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Prognostic Factors for Tracheal Restenosis after Stent Removal in Patients with Post-Intubation and Post-Tracheostomy Tracheal Stenosis

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Purpose: Long-term tracheal stent placement can increase the risk of stent-related complications; hence, removal of the stent after stabilization is attempted. However, little evidence has been established regarding the risk factors for tracheal restenosis. We aimed to identify the risk factors for tracheal restenosis in patients with post-intubation tracheal stenosis (PITS) and post-tracheostomy tracheal stenosis (PTTS).

Materials and Methods: We retrospectively analyzed patients with PITS and PTTS between January 2004 and December 2019. Patients were classified into a success or failure group according to treatment outcomes. Patients with successful stent removal were defined as patients who did not require additional intervention after stent removal during the follow-up period. Multiple logistic regression analysis was performed to identify the factors associated with tracheal restenosis.

Results: Among 269 stented patients, 130 patients who had removed the stent were enrolled in this study. During the follow-up period, 73 (56.2%) patients had a stable clinical course; however, 57 (43.8%) patients had restenosis. The proportion of trauma-induced intubation was higher in the success group than in the failure group (p=0.026), and the median stent length was shorter in the success group (45 mm) than in the failure group (50 mm, p=0.001). On multivariate analysis, trauma-induced intubation [adjusted odds ratio (aOR), 0.329; 95% confidence interval (CI), 0.117–0.927; p=0.036], and stent length <50 mm (aOR, 0.274; 95% CI, 0.130–0.578; p=0.001) were associated with a decreased risk of restenosis.

Conclusion: Trauma-induced intubation and stent length were associated with successful stent removal.

Key Words: Airway stents, interventional bronchoscopy, post-intubation tracheal stenosis, post-tracheostomy tracheal stenosis, tracheal restenosis

INTRODUCTION

Endotracheal intubation and tracheostomy are the most common causes of benign acquired tracheal stenosis.[1] Post-intubation tracheal stenosis (PITS) can be caused by high-volume, high-pressure cuffs leading to mucosal and pressure injuries.[2,3] Post-tracheostomy tracheal stenosis (PTTS) occurs due to an abnormal wound healing process accompanied by the formation of excessive granulation tissue in the stoma after tracheostomy, which is presumed to be related to inflammation and/or infection of the stoma and cartilage damage during tracheostomy.[4] The reported prevalence of tracheal stenosis after intubation varies from 6% to 21%,[5-7] and the estimated incidence of tracheal stenosis in the general population is 4.9 cases per million per year.[8]

The generally preferred treatment for PITS and PTTS is surgical management, such as tracheal resection and end-to-end anastomosis.[7] However, some patients are unable to undergo surgical procedures due to underlying diseases. In such pa-

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tients, bronchoscopic intervention is considered as an alternative to surgical management. Endoscopic techniques for the management of tracheal stenosis include mechanical or balloon dilatation, laser ablation therapy, and endotracheal stent insertion.[9] Tracheal stenting is indicated when airway patency cannot be preserved despite other endoscopic therapeutic techniques. However, long-term stent placement can increase the risk of stent-related late complications, such as mucostasis, granulation tissue formation, and stent migration.[10,11] Therefore, after maintaining the stent for a certain period, stent removal is attempted in patients who are expected to maintain airway patency. Our previous studies have demonstrated that the success rate of tracheal stenting is approximately 40%.[12-14] However, approximately 60% of patients require repeated endoscopic intervention and/or surgical treatment. Furthermore, prognostic factors for post-tuberculous bronchial stenosis (PTBS) after stent removal have been reported in several studies[15-17]; however, to date, prognostic factors for tracheal stenosis in PITS/PTTS patients after stent removal have not been well elucidated. In actual clinical practice, tracheal stenosis is more likely to cause respiratory failure due to central airway obstruction. Therefore, it is important to predict which patients are at a high risk of restenosis before considering stent removal in patients with tracheal stenosis. Accordingly, we attempted to identify potential risk factors for tracheal restenosis after stent removal in patients with PITS and PTTS.

MATERIALS AND METHODS

Patients

We retrospectively reviewed all patients with airway stenosis who underwent rigid bronchoscopy between January 2004 and December 2019 at Samsung Medical Center, which is a 1979-bed referral hospital and performs the most rigid bronchoscopic interventions in South Korea. The Institutional Review Board of Samsung Medical Center approved the collection, analysis, and publication of the data (IRB No. 2021-07-130). The requirement for informed consent was waived due to the retrospective nature of the study.

Airway intervention techniques, follow-up and removal of the stent

The airway anatomy was evaluated using chest radiography, computed tomography (CT), and flexible bronchoscopy. Airway interventions were performed according to standard techniques.[9,18] After induction of general anesthesia and intubation with a rigid bronchoscope tube (Bryan Co.,Woburn, MA, USA), a flexible bronchoscope (BF 1T260 Olympus Corporation, Tokyo, Japan) was introduced through the rigid bronchoscope tube to examine airway stenosis. Various combinations of airway intervention techniques (mechanical dilatation, balloon dilatation, laser, and silicone stent insertion) were used depending on the characteristics and subtype of tracheal stenosis as well as the patient's medical condition.

Airway stent insertion was considered when laser treatment or mechanical dilatation did not satisfactorily maintain airway patency in the patient. It was implanted using the standard technique described by Dumon.[19] The appropriate stent size was determined by an interventionist by measuring the actual length of stenosis through the scale mark of the flexible bronchoscope. During the study period, three types of silicone stents were used for the treatment of tracheal stenosis: Natural stent (M1S Co. Seoul, South Korea), Dumon stent (Novatech, La Ciotat, France), and Montgomery T-tube (Koken, Tokyo, Japan). Natural stent was developed at the Samsung Medical Center in 2002 and was used for the treatment of benign tracheobronchial stenosis. Studies in a canine model of tracheal stenosis and in patients with benign tracheobronchial stenosis have demonstrated that the Natural stent is as effective and safe as the Dumon stent.[20,21] However, since 2015, the production of Natural stent has been suspended due to commercial issues, and Dumon stents have been mainly used in clinical practice. A Montgomery T-tube was considered in patients with a high risk of mucostasis or tracheal stenosis close to the glottis.[22,23]

Following stent placement, patients underwent simple chest radiography and spirometry for evaluation of their condition at 1, 3, 6, 9, and 12 months after the intervention. We used bronchoscopy and chest CT to reevaluate the stent location and airway patency if the patients complained of respiratory symptoms and had abnormal findings on chest radiography or before planning their stent removal. Stent removal was generally considered when the patients maintained the stent in a stable condition for more than 6 months and air pockets were detected on chest CT. To confirm a stable condition after stent removal, follow-up was performed at least once within 1 month after removal.

If symptoms and signs of airway stenosis developed after removal of the tracheal stent, interventional bronchoscopy and/or stent insertion were repeated in the patient. Surgical management or permanent tracheostomy was performed in patients with ineffective or intolerable tracheal stents.

Data collection and clinical outcome

We collected data from the study population including demographics, etiology, characteristics of tracheal stenosis, stent duration, and additional interventional and radiologic data before stent removal. We used the American Society of Anesthesiologists (ASA) physical status classification to evaluate the individual performance status.[24] An ASA physical status ≥3 was considered a poor performance status. To evaluate the severity of tracheal stenosis, we used the Myer–Cotton stenosis grading system.[25]

We measured the air pocket length, air pocket score, and air pocket density on CT scans before removal of the stent. Based on a previous study,[17] an air pocket was defined as a tracheo-

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bronchial air column in the space between the outer surface of the stent and the adjacent airway wall. The air pocket score was calculated as the summation of the number of quadrants containing air pockets in all CT sections extending from the proximal to the distal end of the stent. In addition, we introduced the concept of air pocket density, which is defined as the value obtained after dividing the air pocket score by the stent length.

Clinical outcomes were evaluated during the follow-up period after stent removal. Patients were divided into two groups according to treatment outcomes: success and failure. The success group comprised patients whose airway patency was maintained without an airway prosthesis during the follow-up period, and the failure group comprised patients with recurrence of symptoms and signs of tracheal stenosis during the follow-up period that required additional endoscopic intervention. Patients with successful stent removal were defined as those who did not require additional intervention after stent removal during the follow-up period.

Statistical analysis

SPSS software (IBM SPSS statistics version 27, IBM Corp., Armonk, NY, USA) was used for all statistical analyses. Data are presented as number (%) or interquartile range (IQR). Categorical variables were compared using Pearson's chi-square test or Fisher's exact test. Continuous variables were compared using Mann-Whitney U test. Multivariate logistic regression analysis with backward stepwise selection was performed to determine the risk factors for tracheal restenosis after stent removal. Statistical significance was set at $p<0.05$.

RESULTS

The overall clinical course of the study population is summarized in Fig. 1. During the study period, 357 patients were diagnosed with PITS (n=215) and PTTS (n=142). In 269 of the 357 patients who received stents for tracheal stenosis, stent removal was performed in 143 patients. After excluding 13 patients who were not followed up after stent removal, a total of 130 patients were enrolled in the study. Of the 130 patients, 73 (56.2%) had a stable clinical course after removal of the tracheal stent. However, 57 (43.8%) patients underwent re-intervention for restenosis. Most restenosis cases (88%) developed within 3 months of stent removal. Fig. 2 shows representative cases of success and failure of tracheal stent removal in patients with PITS/PTTS.

Baseline characteristics

The median age was 56 years (IQR, 45–66), and 64 (49.2%) patients were male (Table 1). Ninety-eight (75.4%) patients were intubated for medical reasons, while 32 (24.6%) patients were intubated for surgical reasons. No significant difference was found in baseline characteristics between the two groups except for the proportion of patients who underwent trauma-induced endotracheal intubation, which was more frequent in the successful group than in the failure group (26.0% vs. 10.5%, $p=0.026$). Due to dyspnea, only 58 (44.6%) of the patients were able to perform the pulmonary function test. The median forced expiratory volume in 1 second was 54% of the predicted value (IQR, 34–71), and the median forced vital capacity was 82% of the predicted value (IQR, 68–92).

Characteristics of tracheal stenosis

Among the study population, the number of patients with PITS and PTTS was 93 (71.5%) and 37 (28.5%), respectively (Table 2).

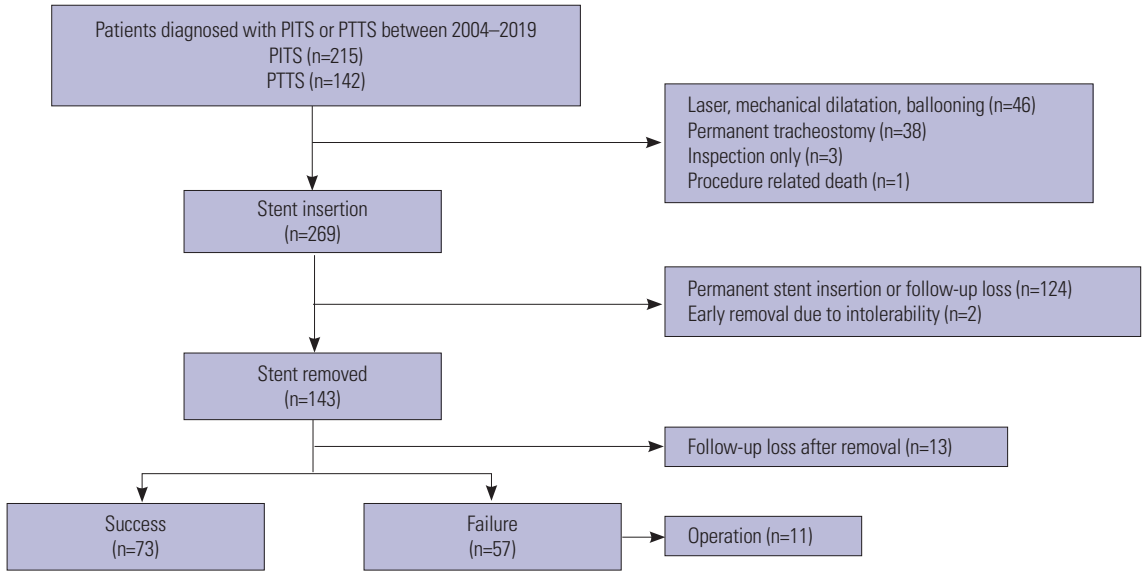

Fig. 1. Clinical course of patients with PITS and PTTS. PITS, post-intubation tracheal stenosis; PTTS, post-tracheostomy tracheal stenosis.

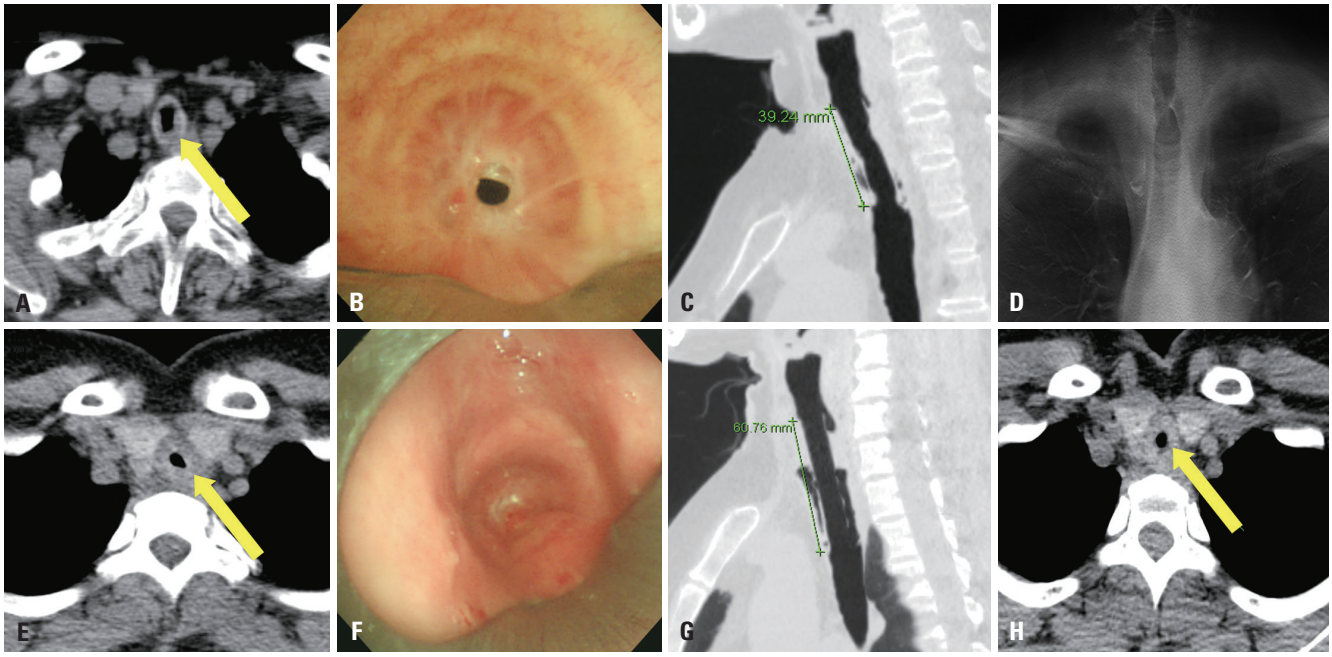

Fig. 2. Representative cases of success (A–D) and failure (E–H) of tracheal stent removal. (A–D) A 56-year-old female patient underwent intubation for 10 days due to subarachnoid hemorrhage. Two months later, she complained of dyspnea. (A) CT scan showing tracheal stenosis at the level of the thoracic inlet (arrow). (B) Bronchoscopic findings of tracheal stenosis. A 40-mm tracheal stent was inserted and maintained for 19 months. (C) CT scan before stent removal. (D) Chest radiograph obtained 1 year after stent removal. During the 1-year follow-up period after stent removal, the patient remained stable without restenosis. (E–F) A 46-year-old female patient underwent intubation for 3 weeks due to epilepsy. She complained of dyspnea 2 weeks after extubation. (E) CT scan showing stenosis of the upper trachea (arrow). The patient underwent an emergency tracheostomy for tracheal stenosis (arrow). (F) Bronchoscopy shows a near-complete obstruction of the trachea above the stoma. A 60-mm tracheal stent was inserted and maintained for 2 years. (G) CT scan before stent removal. Ten days after stent removal, the patient complained of dyspnea again and (H) the CT scan showed tracheal restenosis (arrow). CT, computed tomography.

The median length of the stenosis was 30 mm (IQR, 25–35 mm). The location, severity, and length of stenosis were similar between the two groups. Among the stenosis types, granulation was more frequently observed in the failure group than in the success group (28.1% vs. 12.3%, p=0.024). Forty-one (31.5%) patients suffered from respiratory failure due to tracheal stenosis. Owing to respiratory failure in patients, intubation (n=17), emergency tracheostomy (n=23), and extracorporeal membrane oxygenation (n=2) were performed before interventional bronchoscopy. The median duration of intubation and tracheostomy was 10 days (IQR, 7–15) and 60 days (IQR, 35–116), respectively.

Treatment modalities and characteristics of stent

Natural stents were most commonly used in the patients (91/130, 70.0%) (Table 3). The median stent length was 45 mm (IQR, 40–50 mm). Compared to the failure group, the success group had a shorter stent length (45 mm vs. 50 mm, p=0.001). The proportion of patients with a stent length <50 mm was higher in the success group than in the failure group (64.4% vs. 33.3%, p<0.001). The duration of stenting did not differ between the two groups. The median duration of overall stent placement for each group was 454 days (IQR, 246–890 days) in the success group and 436 days (IQR, 240–811 days) in the failure group. Eighty-one (62.8%) patients maintained the stent for more than 12 months. Before stent removal, 45 (34.6%) patients underwent additional interventional bronchoscopy. In most of the patients, the stent was removed after confirming the presence of air pockets (106/130, 81.5%). There was no difference between the success (8/57, 14.0%) and failure (16/73, 21.9%) groups in the proportion of patients whose air pockets could not be identified due to the lack of available CT scans before stent removal (p=0.267).

The median air pocket length, air pocket score, and median value of air pocket density were 32.5 mm (IQR, 27.5–40.0), 26 (IQR 20–36), and 0.57 (IQR 0.38–0.80), respectively. None of these air pocket indices showed a statistically significant difference between the two groups.

Clinical outcomes and prognostic factors for tracheal restenosis

Tracheal restenosis occurred in 57 (43.8%) patients after stent removal during the follow-up period. The median time-to-restenosis was 20 days (IQR, 13–39). Eleven of the 57 patients (19.3%) could not tolerate the stent, which eventually led to surgical intervention. In patients who underwent intubation due to a traumatic event, the risk of tracheal restenosis was lower than other causes of intubation or tracheostomy [adjusted odds ratio (aOR), 0.329; 95% confidence interval (CI), 0.117–0.927; p=0.036], and a stent length <50 mm was associated

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Table 1. Baseline Characteristics of the Two Groups

	Total (n=130)	Success (n=73)	Failure (n=57)	*p* value
Age, yr	56 (45–66)	54 (45–70)	58 (45–64)	0.877
Sex, male	64 (49.2)	39 (53.4)	25 (43.9)	0.279
BMI, kg/m^2	22.9 (20.4–25.5)	22.6 (20.4–25.9)	23.1 (20.4–25.3)	0.827
Comorbidities				
DM	39 (30.0)	20 (27.4)	19 (33.0)	0.464
Neurologic sequelae	35 (26.9)	22 (30.1)	13 (22.8)	0.350
Cardiovascular disease	29 (22.3)	15 (20.5)	14 (24.6)	0.585
Chronic lung disease	15 (11.5)	7 (9.6)	8 (14.0)	0.431
Cause of intubation or tracheostomy				
Medical	98 (75.4)	52 (71.2)	46 (80.7)	0.214
Respiratory failure	26 (20.0)	16 (21.9)	10 (17.5)	0.536
Neurologic disease	26 (20.0)	12 (16.4)	14 (24.6)	0.251
Cardiovascular disease	21 (16.2)	11 (15.1)	10 (17.5)	0.704
Drug intoxication	12 (9.2)	6 (8.2)	6 (10.5)	0.652
Septic shock	10 (7.7)	5 (6.8)	5 (8.8)	0.748
Other*	3 (2.3)	2 (2.7)	1 (1.8)	>0.999
Surgical	32 (24.6)	21 (28.8)	11 (19.3)	0.214
Trauma	25 (19.2)	19 (26.0)	6 (10.5)	0.026
Postoperative	7 (5.4)	2 (2.7)	5 (8.8)	0.239
ASA physical status ≥3†	51 (39.2)	30 (41.1)	21 (36.8)	0.622
Baseline spirometry (n=58)‡				
FEV_1, % predicted	54 (34–71)	51 (30–70)	61 (43–72)	0.375
FVC, % predicted	82 (68–92)	85 (65–96)	78 (68–90)	0.332

BMI, body mass index; DM, diabetes mellitus; ASA, American Society of Anesthesiologists; FEV_1, forced expiratory volume in 1 s; FVC, forced vital capacity; COPD, chronic obstructive pulmonary disease.
Data are presented as n (%) or median (interquartile range).
*Diabetic ketoacidosis, hypoglycemia, and obesity; †ASA physical status 3 indicates patients with severe systemic disease (e.g., poorly controlled DM or hypertension, COPD); ‡Spirometry before stent insertion was available for 58 patients.

with a decreased risk of tracheal restenosis (aOR 0.274; 95% CI 0.130–0.578; p=0.001) (Table 4).

DISCUSSION

We compared the differences between the groups that successfully maintained and failed to maintain airway patency after stent removal and tried to identify the prognostic factors for restenosis in patients with PITS and PTTS. In our study population, 56% of the patients had successful stent removal without restenosis. We showed that trauma-induced intubation and stent length <50 mm were good prognostic factors for tracheal restenosis. The presence of an air pocket and duration of stent did not show a significant association with restenosis in PITS and PTTS patients, which had been reported as prognostic factors in patients with PTBS.[17,26] To the best of our knowledge, this is the largest study to demonstrate the outcomes of tracheal stenting in patients with PITS and PTTS who were managed with silicone stents. The restenosis rate after stent removal was 44%, which was within the range of 19%–70% for restenosis rate reported in previous studies.[12-14,27,28]

In the present study, the most common cause of trauma (80%) that required tracheal intubation was brain injury after traumatic events. Therefore, when inferred from the multivariate results, we can suspect that the prognosis of traumatic brain injury is better than that of non-traumatic brain injury, such as stroke, epilepsy, and other medical problems, in patients with tracheal stents. This result was consistent with previous research suggesting that patients with traumatic brain injury show greater functional improvement than those with non-traumatic brain injury,[29] and successful removal of airway prosthesis is correlated with performance status.[13]

Our study demonstrated that the length of the tracheal stent (≥50 mm) was more correlated with tracheal restenosis than the length of the tracheal stenosis measured by imaging. The actual length of the stent is determined by bronchoscopy, which extends 1 cm beyond the proximal and distal margins of the stenosis. However, there are some limitations in the evaluation of stenosis by imaging. First, it is difficult to evaluate the exact start and endpoints of tracheal stenosis using only images. Second, since it is difficult for a patient with severe dyspnea to undergo a CT scan in the full inspiration state, the length of the stenosis may be overestimated when the image is taken in the

expiration state. Therefore, we believe that the length of the stent determined during the procedure better reflects the actual length of stenosis and has a meaningful result associated with restenosis. Furthermore, the tracheal stent is a foreign body, and a longer stent length results in an increased area of tracheal mucosal irritation and inflammation, leading to greater gran-

Table 2. Characteristics of Tracheal Stenosis

	Total (n=130)	Success (n=73)	Failure (n=57)	*p* value
Etiology of tracheal stenosis				0.207
Post-intubation	93 (71.5)	49 (52.7)	44 (46.7)	
Post-tracheostomy	37 (28.5)	24 (64.9)	13 (35.1)	
Location of stenosis				0.904
Subglottis to upper trachea	101 (77.7)	57 (78.1)	44 (77.2)	
Mid to lower trachea	29 (22.3)	16 (21.9)	13 (22.8)	
Severity of stenosis* (myer-cotton grade)				0.570†
I	6 (4.6)	4 (5.5)	2 (3.5)	
II	34 (26.2)	18 (24.7)	16 (28.1)	
III	86 (66.2)	50 (68.5)	36 (63.2)	
IV	4 (3.1)	1 (1.4)	3 (5.3)	
Length of stenosis, mm	30 (25–35)	30 (26–35)	29 (25–35)	0.886
Stenosis type‡				
Fibrosis	112 (86.2)	64 (87.7)	48 (84.2)	0.571
Granulation	25 (19.2)	9 (12.3)	16 (28.1)	0.024
Malacia	10 (7.7)	8 (11.0)	2 (3.5)	0.184
Mixed	17 (13.1)	8 (11.0)	9 (15.8)	0.418
Respiratory failure before intervention§	41 (31.5)	18 (24.7)	23 (40.4)	0.056
Intubation duration, day (n=92)¶	10 (7–15)	10 (7–15)	11 (7–17)	0.575
Tracheostomy duration, day (n=35)‖	60 (35–116)	47 (27–104)	66 (46–217)	0.170
Time interval of injury to stenosis, day	62 (38–107)	65 (38–115)	61 (39–96)	0.620
PITS	52 (36–87)	51 (36–85)	54 (36–89)	0.936
PTTS	93 (61–387)	107 (65–384)	78 (61–390)	0.484

PITS, post-intubation tracheal stenosis; PTTS, post-tracheostomy tracheal stenosis; ECMO, extracorporeal membrane oxygenation.
Data are presented as n (%) or median (interquartile range).
*Categorization based on the percentage reduction in cross-sectional area Grade I, ≤50% luminal stenosis; Grade II, 51%–70% luminal stenosis; Grade III, 71%–99% luminal stenosis; and Grade IV, no lumen; †*p* for trend=0.683; ‡Patients (n=17) had more than one type of stenosis; §Intubation (n=17), tracheostomy (n=23), ECMO (n=2) state before interventional bronchoscopy; ¶Missing value=38; ‖Missing value=2.

Table 3. Treatment Modalities and Characteristics of Stent

	Total (n=130)	Success (n=73)	Failure (n=57)	*p* value
Stent type				
Natural stent	91 (70.0)	51 (69.9)	40 (70.2)	0.969
Dumon stent	35 (26.9)	21 (28.8)	14 (24.6)	0.592
Montgomery t-tube	3 (2.3)	1 (1.4)	2 (5.3)	0.319
Stent length, mm	45 (40–50)	45 (40–50)	50 (43–50)	0.001
Stent length <50 mm	66 (50.8)	47 (64.4)	19 (33.3)	<0.001
Duration of stenting, day	448 (253–833)	454 (246–890)	436 (240–811)	0.583
Duration of stent >1 year	81 (62.8)	46 (63.0)	35 (61.4)	0.851
Duration of stent >18 months	54 (41.5)	31 (42.5)	23 (40.4)	0.808
Additional intervention before stent removal*	45 (34.6)	22 (30.1)	23 (40.4)	0.225
Air pocket in CT before stent removal (n=106)†				
Air pocket length, mm	32.5 (27.5–40.0)	34.0 (27.8–41.0)	32.5 (26.3–37.5)	0.345
Air pocket score	26 (20–36)	25 (20–35)	26 (20–35)	0.522
Air pocket density‡	0.57 (0.38–0.80)	0.56 (0.39–0.87)	0.58 (0.38–0.73)	0.235

Data are presented as n (%) or median (interquartile range).
*Reasons for additional interventions included stent migration (n=25), granulation tissue overgrowth (n=16), additional stenosis (n=8), mucostasis (n=3), and malacia (n=2). Nine patients had more than one reason; †24 patients did not have available CT scans before stent removal; ‡Air pocket score/stent length.

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Table 4. Factors associated with Tracheal Restenosis after Stent Removal

	Univariate analysis		Multivariate analysis	
	OR (95% CI)	*p* value	aOR (95% CI)	*p* value
Age	1.000 (0.980–1.020)	0.992	-	-
Sex, male	0.680 (0.339–1.367)	0.280	-	-
BMI	0.986 (0.907–1.072)	0.747	-	-
Comorbidities				
DM	1.325 (0.624–2.815)	0.464	-	-
Neurologic sequelae	0.685 (0.309–1.517)	0.351	-	-
Cardiovascular disease	1.259 (0.550–2.882)	0.586	-	-
Chronic lung disease	1.539 (0.523–4.531)	0.434	-	-
Cause of intubation or tracheostomy				
Respiratory failure	0.758 (0.315–1.826)	0.537	-	-
Neurologic disease	1.655 (0.697–3.928)	0.253	-	-
Cardiovascular disease	1.199 (0.470–3.059)	0.704	-	-
Trauma	0.334 (0.124–0.904)	0.031	0.329 (0.117–0.927)	0.036
ASA physical status ≥3	0.836 (0.410–1.704)	0.622	-	-
Etiology of tracheal stenosis				
Post-intubation	Reference	-	Reference	-
Post-tracheostomy	0.665 (0.306–1.444)	0.302	-	-
Location of stenosis				
Subglottis to upper trachea	Reference	-	Reference	-
Mid to lower trachea	1.053 (0.459–2.416)	0.904	-	-
Severity of stenosis				
Grade I–II	Reference	-	Reference	-
Grade III–IV	0.935 (0.442–1.978)	0.860	-	-
Length of stenosis	1.015 (0.961–1.072)	0.592	-	-
Stenosis type				
Fibrosis	0.750 (0.277–2.032)	0.572	-	-
Granulation	2.775 (1.122–6.866)	0.027	-	-
Malacia	0.295 (0.060–1.450)	0.133	-	-
Mixed	1.523 (0.548–4.237)	0.420	-	-
Respiratory failure before intervention	2.067 (0.976–4.378)	0.058	-	-
Stent length <50 mm	0.277 (0.133–0.574)	<0.001	0.274 (0.130–0.578)	0.001
Duration of stent >1 year	0.934 (0.457–1.907)	0.934	-	-
Additional intervention before stent removal	1.568 (0.757–3.248)	0.226	-	-

BMI, body mass index; DM, diabetes mellitus; ASA, American Society of Anesthesiologists; aOR, adjusted odds ratio; CI, confidence interval.

ulation tissue formation and fibrosis. A previous study showed that there is a direct correlation between mucus plugging and granulation tissue formation when the length of the stent was over 60 mm in patients with malignant airway lesions.[30] Another study reported that tracheal stenosis >30 mm was associated with a reduced chance of procedural success.[31] Eventually, seven of the patients who had a stent ≥50 mm in our study underwent surgical treatment. Based on these results, if surgical treatment is feasible for a patient expected to require a long stent, it may be an option to consider surgery from the very beginning.

Verma, et al.[17] reported that the extent of air pockets in chest CT was a prognostic factor in patients with PTBS. In this study, the air pocket score was defined as the number of quadrants containing air pockets in section 1 (most proximal section, cranial to caudal)+number of quadrants containing air pockets in section 2+number of quadrants containing air pockets in section n (most distal section). Based on this, we analyzed whether the air pocket was associated with tracheal restenosis in patients with PITS and PTTS. Additionally, we introduced the concept of air pocket density, which was defined as the value obtained by dividing the air pocket score with the stent length. The air pocket score, length, and density did not differ significantly between the two groups. The previous PTBS study was conducted without knowledge of the importance of the air pocket. However, after knowing the importance of air pockets, most patients in this study attempted to remove stents when air pockets were present. We believe that these differences in study subjects resulted in a negative result of air pockets for re-

stenosis.

Our study had several limitations. First, since this was a retrospective study based on single-center data, it could not represent all patients with PITS and PTTS. Furthermore, our center performed the most rigid bronchoscopic interventions in South Korea, and patients with complex airway stenosis and those who failed the procedure were referred to our hospital. Therefore, a selection bias may have occurred in this study. Second, since most of the patients had intubation or tracheostomy performed in other hospitals, there were incomplete and missing data for the exact periods of intubation and tracheostomy in some patients. Third, we grouped PITS and PTTS together in this study, although our previous study suggested that PITS and PTTS may have differences in clinical characteristics and outcomes.[13,32] To overcome these limitations, further prospective and multicenter studies are required.

In conclusion, trauma-induced intubation and stent length <50 mm were associated with successful stent removal in patients with PITS and PTTS. Clinicians may need to pay attention to the expected length of the stent when deciding to perform interventional bronchoscopy and tracheal stenting in their patients.

AUTHOR CONTRIBUTIONS

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