis.

Airway intervention techniques

We assessed airway anatomy and function using chest radiography, computed tomography (CT), flexible bronchoscopy, and, if possible, pulmonary function tests (PFT). When tracheal stenosis was greater than 50% in cross-sectional area and/or the patient had symptomatic dyspnea limiting activities of daily living, interventional bronchoscopy was performed (11-13).

Interventional bronchoscopy was performed according

to standard techniques after induction of general anesthesia and intubation with a rigid bronchoscope tube (Bryan Co., Woburn, MA, USA) (14,15). Depending on the subtype of tracheal stenosis and the general health status of the patient, individualized intervention techniques were designed, such as mechanical dilation, balloon dilation, laser therapy, and insertion of a silicone stent, as previously reported (10,16-18). When localized dense fibrosis was observed, a laser was used to cut the fibrotic band. When mechanical dilation or laser treatment did not satisfactorily preserve airway patency, airway stents were implanted using the standard technique described by Dumon (19). A stent of the appropriate size was folded longitudinally, introduced into a stent pusher (Bryan Corp., Woburn, MA, USA), and properly repositioned using alligator forceps. If the stent did not fully expand, balloon dilation was performed (20).

Patients could usually return to normal activity 1 to 3 days after the procedure and underwent simple chest radiography and spirometry at 1, 3, 6, 9, and 12 months after procedures to evaluate each patient's condition. Bronchoscopy and chest CT were performed when needed to reassess stent location and airway patency. Stent removal was planned when the patients had exhibited stable conditions for 1 year and when air pockets were confirmed on CT. An air pocket was defined as tracheobronchial air columns in the space between the outer surface of the stent and the adjacent airway wall (21). If restenosis or malacia developed, stent insertion was repeated. If the procedures were ineffective, surgical resection and anastomosis or permanent tracheostomy was considered.

Stents

The types of airway silicone stents used during the study period included the Natural stent (M1S Co., Seoul, Korea), the DUMON stent (Novatech, La Ciotat, France), and the Montgomery T-tube (Koken, Tokyo, Japan). The Natural stent is a silicone stent developed at the Samsung Medical Center in 2002. Studies in a canine model of tracheal stenosis and clinical studies in patients with benign tracheobronchial stenosis have shown that the Natural stent is as effective and safe as the Dumon stent (22,23). However, the production of Natural stents ceased due to commercial issues. Dumon stents have been commercially available for medical use since 2015. Montgomery T-tubes were used in patients with high probability of mucostasis or with tracheal stenosis close to the glottis (24,25). External fixation with unabsorbable nylon was performed in patients treated with DUMON or Natural stents.

Data collection

Demographic data, stenosis characteristics, and clinical outcomes were obtained as in our previous study (10). In short, poor performance was defined as an Eastern Cooperative Oncology Group (ECOG) grade ≥3, which means the patient is confined to bed or a chair more than 50% of their waking hours (26). The degree of tracheal stenosis was determined according to the Myer-Cotton stenosis grading system (27). In this study, respiratory failure requiring intubation or emergent tracheostomy before interventional bronchoscopy was considered grade IV. Final success was assessed by two methods: (I) the "successful removal of tracheostomy tube" group included patients who maintained airway patency without disease-related or procedure-related mortality or surgical management and could have the tracheostomy tube removed, and (II) the "successful removal of airway prosthesis" group included patients whose airway patency was maintained without an airway stent.

Statistical analyses

All results are presented as median and interquartile range (IQR) or numbers (percentages). Continuous variables are compared using the Mann-Whitney U test. Categorical variables are compared using Pearson's chi-square test or Fisher's exact test. Forced expiratory volume in one second (FEV_1) before and after the procedure was compared using the Wilcoxon signed rank test. To identify risk factors independently associated with clinical outcomes, we conducted multivariate analyses using logistic regression models with backward selection. Statistical differences were considered significant at $P<0.05$. All analyses were performed using SPSS software (IBM SPSS Statistics ver. 22, Chicago, IL, USA).

Results

Baseline characteristics

Of the total 99 patients with PTTS, the median patient age was 58 years, 52.5% of patients were male, and 62.6% of patients had poor performance status (*Table 1* and *Table S1*). There were no statistically significant differences in demographic data between groups except for body mass index (BMI). BMI was lower in patients with cuff or tip

Table 1 Baseline characteristics

Variables	Total (n=99)	Subglottic or stoma type (n=59)	Cuff or tip type (n=40)	P value
Age (years)	58 (44–70)	58 (49–70)	55 (33–70)	0.269
Male	52 (52.5)	33 (55.9)	19 (47.5)	0.421
Body mass index (kg/m^2)	21.4 (19.2–23.2)	21.7 (20.0–23.6)	20.7 (17.8–22.4)	0.042
Poor performance status*	62 (62.6)	34 (57.6)	28 (70.0)	0.290
Reason for tracheostomy				
Medical	72 (72.7)	46 (78.0)	26 (65.0)	0.174
Neurological disease	35 (35.3)	19 (32.2)	16 (40.0)	0.521
Respiratory failure	19 (19.2)	14 (23.7)	5 (12.5)	0.200
Heart failure	9 (9.1)	6 (10.2)	3 (7.5)	0.736
Septic shock	3 (3.0)	3 (5.1)	0	0.270
Burn	3 (3.0)	2 (3.4)	1 (2.5)	1.000
Drug intoxication	2 (2.0)	1 (1.7)	1 (2.5)	1.000
Obesity	1 (1.0)	1 (1.7)	0	1.000
Trauma	27 (27.3)	13 (22.0)	14 (35.0)	0.174
Previous treatment history at another hospital	26 (26.3)†	13 (22.0)	13 (32.5)	0.256
Severity of tracheal stenosis (Myer and Cotton grade‡)				0.660
I	5 (5.0)	3 (5.1)	2 (5.0)	
II	10 (10.1)	5 (8.5)	5 (12.5)	
III	9 (9.1)	7 (11.9)	2 (5.0)	
IV	75 (75.8)	44 (74.6)	31 (77.5)	
Length of stenosis (mm)	25 (19–35)	27 (20–35)	25 (15–38)	0.640
Stenosis types				
Fibrosis	74 (74.7)	48 (81.4)	26 (65.0)	0.098
Granulation	56 (56.6)	33 (55.9)	23 (57.5)	1.000
Malacia	20 (20.2)	11 (18.6)	9 (22.5)	0.799
Mixed	48 (48.5)	32 (54.2)	16 (40.0)	0.219

Data are presented as n (%) or median (IQR). *, Eastern Cooperative Oncology Group (ECOG) performance grade ≥3 means patients were confined to a bed or chair more than 50% of the day; ‡, categorization based on the percentage of reduction in cross-sectional area: grade 1, ≤50% lumenal stenosis; grade II, 51–70% lumenal stenosis; grade III, 71–99% lumenal stenosis; grade IV, no lumen, intubation or tracheostomy state due to respiratory failure before interventional bronchoscopy; †, in patients with subglottic or stoma type, Montgomery T-tube (n=5), surgical correction (n=4), ballooning (n=3), and laser therapy (n=3) were undergone at previous hospital. In patients with cuff or tip type, Montgomery T-tube (n=6), surgical correction (n=5), metallic stent (n=3), ballooning (n=2), and laser therapy (n=2) were undergone at previous hospital. Patients could undergo more than one procedure at previous hospital. IQR, interquartile range.

type stenosis than in those with subglottic or stoma type stenosis (20.7 *vs.* 21.7 kg/m^2, P=0.042). Most patients (72.7%) underwent tracheostomy due to medical problems such as neurologic disease (35.3%) and respiratory failure (19.2%). Of the total 99 patients, 26 (26.3%) were referred to our hospital after failed surgical correction (n=9) and/or interventional bronchoscopy with stent insertion [Montgomery T-tube (n=11) or metal stents (n=3)], balloon

Table 2 Treatment modalities

Variables	Total (n=99)	Subglottic or stoma type (n=59)	Cuff or tip type (n=40)	P value
Time interval (months)				
From injury to detection	4.0 (2.0–7.8)	3.8 (1.7–7.0)	4.1 (2.3–15.9)	0.160
From detection to intervention	0.9 (0.3–3.0)	0.8 (0.3–2.9)	1.1 (0.3–3.3)	0.841
Treatment modalities*				
Silicone stent	67 (67.7)	45 (76.3)	22 (55.0)	0.031
Natural or DUMON stent	50 (50.5)	35 (59.3)	15 (37.5)	0.041
Montgomery T-tube	17 (17.2)	10 (16.9)	7 (17.5)	1.000
Laser	20 (20.2)	11 (18.6)	9 (22.5)	0.799
Ballooning	9 (9.1)	5 (8.5)	4 (10.0)	1.000
Number of interventional bronchoscopies	2 (1–3)	2 (1–3)	2 (1–3)	0.918

Data are presented as n (%) or median (IQR). *, patients could undergo more than one procedure. IQR, interquartile range.

dilation (n=5), and/or laser cauterization (n=5).

Characteristics of the stenosis site were similar between groups (*Table 1* and *Table S1*). Most patients (84.8%) had tracheal stenosis of grade III or IV. The median length of stenosis was 25 mm (IQR, 19–35 mm). Although the most common type of stenosis was fibrosis (74.7%), mixed stenosis was also common (48.5%).

Treatment modalities

Among 99 patients with PTTS, the median time interval from tracheostomy injury to stenosis detection was 4.0 months and from stenosis detection to bronchoscopic intervention was 0.9 months (*Table 2* and *Table S2*). Bronchoscopic interventions were usually performed using a combination of each treatment modality, including stent insertion, laser cauterization, and ballooning. Silicone stent insertion was required more often in patients with subglottic or stoma type stenosis (45/59, 76.3%) than in those with cuff or tip type stenosis (22/40, 55.0%; P=0.031). The frequency of use of Montgomery T-tubes did not differ between groups, but Natural or DUMON stents were more frequently needed in patients with subglottic or stoma type stenosis (35/59, 59.3%) than those with cuff or tip type stenosis (15/40, 37.5%; P=0.041). Each patient underwent a median of two procedures during their treatment course.

Complications and clinical outcomes

The clinical courses of patients with PTTS are shown in *Figure 2*, and the clinical outcomes are shown in *Table 3* and *Table S3*. Acute complications associated with procedures occurred in some patients, including vocal cord dysfunction (n=3), respiratory distress (n=3), and excessive bleeding (n=2). Although chronic complications including granulation tissue overgrowth (43.4%), mucostasis (41.4%), stent migration (33.3%), and restenosis (23.5%) were common, most cases with complications were manageable after additional procedures. There were no significant differences in the complication rates between the two groups. Of the total 99 patients with PTTS, only 20 (20.2%) were able to perform the PFT within 1 month before and after their first procedures. After intervention, FEV_1 was significantly increased in patients with PTTS (median, 1.55–1.72 L; P=0.035).

The median duration of follow-up after the first interventional bronchoscopy was 21.0 months (9.0–45.0 months). Finally, permanent tracheostomy was more frequently needed in patients with cuff or tip type stenosis than those with subglottic or stoma type stenosis (50.0% *vs.* 18.6%, P=0.002). However, there were no differences in surgical management and mortality rates between the two groups. During the clinical course, only 6 (10.2%) patients with subglottic or stoma type stenosis and 4 (10.0%) patients with cuff or tip type stenosis were able to maintain airway patency with bronchoscopic intervention without stenting. Successful removal of the tracheostomy tube was significantly more frequent in patients with subglottic or stoma type stenosis than those with cuff or tip type stenosis (71.2% *vs.* 45.0%, P=0.012). In addition,

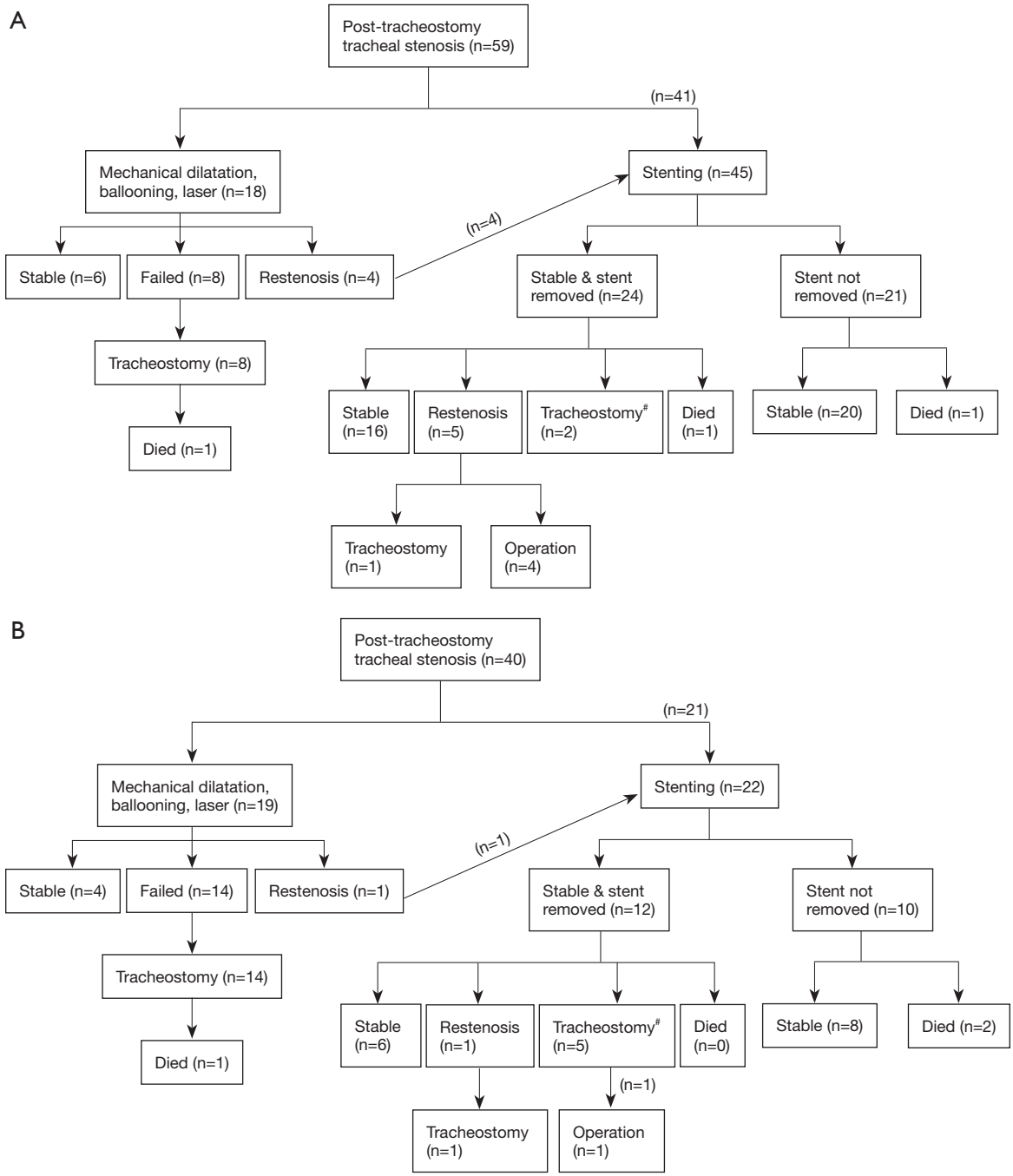

Figure 2 Clinical course of patients with PTTS. (A) Patients with subglottic or stoma type stenosis; (B) patients with cuff or tip type stenosis. #, these patients underwent tracheostomy because of poor expectoration and/or underlying neurological problems. PTTS, post-tracheostomy tracheal stenosis.

Table 3 Complications and clinical outcomes

Variables	Total (n=99)	Subglottic or stoma type (n=59)	Cuff or tip type (n=40)	P value
Acute complications*				
Vocal cord dysfunction	3 (3.0)	3 (5.1)	0	0.270
Respiratory distress	3 (3.0)	2 (3.4)	1 (2.5)	1.000
Excessive bleeding	2 (2.0)	1 (1.7)	1 (2.5)	1.000
Pneumothorax	0	0	0	NA
Chronic complications*				
Granulation tissue overgrowth	43 (43.4)	27 (45.8)	16 (40.0)	0.680
Mucostasis	41 (41.4)	28 (47.5)	13 (32.5)	0.152
Stent migration†	22/67 (33.3)	13/45 (28.9)	9/22 (40.9)	0.409
Restenosis‡	8/34 (23.5)	6/25 (24.0)	2/9 (22.2)	1.000
Duration of follow-up after first treatment (months)	21.0 (9.0–45.0)	23.0 (11.0–52.0)	17.0 (4.5–42.5)	0.142
Duration of follow-up after last treatment (months)	10.0 (1.0–24.0)	12.0 (2.0–26.0)	4.5 (0.3–22.3)	0.080
Clinical outcomes				
Permanent tracheostomy	31 (31.3)	11 (18.6)	20 (50.0)	0.002
Surgical management	5 (5.1)	4 (6.8)	1 (2.5)	0.645
Mortality	6 (6.1)	3 (5.1)	3 (7.5)	0.683
Disease related	4 (4.0)	2 (3.4)	2 (5.0)	1.000
Procedure related	2 (2.0)	1 (1.7)	1 (2.5)	1.000
Successful intervention without stenting	10 (10.1)	6 (10.2)	4 (10.0)	1.000
Duration of follow-up after intervention	23.5 (10.0–55.8)	15.0 (8.3–37.0)	58.5 (17.8–85.0)	0.233
Stent insertion	67 (67.7)	45 (76.3)	22 (55.0)	0.031
Successful stent removal	22/67 (32.8)	16/45 (35.6)	6/22 (27.3)	0.586
Duration of follow-up after stent removal	9.5 (1.0–22.8)	9.5 (1.3–19.0)	6.5 (0–40.8)	0.601
Persistent stent placement	28/67 (41.8)	20/45 (44.4)	8/22 (36.4)	0.604
Duration of stent placement	28.5 (10.5–60.8)	33.0 (12.3–77.3)	22.0 (3.3–33.5)	0.153
Successful removal of tracheostomy tube§	60 (60.6)	42 (71.2)	18 (45.0)	0.012
Successful removal of airway prosthesis¶	32 (32.3)	22 (37.3)	10 (25.0)	0.274

Data are presented as n (%) or median (IQR). *, patients could have more than one complication; †, patients who had a stent inserted were used as the denominator; ‡, patients who have ever been removed stent were denominator; §, patients who survived and maintained airway patency without a tracheostomy tube or surgical management; ¶, patients who survived and maintained airway patency without a tracheostomy tube, silicone stent, or surgical management. NA, not applicable; IQR, interquartile range.

the successful removal of airway prostheses was greater in patients with subglottic or stoma type stenosis than those with cuff or tip type stenosis (37.3% *vs.* 25.0%, P=0.274). However, this difference was not statistically significant.

Predictors related to clinical success

Table 4 shows relationships between patient characteristics and clinical success. Successful removal of the tracheostomy tube was associated with the severity of tracheal stenosis and PTTS type. It was more difficult to remove the tracheostomy tube in patients with stenosis grade IV than those with stenosis grades I–III [adjusted odds ratio (aOR), 0.114; 95% confidence interval (CI), 0.021–0.627; P=0.013]. It was more difficult to remove the tracheostomy tube in patients with cuff or tip type stenosis than those with subglottic or stoma type stenosis (aOR, 0.290; 95% CI, 0.087–0.967; P=0.044). Meanwhile, successful removal of the airway prosthesis was associated with performance status and severity of tracheal stenosis. It was harder to remove the airway prosthesis in patients with poor performance status than in those with good performance status (aOR, 0.226; 95% CI, 0.067–0.763; P=0.017). It was harder to remove the airway prosthesis in patients with stenosis grade IV than those with stenosis grade I–III (aOR, 0.189; 95% CI, 0.052–0.681; P=0.011).

Discussion

To the best of our knowledge, this study is the largest to report the results of interventional bronchoscopy in patients with PTTS and the first to compare types of PTTS. There were no differences between types of PTTS in terms of patient characteristics and features of tracheal stenosis, except for BMI. However, patients with subglottic or stoma type stenosis more frequently required silicone stents and less frequently required permanent tracheostomy to maintain airway patency than those with cuff or tip type stenosis. Finally, patients with subglottic or stoma type stenosis showed more favorable outcomes, measured by the successful removal of the tracheostomy tube and closure of the stoma without surgical intervention or procedure- and disease-related death, than those with cuff or tip type stenosis.

PTTS can be categorized according to the stenosis site and pathophysiology such as subglottic, stoma, cuff, and tip granuloma type (9). Subglottic type can be caused by incorrect needle puncture or incision during the tracheostomy procedure. According to an observation study, PTTS of subglottic type more frequently occurred in patients with percutaneous dilational tracheostomy (PDT) than those with surgical tracheostomy (SGT) [25/105 (23.8%) *vs.* 3/41 (7.3%), P=0.033] (28). Stoma type is associated with inadequate tracheal incision and ongoing stomal infection. These types of damage during tracheostomy procedures may result in abnormal wound healing and excess granulation tissue formation around damaged cartilage (29). In a previous study, stenosis of the stoma site was the most common type in patients with PTTS (30). Cuff type stenosis is caused by ischemic mucosal damage when cuff-to-tracheal wall tension exceeds the mucosa capillary perfusion pressure, usually by 20 to 30 mmHg (31). Risk can be minimized by the use of large-volume and low-pressure cuffs (32). Lastly, tip granuloma type stenosis results from the inappropriate positioning of the tube or excessive recurrent suction (9). Although we have no data regarding detailed tracheostomy procedures and cuff types, subglottic or stoma type PTTS may be more frequently encountered in clinical settings than cuff or tip type stenosis, because PDT and high-volume low-pressure cuffs are more widely used than SGT and low-volume high-pressure cuffs (28,32,33).

Few studies have evaluated the incidence, treatment modalities, and prognosis of each type of PTTS. The present study categorized PTTS into two groups according to similar mechanisms of tracheal stenosis, and then assessed differences in the demographic data, treatment modalities, and clinical outcomes between the two groups. Although there were no differences in baseline characteristics, successful removal of the tracheostomy tube was achieved more frequently in patients with subglottic or stoma type stenosis than those with cuff or tip type stenosis. This finding was supported in a multiple logistic regression model. In addition, classification of PTTS type and stenosis grade were important factors predicting the successful removal of the tracheostomy tube, and performance status was critical for the successful removal of airway prostheses including the tracheostomy tube, Montgomery T-tube, and airway silicone stents.

In present study, stent migration is a common complication. Stent can be migrated more frequently when stent is placed closer to the subglottic area, because movement of the head and neck or coughing tend to induce stent migration (34,35). However, present study did not show an increased incidence of stent migration across each type of PTTS from tip type to subglottic type (Table S3), because we had performed the external fixation with a nylon

Table 4 Patient characteristics associated with clinical success of the procedures

Variables	Successful removal of tracheostomy tube*				Successful removal of airway prosthesis†			
	Univariate analysis		Multivariate analysis		Univariate analysis		Multivariate analysis	
	OR (95% CI)	P value	aOR (95% CI)	P value	OR (95% CI)	P value	aOR (95% CI)	P value
Age (years)	0.989 (0.966–1.012)	0.353	–	–	0.990 (0.967–1.014)	0.417	–	–
Male	0.773 (0.344–1.738)	0.533	–	–	1.036 (0.446–2.409)	0.934	–	–
Body mass index (kg/m^2)	0.993 (0.886–1.112)	0.903	–	–	0.961 (0.854–1.082)	0.513	–	–
Poor performance status‡	0.219 (0.084–0.572)	0.002	0.288 (0.080–1.036)	0.057	0.204 (0.083–0.503)	0.001	0.226 (0.067–0.763)	0.017
Reason for tracheostomy								
Neurological disease	0.800 (0.346–1.852)	0.602	–	–	0.494 (0.193–1.261)	0.140	–	–
Respiratory failure	1.521 (0.525–4.412)	0.440	–	–	0.701 (0.228–2.152)	0.535	–	–
Heart failure	0.795 (0.200–3.166)	0.745	–	–	1.052 (0.246–4.505)	0.946	–	–
Trauma	0.750 (0.306–1.838)	0.529	–	–	1.670 (0.665–4.192)	0.275	–	–
Previous treatment history at another hospital	1.055 (0.421–2.643)	0.910	–	–	0.907 (0.346–2.383)	0.844	–	–
Severity of tracheal stenosis								
Grade I–III	Reference	–	Reference	–	Reference	–	Reference	–
Grade IV	0.093 (0.020–0.425)	0.002	0.114 (0.021–0.627)	0.013	0.136 (0.049–0.373)	<0.001	0.189 (0.052–0.681)	0.011
Length of stenosis (mm)	0.980 (0.950–1.011)	0.205	–	–	0.964 (0.927–1.002)	0.063	–	–
Stenosis types								
Fibrosis	2.000 (0.789–5.010)	0.139	–	–	1.715 (0.610–4.826)	0.307	–	–
Granulation	0.500 (0.217–1.154)	0.104	–	–	0.560 (0.239–1.310)	0.181	–	–
Malacia	0.748 (0.278–2.016)	0.566	–	–	0.455 (0.139–1.495)	0.195	–	–
Mixed	0.701 (0.312–1.575)	0.390	–	–	0.517 (0.218–1.223)	0.133	–	–
PTTS types								
Subglottic or stoma type	Reference	–	Reference	–	Reference	–	Reference	–
Cuff or tip type	0.331 (0.143–0.767)	0.010	0.290 (0.087–0.967)	0.044	0.561 (0.230–1.364)	0.202	0.480 (0.143–1.611)	0.235

*, patients who survived and maintained airway patency without a tracheostomy tube or surgical management; †, patients who survived and maintained airway patency without a tracheostomy tube, silicone stent, or surgical management; ‡, Eastern Cooperative Oncology Group (ECOG) performance grade ≥3 means patients were confined to a bed or chair more than 50% of the day. aOR, adjusted odds ratio; CI, confidence interval; PTTS, post-tracheostomy tracheal stenosis.

thread in the majority of patients with tracheal stenosis. In these 22 patients with stent migration, 32 events of migration were occurred during 53.8 years of the whole period of stent insertion. Arithmetically, migration event was occurred every 1.9 years. Almost cases of migration were occurred after spontaneous cut of thread.

There are several limitations to the present study that should be acknowledged. First, our study was retrospective and conducted at a single institution. In addition, our institution is almost the only hospital to actively perform the rigid bronchoscopy and insertion of silicone stent in Korea. Actually, 26 patients were transferred to our hospital after some treatment for PTTS, 72 patients were transferred to our hospital after confirmation of PTTS without any treatment for PTTS, and only one patient was diagnosed with PTTS in our hospital. There is therefore a possibility that selection bias was present. Second, although the present study is the biggest study of PTTS ever conducted, the number of patients was too small to compare characteristics and outcomes among all four types of PTTS. We therefore only discovered differences between "subglottic or stoma type" stenosis and "cuff or tip type" stenosis. Therefore, further studies are needed to evaluate the characteristics of each type. Third, we failed to obtain detailed information on tracheostomy procedure such as PDT, SGT, and cuff types because of difficulties in obtaining complete medical records. Further studies are needed to characterize stenosis type according to detailed tracheostomy procedures and tracheostomy maintenance methods.

Conclusions

In conclusion, there were no significant differences in baseline characteristics between patients with two different types of PTTS. However, patients with subglottic or stoma type stenosis had more favorable outcomes than those with cuff or tip type stenosis. Therefore, distinguishing between types of PTTS could be important in predicting patient prognosis.

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None.

Footnote

Conflicts of Interests: The authors have no conflicts of interests to declare.

Ethical Statement: This retrospective observational study received Institutional Review Board of Samsung Medical Center approval (IRB No. 2016-08-139). The need for informed consent was waived because patient information was anonymized and de-identified prior to analysis.

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Supplementary

Table S1 Baseline characteristics according to each type

Variables	Subglottic type (n=28)	Stoma type (n=31)	Cuff type (n=18)	Tip type (n=22)
Age (years)	56 (48–65)	63 (49–71)	70 (43–75)	44 (23–61)
Male	17 (60.7)	16 (51.6)	8 (44.4)	11 (50.0)
Body mass index (kg/m^2)	21.7 (20.4–23.8)	21.4 (19.7–23.6)	21.1 (18.1–22.1)	20.3 (17.7–22.9)
Poor performance status*	15 (53.6)	19 (61.3)	12 (66.7)	16 (72.7)
Reason for tracheostomy				
Medical	25 (89.3)	21 (67.7)	13 (72.2)	13 (59.1)
Neurological disease	14 (50.0)	5 (16.1)	10 (55.6)	6 (27.3)
Respiratory failure	6 (21.4)	8 (25.8)	2 (11.1)	3 (13.6)
Heart failure	1 (3.6)	5 (16.1)	1 (5.6)	2 (9.1)
Septic shock	1 (3.6)	2 (6.5)	0	0
Burn	1 (3.6)	1 (3.2)	0	1 (4.5)
Drug intoxication	1 (3.6)	0	0	1 (4.5)
Obesity	1 (3.6)	0	0	0
Trauma	3 (10.7)	10 (32.3)	5 (27.8)	9 (40.9)
Previous treatment history at another hospital	6 (21.4)	7 (22.6)	5 (27.8)	8 (36.4)
Severity of stenosis (Myer and Cotton grade‡)				
I	2 (7.1)	1 (3.2)	0	2 (9.1)
II	2 (7.1)	3 (9.7)	3 (16.7)	2 (9.1)
III	3 (10.7)	4 (12.9)	2 (11.1)	0
IV	21 (75.0)	23 (74.2)	13 (72.2)	18 (81.8)
Length of stenosis (mm)	30 (21–35)	25 (19–30)	31 (20–41)	20 (15–32)
Stenosis type				
Fibrosis	21 (75.0)	27 (87.1)	14 (77.8)	12 (54.5)
Granulation	17 (60.7)	16 (51.6)	8 (44.4)	15 (68.2)
Malacia	5 (17.9)	6 (19.4)	5 (27.8)	4 (18.2)
Mixed	14 (50.0)	18 (58.1)	8 (44.4)	8 (36.4)

Data are presented as n (%) or median (IQR). *, Eastern Cooperative Oncology Group (ECOG) performance grade ≥3 means patients were confined to a bed or chair more than 50% of the day; ‡, categorization based on the percentage of reduction in cross-sectional area: grade 1, ≤50% lumenal stenosis; grade II, 51–70% lumenal stenosis; grade III, 71–99% lumenal stenosis; grade IV, no lumen, intubation or tracheostomy state due to respiratory failure before interventional bronchoscopy. IQR, interquartile range.

Table S2 Treatment modalities according to each type

Variables	Subglottic type (n=28)	Stoma type (n=31)	Cuff type (n=18)	Tip type (n=22)
Time interval (months)				
From injury to detection	4.0 (2.0–9.9)	3.1 (1.7–6.9)	3.5 (1.8–11.7)	5.3 (2.7–18.4)
From detection to intervention	0.7 (0.2–5.5)	0.9 (0.3–2.4)	0.9 (0.3–4.9)	1.1 (0.4–2.7)
Treatment modalities*				
Silicone stent	23 (82.1)	22 (71.0)	10 (55.6)	12 (54.5)
Natural or DUMON stent	18 (64.3)	17 (54.8)	6 (33.3)	9 (40.9)
Montgomery T-tube	5 (17.9)	5 (16.1)	4 (22.2)	3 (13.6)
Laser	8 (28.6)	3 (9.7)	7 (38.9)	2 (9.1)
Ballooning	1 (3.6)	4 (12.9)	2 (11.1)	2 (9.1)
Number of interventional bronchoscopies	2 (1–3)	2 (1–3)	2 (1–4)	2 (1–3)

Data are presented as n (%) or median (IQR). *, patients could undergo more than one procedure. IQR, interquartile range.

Table S3 Complications and clinical outcomes according to each type

Variables	Subglottic type (n=28)	Stoma type (n=31)	Cuff type (n=18)	Tip type (n=22)
Acute complications*				
Vocal cord dysfunction	3 (10.7)	0	0	0
Respiratory distress	1 (3.6)	1 (3.2)	1 (5.6)	0
Excessive bleeding	0	1 (3.2)	1 (5.6)	0
Pneumothorax	0	0	0	0
Chronic complications*				
Granulation tissue overgrowth	15 (53.6)	12 (38.7)	7 (38.9)	9 (40.9)
Mucostasis	15 (53.6)	13 (41.9)	6 (33.3)	7 (31.8)
Stent migration†	9/23 (39.1)	4/22 (18.2)	5/10 (50.0)	4/12 (33.3)
Restenosis‡	3/12 (25.0)	3/13 (23.1)	1/5 (20.0)	1/4 (25.0)
Duration of follow-up after first treatment (months)	29 (11–60)	19 (10–45)	14 (4–33)	21 (8–49)
Duration of follow-up after last treatment (months)	14 (2–34)	10 (2–22)	5 (1–17)	4 (0–27)
Clinical outcomes				
Permanent tracheostomy	3 (10.7)	8 (25.8)	9 (50.0)	11 (50.0)
Surgical management	2 (7.1)	2 (6.5)	1 (5.6)	0
Mortality	1 (3.6)	2 (6.5)	2 (11.1)	1 (4.5)
Disease related	0	2 (6.5)	2 (11.1)	0
Procedure related	1 (3.6)	0	0	1 (4.5)
Successful intervention without stenting	3 (10.7)	3 (9.7)	2 (11.1)	2 (9.1)
Stent insertion	23 (82.1)	22 (71.0)	10 (55.6)	12 (54.5)
Successful stent removal	7/23 (30.4)	9/22 (40.9)	3/10 (30.0)	3/12 (25.0)
Persistent stent placement	12/23 (52.2)	8/22 (36.4)	3/10 (30.0)	5/12 (41.7)
Successful removal of tracheostomy tube§	22 (78.6)	20 (64.5)	8 (44.4)	10 (45.5)
Successful removal of airway prosthesis¶	10 (35.7)	12 (38.7)	5 (27.8)	5 (22.7)

Data are presented as n (%) or median (IQR). *, patients could have more than one complication; †, patients who had a stent inserted were used as the denominator; ‡, patients who have ever been removed stent were denominator; §, patients who survived and maintained airway patency without a tracheostomy tube or surgical management; ¶, patients who survived and maintained airway patency without a tracheostomy tube, silicone stent, or surgical management. IQR, interquartile range.