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Original Article / Özgün Makale

How long should it be insisted on rigid bronchoscopy in the treatment of postintubation tracheal stenosis in accordance with different stenosis classification systems?

Farklı darlık sınıflama sistemlerine göre entübasyon sonrası trakeal darlık tedavisinde rijit bronkoskopide ne kadar ısrarcı olunmalıdır?

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ABSTRACT

Background: In this study, we aimed to investigate the effectiveness of isolated rigid bronchoscopy used in the treatment of postintubation tracheal stenosis by its relationship with the most frequently used classifications, our own classification Stenosis Index, stenosis dimensions and its combinations.

Methods: Between March 2010 and July 2020, a total of 39 patients (16 males, 23 females; mean age: 41.5±20.7 years; range, 15 to 72 years) who had isolated rigid bronchoscopic dilation as a result of postintubation tracheal stenosis were retrospectively analyzed. The duration of treatment, the number of procedures, and the success of the treatment of patients were analyzed according to the most frequently used classifications and compared to our new classification.

Results: A statistically significant difference was found between the Stenosis Index groups in terms of the number of procedures and duration of treatment ($p<0.01$, $p<0.01$, respectively). No statistically significant differences were observed among the most frequently used classifications in terms of number of procedures and duration of treatment. The Stenosis Index classification groups most consistently reflected the success rate of the procedure, the number of procedures, the duration of the treatment and the rate of patients resected.

Conclusion: The Stenosis Index classification was considered to be a more effective parameter than the most frequently used classifications on the decision to give the patients with postintubation tracheal stenosis a chance to treat with bronchoscopic dilations procedure before resection.

Keywords: Cotton-Myer classification, McCaffrey classification, postintubation tracheal stenosis, Simple-Complex classification.

ÖZ

Amaç: Bu çalışmada entübasyon sonrası trakeal darlık tedavisinde kullanılan izole rijit bronkoskopinin etkinliğinin en sık kullanılan sınıflandırmalar, kendi sınıflamamız (Stenoz İndeksi), darlığın boyutları ve kombinasyonları ile olan ilişkisi araştırıldı.

Çalışma planı: Mart 2010 - Temmuz 2020 tarihleri arasında entübasyon sonrası trakeal darlığa bağlı izole rijit bronkoskopik dilatasyon uygulanan toplam 39 hasta (16 erkek, 23 kadın; ort. yaş: 41.5±20.7 yıl; dağılım, 15-72 yıl) retrospektif olarak incelendi. Hastaların tedavi süreleri, işlem sayıları ve tedavi başarıları en sık kullanılan sınıflamalara göre incelendi ve yeni sınıflamamız ile karşılaştırıldı.

Bulgular: Stenoz İndeks grupları arasında işlem sayısı ve tedavi süresi açısından istatistiksel olarak anlamlı bir fark saptandı (sırasıyla, $p<0.01$, $p<0.01$). İşlem sayısı ve tedavi süresi açısından en sık kullanılan sınıflamalar arasında istatistiksel olarak anlamlı bir fark bulunmadı. Stenoz İndeks sınıflama gruplarının işlemin başarı oranını, işlem sayısını, tedavi süresini ve rezeksiyon yapılan hasta oranını en tutarlı şekilde yansıttığı görüldü.

Sonuç: Entübasyon sonrası trakeal darlığı olan hastalara rezeksiyon tedavisi yerine öncelikle bronkoskopik dilatasyon tedavisi şansı verme kararında Stenoz İndeks sınıflamasının en sık kullanılan sınıflamalardan daha etkili bir parametre olduğu düşünüldü.

Anahtar sözcükler: Cotton-Myer sınıflandırması, McCaffrey sınıflandırması, entübasyon sonrası trakeal darlık, Simple-Complex sınıflandırma.

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Tracheal stenosis is considered to be more than 50% narrowing of the tracheal passage.[1] Tracheal stenosis often occurs due to prolonged intubation, tracheostomy, or trauma.[2,3] Postintubation tracheal stenosis is the most common benign tracheal stenosis group.[4] Its frequency is reported between 0.6 and 22%.[2-6] It is frequently caused by high pressure, over volume on endobronchial tube cuffs.[2,7] Depending on the medical condition of the patient, follow-up, conservative approach, tracheostomy, isolated or combined bronchoscopic interventions with medical treatment, stenting can be applied.

In the present study, we aimed to investigate the effectiveness of isolated rigid bronchoscopy used in the treatment of postintubation tracheal stenosis by its relationship with the most frequently used classifications, our own classification as Stenosis Index (S. Index), and stenosis sizes. Therefore, we planned to create a new parameter in addition to the existing classifications that can be used to decide rigid bronchoscopic dilatation treatment, which is a less invasive method compared to surgical resection.

PATIENTS AND METHODS

This single-center, retrospective study was conducted at Kocaeli University, Faculty of Medicine Hospital, Thoracic Surgery Clinic between March 2010 and July 2020. Procedural success and failure criteria were determined in patients who underwent dilatation treatment with continuous rigid bronchoscopy due to postintubation tracheal stenosis. The procedures were continued until the success criteria were reached, and when the failure criteria were met, stent or surgical resection was performed on the patients (Figure 1). The characteristics of the patients including demographic characteristics and disease history and the results related to the procedure including the number of procedures and duration of treatment were analyzed. Tracheal stenosis features were grouped under generally accepted classifications and a new classification that we proposed. It was analyzed whether there was standardization in terms of patient characteristics among subgroups of each group. Afterward, by analyzing the extent to which each classification group reflected the results related to the procedure, the ability of the groups to predict the success of the procedure and their superiority to each other were examined. Therefore, it was revealed which classification could be used as a consistent parameter in terms of insisting on the number of procedures and the chance of procedural success.

A total of 45 patients who underwent rigid bronchoscopic dilatation due to postintubation tracheal stenosis due to non-malignant reasons were reviewed. Six patients with missing data were excluded from the study. Finally, a total of 39 patients (16 males, 23 females; mean age: 41.5±20.7 years; range, 15 to 72 years) were analyzed. The data of five patients who underwent surgical resection and three patients who underwent stenting were used for calculating the success of the procedure. Overall demographic characteristics, intubation time, duration of symptoms, stenosis sizes characteristics, number of procedures, duration of treatment, and procedural success were analyzed. The information about the patients was reached through hospital files, radiological imaging system, national tracking system (e.g., e-Nabız) and phone calls. The patients who were followed by our clinic or whose follow-up information could be accessed fully were included in the study.

Definitions and criteria

Axial computed tomography (CT) images of 1-mm thickness were used for stenosis measurement. In the localization where the lumen of the trachea is the smallest in the stenosis area was defined as stenosis size, measurements were made from the edge of the stenosis on the lumen surface to the outside edge of the trachea was defined as tissue

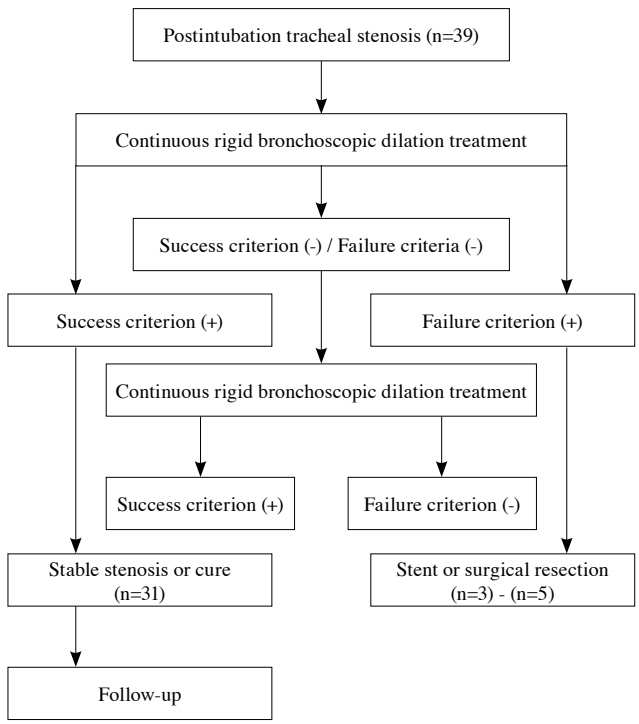

Figure 1. Treatment algorithm.

size. Measurements were performed by a single operator from three different places and the average value was used. In some CT images, tissue size could not be measured, as the borders of the trachea were not clearly visible. The non-pathological tracheal lumen diameter closest to the stenosis was measured and the stenosis lumen value was subtracted from the calculated value and the result obtained was divided by two and tissue size was obtained. On axial CT images, between start and end points of the stenosis was measured three times, and the average value was used as the length of the stenosis (vertical stenosis size). In determining the length of the trachea, the distance between the carina and the level of the vocal cords was measured from three different places on the sagittal Thoracic CT images in accordance with the trachea angle and the average value was used (Figure 2a, b).

A S. Index parameter was developed to express the effectiveness of isolated rigid bronchoscopic dilatation therapy. It was designed not only to consider without depending on narrow field parameters such as two dimensional, and to be used in analysis to minimize interpersonal size difference. While obtaining the S. Index, the tissue size and the vertical stenosis size were multiplied and divided by the length of the trachea. The patients were divided into two groups with S. Index values less than 2 (S. Index Group 1) and over than 2 (S. Index Group 2). In addition to the S. Index, Cotton-Myer classification,[8] Simple-Complex classification,[9,10] McCaffrey classification[11] were also used. In the Cotton-Myer classification, it was divided into four categories according to the ratio of the stenosis size to tracheal diameter size (0-50%, 51-70%, 71-99%, 100%). In the Simple-Complex classification, lesions smaller than 1 cm, web-like, granuloma were considered simple and larger than 1 cm, fibrosis, malaise, and cartilage damage were considered complex. In the McCaffrey classification, considering the distance to the subglottic area and the vertical stenosis size, subglottic lesions smaller than 1 cm were accepted as Grade 1, subglottic lesions larger than 1 cm as Grade 2, those extending from the subglottic to the upper trachea as Grade 3, and lesions with glottic and vocal cord paralysis as Grade 4 (Table 1). Stenosis localizations in our study were grouped as between the vocal cords to the subglottic region (level 1), between the subglottic region and 2 cm distal (level 2), between 2 cm and 4 cm (level 3), and the distal from 4 cm (level 4). The duration of treatment was determined as the time between the first and last rigid bronchoscopies, and the patients who had a single procedure were considered as 0 days. In addition, to analyze the factors affecting the duration of the procedure, the number of procedures was grouped as one (Group 1a) and more (Group 1b) and grouped as two or less (Group 2a) and more than two (Group 2b).

Surgical technique and follow-up

Using thoracic CT, the patients with tracheal stenosis size 8 mm or symptomatic were treated under emergency conditions and in other patients under elective conditions to wait for the fasting period. Thoracic CT examination was performed in all patients before the procedure. Rigid bronchoscopy was repeated according to the presence of symptoms after the procedure. The procedure was performed from small to large size under general anesthesia using the Storz brand rigid bronchoscopes with a

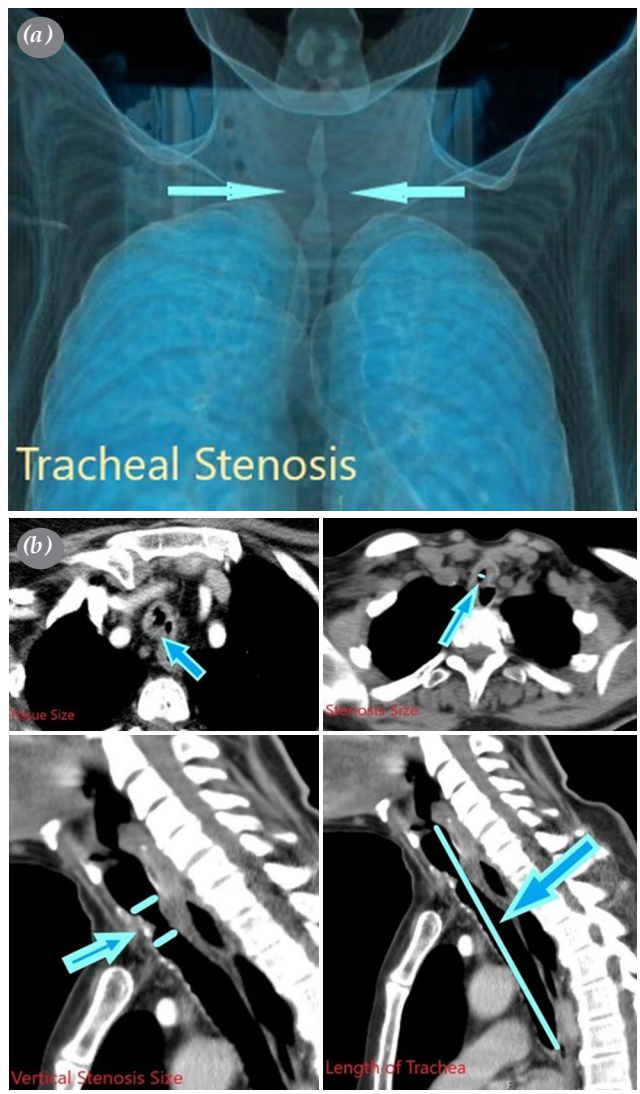

Figure 2. (a) Tracheal stenosis. **(b)** Tracheal stenosis dimensions.

Table 1. Classification features

Cotton-Myer (Stenosis size/tracheal lumen size)	Grade 1	0 to 50% decrease in lumen surface
	Grade 2	51 to 70% decrease in lumen surface
	Grade 3	71 to 99% decrease in lumen surface
	Grade 4	No detectable lumen
McCaffrey (Considering the distance to the subglottic area and the length of the stenosis)	Grade 1	Subglottic lesions smaller than 1 cm
	Grade 2	Subglottic lesions larger than 1 cm
	Grade 3	Lesions are extending from the subglottic to the upper trachea
	Grade 4	Lesions with glottic and vocal cord paralysis
Simple-Complex	Simple	Lesions are smaller than 1 cm, web-like, granuloma
	Complex	Lesions are larger than 1 cm, fibrosis, malaise, and cartilage damage
S. Index Tissue X vertical stenosis size/ tracheal size	Group 1	S. Index value 2 and less than 2
	Group 2	S. Index value more than 2

length of 27 to 35 cm and size No. 4, 5, 6.5, 7.5, and 8.5. The stenosis was passed gently with rigid bronchoscopes, bleeding was controlled through the bronchoscope, and any residual granulation tissue was excised with forceps. The patients were followed in the intensive care and service according to their medical conditions after the procedure. The patients in good general condition were discharged the next day with chest radiography checkups. Patients with terminated symptoms were followed with X-ray and physical examinations at one, three, six, and 12 months. The patients who did not experience symptoms for more than 12 months were excluded from follow-up. Thoracic CT control was performed in certain patients. The procedures were considered unsuccessful for eight patients, due to resection in five (12.8%) patients and bronchial stent placement in three (7.7%) patients.

The criteria for treatment success and failures

Successful treatment criteria were no symptoms for six months after the last procedure, being able to obtain pre-stenosis effort state and able to maintain this state for at least three months, being ability to make five consecutive sentences without stopping while speaking (positive sentence construction test). The tracheal passage must be at least 2 cm in the narrowest area or the stenosis passage must be two times larger than before on the CT imaging a month after the last procedure. Bronchoscopic imaging revealed that the tracheal passage was wide enough with good airway patency.

Failure criteria were the conditions that recurred acute symptoms within two weeks after the second procedure, or within three weeks after three or more procedures. Some conditions that independent of the number such as acute symptoms to develop within one week after the procedure or could not achieve adequate tracheal passage during the procedure or occurrence of situations that do not provide patient satisfaction.

Statistical analysis

Using the power analysis, the power of the study was calculated as 86% (α=0.05). Statistical analysis was performed using the IBM SPSS for Windows version 20.0 (IBM Corp., Armonk, NY, USA). The Shapiro-Wilk test was used to assess the assumption of normality. Continuous variables were presented in mean ± standard deviation (SD) or median (25^{th} to 75^{th} percentile). Categorical variables were presented in number and frequency. Comparisons of continuous variables between the groups were carried out using independent samples t-test/Mann-Whitney U test, whichever was appropriate. The Dunn test was used for multiple comparisons. Binary logistic regression analysis was performed to identify the factors affecting the outcome variable. The relationships between the categorical variables were evaluated using the chi-square analysis. Spearman correlation analysis was used, when the assumption of normal distribution was not provided in the analysis of the relationships between the numerical variables. A p value of <0.05 was considered statistically significant.

RESULTS

The median follow-up was 37 (range, 13.0 to 63.0) months. The mean number of procedures was 2.9±1.9, and the mean duration of treatment was 4.7±6.5 months.

Table 2. Overall characteristic (n=31)

	n	%	Mean±SD	Median	Q1-Q3	Cotton-Myer Grade 1-2-3	S. Index group Group 1 (n=18), Group 2 (n=13)	Simple-Complex group	McCaffery Grade 2-3	Number of procedures 2a, 2b	Number of procedures 1a, 1b
						p	*p*	*p*	*p*	*p*	*p*
Age (year)			41.5±20.7			0.741[a]	0.259[c]	0.740[c]	0.693[c]	0.539[c]	0.531[c]
Sex						0.618[b]	0.449[b]	1.00[b]	0.262[b]	0.894[b]	0.429[b]
Male	11	35.5									
Female	20	64.5									
Disease history											
Pulmonary	5	16.1				0.092[b]	0.625[b]	0.291[b]	1.00[b]	0.654[b]	0.613[b]
Cardiovascular	12	38.7				0.865[b]	1.00[b]	0.433[b]	0.447[b]	0.821[b]	0.704[b]
Other	13	41.9				0.855[b]	0.483[b]	1.00[b]	1.00[b]	0.192[b]	0.114[b]
Intubation cause						0.169[b]	0.790[b]	0.324[b]	0.900[b]	0.946[b]	0.505[b]
Shortness of breath	10	32.3									
Trauma	7	22.6									
Chemical exposure	2	6.5									
Medical	12	38.7									
Intubation time (day)			19.1±14.0			0.115[a]	0.352[d]	0.674[d]	0.917[b]	0.379[d]	0.428[d]
Number of tracheostomies/ duration of tracheostomy (month)	19	61.29	7.0±18.2			0.364/0.226[d] 0.928/1.00[d] 0.542/0.950[d] 0.356/0.232[d] 0.588/0.623[d]	0.364/0.226[d]	0.928/1.00[d]	0.542/0.950[d]	0.356/0.232[d]	0.588/0.623[d]
Pre-application symptom duration (week)			8.4±11.0			0.282[a]	0.984[d]	0.312[d]	0.917[d]	0.922[d]	0.254[d]
Symptom onset time after extubation (week)				7	3-13	0.561[a]	0.921[d]	0.362[d]	0.574[d]	0.401[d]	0.623[d]
Trachea length (mm)			100.7±11.7			0.406[a]	0.286[d]	0.642[d]	0.917[d]	0.626[d]	0.236[d]
Application symptom											
Stridor	8	25.8				0.379[b]	0.412[b]	0.076[b]	1.00[b]	0.220[b]	0.027[b]
Dyspnea	25	80.6				0.237[b]	0.359[b]	0.298[b]	0.634[b]	0.172[b]	0.004[b]
Localization						0.031[b]	0.557[b]	0.654[b]	<0.001[b]	0.645[b]	0.379[b]
1	7	22.6									
2	9	29									
3	8	25.8									
4	7	22.6									
Follow-up (month)			50.4±4.1			0.592[a]	0.417[d]	0.542[d]	0.634[d]	0.202[d]	0.078[d]
Number of procedures			2.9±1.9			0.452[a]	<0.01[d]	0.947[d]	0.466[d]	-	-
Treatment duration (month)			4.7±6.5			0.203[a]	<0.01[d]	0.437[d]	0.466[d]	-	-
Stenosis sizes											
Stenosis size (mm)			7.1±2.1							0.243[d]	0.428[d]
Tissue size (mm)			12.1±3.9							0.004[d]	0.003[d]
Vertical stenosis size (mm)			14.1±4.2							0.240[d]	0.716[d]

SD: Standard deviation; Q1-Q3: 25th-75th percentile; a: Kruskal-Wallis Test; b: Chi-square test; c: Independent Samples T test; d: Mann-Whitney U test.

The patients were classified according to the Cotton-Myer, Simple-complex, McCaffery, S. Index groups, and the number of procedures, and general, diagnostic, treatment characteristics and rates were analyzed (Tables 2-5). There was no statistically significant difference between the Cotton-Myer classification groups in terms of the number of procedures (p=0.452) and duration of treatment (p=0.203). In the Simple-Complex classification, no statistically significant difference was found between the groups in terms of the number of procedures (p=0.947) and duration of treatment (p=0.437). In the McCaffery classification, no statistically significant difference was found between the groups in terms of the number of procedures (p=0.466) and duration of treatment (p=0.466). There was a statistically significant

Table 3. Factors affecting the number of procedures, treatment duration and symptom onset time

	Number of procedures		Treatment duration	
	r	*p*	r	*p*
Stenosis size	-0.048[a]	0.798[a]	-0.063[a]	0.737[a]
Vertical stenosis size	0.170[a]	0.360[a]	0.086[a]	0.645[a]
Tissue size	0.507[a]	0.004[a]	0.553[a]	0.001[a]
	Odds ratio	Lower/Upper[g]	*p*	
Tissue size	1618[b]	1.098-2.382[b]	0.015[b]	
Vertical stenosis size	0.935[b]	0.736-1.187[b]	0.580[b]	
	r	*p*		
Stenosis size	-0.471[a]	0.008[a]		
Vertical stenosis size	-0.270[a]	0.142[a]		
Tissue size	-0.64[a]	0.152[a]		
Number of procedures	-0.099[a]	0.596[a]		
Treatment duration	-0.041[a]	0.828[a]		

r: Correlation coefficient; g: 95% confidence intervals; a:Nonparametric correlations test; b: Binary logistic regression test.

Table 4. Number and success of procedures in classification groups

Classification			*p* value		
			Number of procedures	Number of procedures	Success
	n	%	2[a], 2[b]	1[a], 1[b]	%
Stenosis Index			<0.001[a]	0.04[b]	
Group 1	18	58.1			84.21
Group 2	13	41.9			70.59
Cotton-Myer			0.643[b]	0.163[b]	
Grade 1	5	16.1			66.7
Grade 2	22	71			88
Grade 3	4	12.9			50
Simple-Complex			1.00[b]	1.00[b]	
Simple	8	25.81			80
Complex	23	74.19			79.31
McCaffery			1.00[b]	0.205[b]	
Grade 2	21	67.75			77.78
Grade 3	10	32.26			90

a: Mann Whitney U test; b: Chi-square test.

Table 5. Complete procedure list

Age (year)	Sex	Stenosis Index value	Cotton Myer Grade	Caffery Grade	Simple-Complex type	Number of process	Surgical resection or stent treatment
54	Female	1.989	2	2	2	1	No
58	Female	2.24	2	3	2	7	No
52	Female	2.082	2	2	2	3	No
23	Male	3.23	3	3	2	6	No
58	Male	1.564	2	2	1	3	No
58	Female	0.378	2	3	1	2	No
15	Male	2.103	1	2	1	3	No
67	Male	1.874	2	2	2	1	No
17	Female	1.734	2	2	2	1	No
72	Female	2.128	3	3	2	3	No
18	Male	1.281	2	2	2	2	No
48	Female	1.111	1	2	2	1	No
25	Female	1.863	2	2	2	1	No
30	Male	1.691	2	3	2	2	No
18	Male	0.908	2	2	1	2	No
64	Female	2.06	2	2	2	7	No
57	Female	1.649	2	3	2	2	No
70	Female	2.119	2	2	2	3	No
43	Female	0.595	1	2	1	1	No
23	Male	1.721	2	2	2	1	No
41	Male	2.142	2	2	2	5	No
60	Male	2.026	2	2	1	4	No
26	Female	1.222	2	3	2	1	No
24	Male	2.019	2	2	2	6	No
19	Male	2.978	2	2	2	5	No
65	Female	0.33	1	2	1	1	No
45	Female	2.022	2	3	2	4	No
72	Female	1.346	2	2	2	2	No
27	Female	0.819	2	3	1	3	No
61	Female	2.024	3	2	2	3	No
22	Male	2.535	3	1	1	1	No
40	Male	2.068	2	2	1	4	S. Resection
69	Female	0.523	1	2	1	3	S. Resection
35	Female	2.102	3	2	2	1	S. Resection
72	Male	2.114	3	2	2	1	S. Resection
47	Female	2.119	2	2	2	1	S. Resection
27	Female	2.087	2	2	1	6	Stent
36	Female	2.446	3	3	2	2	Stent
37	Male	2.696	1	3	1	5	Stent

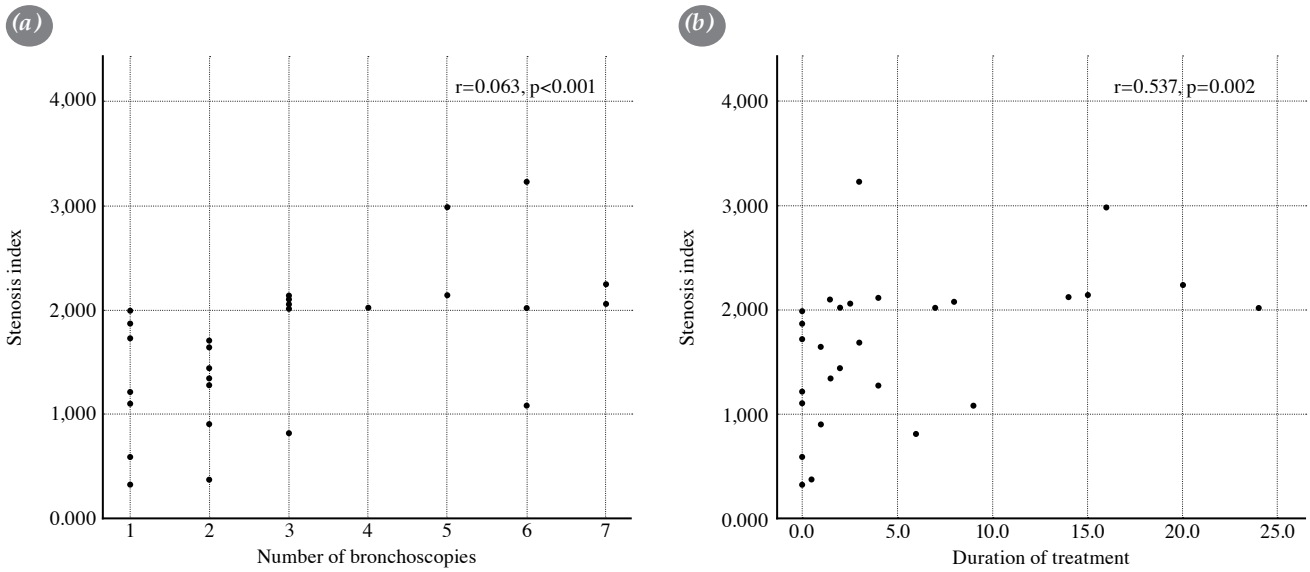

Figure 3. (a) Stenosis index and number of procedures relationship. **(b)** Stenosis index and duration of treatment relationship.

difference between the S. Index groups in terms of the number of procedures ($p<0.01$) and duration of treatment ($p<0.01$) (Table 2, Figure 3a, b). The mean number of procedures for the S. Index Group 1 was 1.8±1.2 and the mean treatment duration was 1.6±2.5 days for S. Index Group 2, while the number of procedures was 4.5±1.6 and the mean treatment duration was 9.2±7.7 days. When the number of the procedure is classified as two or less and more than two, there was a statistically significant difference between the tissue size ($p=0.004$) and S. Index groups ($p<0.001$). The mean tissue thickness was 10.2±3.6 mm in Group 2a and 14.1±3.3 mm in Group 2b. When the number of the procedure was grouped as one and more, there was a statistically significant difference between the tissue size ($p=0.003$) and S. Index groups ($p<0.04$). However, there was no statistically significant difference between the localization groups and the number of procedures ($p=0.281$) and duration of treatment ($p=0.281$, $p=0.832$, respectively).

In the non-parametric correlation test, in which the relationship between the number of procedures and the duration of the treatment with the stenosis size, vertical stenosis size and the tissue size in the stenosis area were analyzed and there was a statistically significant and directly proportional relationship between S. Index groups and the number of procedures and treatment duration ($r=0.063/p<0.001$, $r=0.537/p=0.002$, respectively) (Figure 1a, b). There was a statistically significant and directly proportional relationship between the tissue size in the stenosis area and the number of procedures and duration of treatment ($r=0.507/p=0.004$, $r=0.553/p=0.001$, respectively). However, there was a statistically non-significant and directly proportional relationship between the vertical stenosis size and the number of procedures and the duration of treatment ($r=0.170/p=0.360$, $r=0.086/0.645$, respectively). There was a statistically non-significant inverse correlation between the stenosis size and the number of procedures and duration of treatment ($r=-0.048/p=0.798$, $r=-0.063/p=0.737$, respectively).

In the logistic regression analysis, a statistically significant difference was found in terms of the number of procedures and tissue size; however, no statistically significant difference was found in terms of the vertical stenosis size (odds ratio [OR]=1.618/ $p=0.015$, or=0.935/$p=0.580$, respectively).

In the Simple-Complex classification, the success of the procedure was 80% in the simple group and 79.31% in the complex group. Three (60%) of the patients were resected according to the Simple-Complex groups and all of the patients with stents were in the Complex group. In the Cotton-Myer classification, procedural success was 66.67% in the Grade 1 group, 88% in the Grade 2 group, and 50% in the Grade 3 group. One (20%) of the patients who underwent surgery were Grade 1, two (40%) were Grade 2, and two (40%) were Grade 3. There was one patient in all three groups who had a stent. The success of the procedure in the McCaffery groups was 77.78% in the Grade 2 group and 90% in the Grade 3 group (Table 4). All of the patients who underwent

resection according to the McCaffery classification were Group 2, two of the patients who underwent stenting were Group 3, and one was Group 2. The success rate in the S. Index groups was 84.21% in Group 1 and 70.59% in Group 2. Four (80%) of the patients who underwent resection were in the S. Index Group 2, all of the patients who were stented were in the S. Index Group 2. For localizations of patients who underwent resection; one (20%) was level 1, three (60%) was level 2, and one (20%) was level 3 (Table 5).

DISCUSSION

Acquired tracheal stenoses often occur after intubation.[1] The etiology of tracheal stenosis is associated with an intubation time of more than 10 days and an intubation tube cuff pressure greater than 30 mmHg.[12] Mucosal damage, ischemic necrosis, granulation tissue formation, and fibrosis develop in the trachea, respectively.[4,13] The most common etiological reasons found in our study were intubation longer than 10 days (87.1%) and tracheostomy (61.3%).

Postintubation tracheal stenoses are more common in the subglottic area and female sex.[2,4,10,11] In our study, 51.6% of the stenotic lesions were located within the first 2 cm of the trachea below the vocal cords and 64.5% in the female sex.

After intubation, 1 to 2% of patients develop symptomatic stenosis.[2,4] In the Marel et al.'s[5] study, the first symptoms were reported as shortness of breath and inspiratory stridor. In the study of Cavaliere et al.,[10] the most common presenting symptom was reported as effort dyspnea. The most common symptoms in our study were dyspnea and stridor. It is reported that symptoms usually begin between one and eight weeks after extubation or closure of tracheostomy.[3,10] In our study, the symptom onset time was seven weeks, consistent with the literature. There was an inverse correlation between symptom onset time and stenosis size, vertical stenosis size, tissue size, number of procedures, and there was a directly proportional to the duration of treatment.

The generally accepted view in the treatment of postintubation tracheal stenosis is surgical resection and end-to-end anastomosis.[2,7,14] Surgical resections up to approximately 4 to 5 cm in length can be performed.[7] Success rates of surgical resection are reported above 90%.[4,10] Morbidity and mortality rates in resections are higher than in endoscopic bronchial procedures. The most common postoperative complications are granulation tissue formation, fistula, laryngeal nerve paralysis, glottic dysfunction, wound infection, dehiscence, and restenosis.[1,4] The treatment approach in uncomplicated tracheal stenosis is controversial in the literature.[15] The approach to be applied in short vertical stenosis size varies depending situation on the experience of the surgeon. Bronchoscopic methods are beneficial in terms of eliminating the emergency in the early period of tracheal stenosis and saving time, if surgery is required.[7,15] In addition, it is an alternative to open surgery with fewer complications for patients whose medical condition does not allow the procedure.[9,13] Several studies have reported that bronchoscopic procedures may be sufficient for short and simple stenoses[4,11,13,14,16] or that endoscopic procedures may be an alternative to surgery in a certain patient group.[2] Treatment success of endoscopic interventions alone is reported between 32 and 66%.[10] The most common complications in endobronchial tracheal dilatation procedures are tracheal rupture, bleeding, hypoxia, and stent shift.[2,4,10] Considering the studies using both surgical resection and endoscopic bronchial procedures, in a study of patients with benign tracheal stenosis, 9.9% of 209 patients were operated over 10 years.[15] In another study in which 392 patients, independent of the type of stenosis, were analyzed, 301 (77%) patients were resected end-to-end, and satisfactory treatment success was achieved at a rate of 96%.[7] Our study is the most comprehensive in the literature on the effectiveness of the isolated rigid bronchoscopy procedure in terms of the number of patients and the number of parameters, combination criteria used. In our study, five (12.8%) patients underwent surgical resection and three (7.7%) patients underwent tracheal stenting. Our overall procedure success was 79.5%. In our study, we did not encounter any complications or mortality related to dilatation with rigid bronchoscopy.

Different classifications are used for tracheal stenoses. In a commonly used classification, tracheal stenoses are grouped as the Simple and Complex according to their morphological features, the presence or absence of additional tracheal pathology, and the vertical stenosis size.[9,10,15] Galluccio et al.[15] reported that they used endoscopic methods and laser primarily in simple lesions, and that they repeated the procedure up to three times when recurrence was observed, and that they used stent if it was more repeated. In the same study, 167 patients with Simple stenosis underwent an average of 2.07 times endobronchial procedures, while 33 patients with Complex stenosis underwent an average of 3.27 times with an overall success rate of 69%.[15] In the study of Cavaliere et al.,[10] after endoscopic interventions performed in 13 Simple 60 patients

with Complex stenosis, the success rate was 69% in a single procedure and 100% in multiple procedures in Simple stenosis, 22% in a single procedure in Complex stenosis, 37% in multiple procedures, and 66% in total. In another study, the success rate was 66% in simple stenosis, and it was successful in three of 17 patients with Complex stenosis.[9] In our study, eight (25.8%) patients had Simple stenosis in 23 (74.2%) patients that we described as complex. The success rate of the procedure was 80% in Simple stenosis and 79.3% in Complex stenosis. No statistically significant difference was found between the two groups in terms of the number of procedures and duration of treatment (p=0.947, p=0.437, respectively). Complex stenosis was present in three (60%) of the patients who underwent resection.

The Cotton-Myer is another classification based on the ratio of tracheal stenosis to the total tracheal passage diameter.[8] In a study of extensively Grade 2-3 patients using this classification, an overall success rate of 72% was reported for grade independent endoscopic procedures.[17] In another study using bronchoscopic procedures with 11 patients using this classification, all patients with Cotton-Myer Grades 1 and 2 returned to their previous trauma level of exercise.[13] In our study, the success rate in tracheal stenosis was 66.7% in Grade 1, 88% in Grade 2, and 50% in Grade 3. No statistically significant difference was found between the Cotton-Myer groups in terms of the number of procedures and duration of treatment (p=0.643, p=0.203, respectively). Resected patients showed a heterogeneous distribution according to the Cotton-Myer classification, and there were three (60%) patients in the Grade 2 group and one (20%) in the narrower Grade 3 group.

In another classification, McCaffrey[11] identified tracheal stenosis localizations as glottic, subglottic, and tracheal, and graded according to the combination of the length of the stenosis. In the same study, subglottic stenoses shorter than 1 cm were classified as Grade 1 and it was reported that dilatation with a rigid bronchoscope would be sufficient in treatment. In the literature review, there is no study using this classification and regarding the results included in our study concept. In our study, the success of the procedure was 77.8% in the Grade 2 group, while it was 90% in the Grade 3 group. While the patients who underwent resection were expected to be in a more advanced stage, all of them were in the McCaffery Grade 2 group. No statistically significant difference was found between the McCaffery groups in the analyzed patients in terms of the number of procedures and duration of treatment (p=0.466, p=0.466, respectively).

The success rate in the S. Index groups was 84.2% in Group 1 and 70.59% in Group 2. A statistically significant difference was found between the S. Index groups in terms of the number of procedures and duration of treatment ($p<0.01$, $p<0.01$, respectively). Four (80%) of five patients who underwent resection were in Group 2.

The number of studies on the treatment of tracheal stenosis with an isolated bronchoscopic procedure is small and the number of patients is limited. In these studies, the effectiveness of dilatation was not evaluated with isolated rigid bronchoscopy, and applications such as laser and mitomycin C were used together with bronchoscopy. In general, these studies focused on the stenosis sizes or vertical stenosis size. In our study, evaluation was made in the form of a few parameters and their combination.

The effect of two dimensional parameters used in groupings other than the S. Index may vary from individual to individual; for instance, a stenosis size that may be symptomatic in a patient with a short trachea diameter may not cause symptoms in a patient with a larger trachea. This may be the reason why the results are different from those expected in the number of procedures, duration of treatment, success rate calculations among the groups of classifications. Therefore, stenosis size should not be adhered to alone, and combinations with multiple variable parameters should be used. In our study, apart from the effect of tissue size and stenosis size, combinations of vertical stenosis size and trachea length were used and a different parameter (S. Index) related to this subject was presented.

In our study, among the factors that negatively affected the success of the treatment, the most statistically significant factor was long tissue size, while statistically non-significant factors were the small stenosis size and the increase in the vertical stenosis size. The S. Index classification groups within the classifications most consistently reflected the success rate of the procedure, the number of procedures, the duration of the treatment, and the rate of patients resected. No statistically significant difference was found between the groups in Cotton-Myer, Simple-Complex, and McCaffery classifications in terms of the number of procedures and duration of treatment; however, it was found in the S. Index groups.

The main limitations of our study are its single-center, retrospective design with a relatively small sample size.

In conclusion, unlike the current tracheal stenosis classifications, the Stenosis Index classification, which has a three-dimensional structure and is far from subjective evaluations, may be a more effective parameter than the most frequently used classifications on the decision to give the patient a chance to treat with a bronchoscopic procedure before resection. It should be insistent to patients with the Stenosis Index ≤2 in terms of the number of repetitive procedures. If the Stenosis Index value is higher than 2, it should be kept in mind that the number of procedures and treatment duration would be long and the success rate would be low, and stent or surgical resection treatment should be decided earlier.

Ethics Committee Approval: The study protocol was approved by the Kocaeli University, Faculty of Medicine, Ethics Committee (Date: 11/09/2020, No: 2020/263). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from each patient.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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