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Surgical outcomes and risk factors for complications after tracheal resection in benign tracheal stenosis: A 15-year single-center experience

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Abstract

Background: Surgical resection is an established treatment for benign tracheal stenosis with favorable outcomes in selected patients. This study aimed to evaluate postoperative outcomes in patients undergoing tracheal resection and reconstruction.

Methods: A retrospective analysis was performed on patients who underwent surgical treatment for tracheal stenosis between January 2010 and December 2024. Of 110 patients, those with tracheoesophageal fistula (n=25), malignancy (n=18), or incomplete follow-up (n=5) were excluded. A total of 62 patients with benign tracheal stenosis were included. Demographic characteristics, surgical details, airway management strategies, perioperative interventions, comorbidities, and postoperative outcomes were analyzed.

Results: Among the 62 patients, 24 (38.7%) were female and 38 (61.3%) were male, with a median age of 37 years (range: 4-83). The primary etiology was post-intubation stenosis in 50 patients (80.7%) and post-tracheostomy stenosis in 12 (19.3%). No cases of idiopathic laryngotracheal stenosis were identified in our surgical cohort. The mean resection length was 2.76±0.9 cm. Surgical access was achieved via collar incision in 87.1% of patients. Ventilation was managed using a laryngeal mask airway in 59.6% and an endotracheal tube in 40.4%. Postoperative complications occurred in 13 patients (20.9%), including wound infection, restenosis, and vocal cord edema. Although complications were more frequent in patients with comorbidities, the difference was not statistically significant ($p>0.05$). No mortality was observed.

Conclusion: Tracheal resection and reconstruction is a safe and effective treatment for benign tracheal stenosis, with low morbidity and no mortality in this series. Increased complication rates were associated with extended resections and proximal airway involvement. Careful patient selection and meticulous surgical planning are essential to optimize outcomes.

Keywords: Tracheal stenosis, cricotracheal resection, tracheal surgery, airway reconstruction.

Post-intubation tracheal stenosis (TS) is the most common acquired cause of tracheal narrowing and typically develops following prolonged intubation or tracheostomy.[1] Post-intubation TS occurs as a result of ischemic injury to the tracheal mucosa caused by cuff pressure, leading to cicatricial healing and fibrotic changes. In addition, improperly performed tracheostomy procedures and tracheal ring fractures may contribute to its development.[2,3] The incidence of post-intubation TS ranges between 10% and 22%, although only 1-2% of these cases become symptomatic, usually presenting with dyspnea that is unresponsive to corticosteroid therapy.[4] The need for treatment due to stenosis following tracheostomy varies between 1% and 20%.[5,6]

In recent years, particularly in association with the coronavirus disease-2019 (COVID-19) pandemic, prolonged intubation has been increasingly required in intensive care units. It has been reported that 5-10% of COVID-19 patients and up to 80% of those treated in intensive care units require prolonged mechanical ventilation.[7,8]

Treatment options for TS include both surgical and non-surgical approaches. Surgical resection remains the definitive treatment in patients with good general condition and suitable anatomy. Cricotracheal and tracheal resections can be performed with acceptable complication rates and favorable outcomes, particularly in patients with benign stenosis.[9] In cases where surgery is not feasible, endoscopic/bronchoscopic treatment modalities may be considered.[1]

We previously reported our initial experience with tracheal resections in 2019.[10] With the increase in the number of patients, the addition of COVID-19-related cases, and the more frequent use of laryngeal mask airway (LMA), we aimed to present our updated surgical outcomes. Since there is no universally accepted definition of extended tracheal

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resection in the literature.[11] In this study we defined extended resections as: (I) Resections involving the cricoid cartilage or above, (II) resections exceeding 3 cm in length, and (III) procedures requiring T-tube placement, anterior or posterior cricoid split procedures, or mold application.

However, data regarding the impact of extended resections, ventilation strategies, and post-COVID airway pathology on surgical outcomes remain limited. Therefore, this study aims to evaluate surgical outcomes and identify risk factors for postoperative complications in patients undergoing tracheal resection for benign stenosis.

Methods

Following approval from the Local Ethics Committee of Gazi University (date: 13.01.2025, approval number: 2026-70), the requirement for informed consent was waived due to the retrospective nature of the study. The medical records of patients who underwent surgery for benign TS at our institution between January 2010 and December 2024 were retrospectively reviewed. Patients operated on for tracheoesophageal fistula or malignancy, as well as those with unavailable follow-up data, were excluded from the study. No cases of idiopathic laryngotracheal stenosis were identified in our surgical cohort.

Patients were analyzed in terms of age, sex, indication for intubation, surgical indication, timing of surgery, surgical approach, ventilation management (LMA/ETT), pre- and postoperative bronchoscopic tracheal interventions, comorbidities, length of the resected tracheal segment, postoperative complications, tracheostomy status, length of hospital stay, and development of restenosis.

Statistical Analysis

Statistical analyses were performed using SPSS version 20.0. The normality of numerical data was assessed using histogram analysis. Normally distributed variables were expressed as mean ± standard deviation, while non-normally distributed variables were expressed as median (minimum-maximum). Categorical variables were presented as numbers and percentages. Survival analysis was not performed due to the benign nature of the disease. The relationship between comorbidities, type of tracheal resection, and the presence of postoperative complications was evaluated using the chi-square test or Fisher's exact test where appropriate. A p-value <0.05 was considered statistically significant. Postoperative complications were defined as any adverse event after surgery, including restenosis, wound infection, vocal cord dysfunction, or need for re-intervention.

Surgical Technique

All patients were evaluated preoperatively with two-view chest radiography and neck and thoracic computed tomography. Rigid bronchoscopy was performed in all patients prior to resection.

Patients were positioned in the supine position during surgery. Since 2019, LMA has been used in the majority of cases in our practice, whereas endotracheal intubation was predominantly used in cases performed before this period. No intraoperative conversion from LMA to endotracheal intubation was required in our series, and all procedures planned with LMA were successfully completed without airway-related complications. A shoulder roll was used to achieve adequate neck extension. Depending on the location of the stenosis, the trachea was exposed via a collar incision or a collar incision combined with partial sternotomy. Sternotomy was primarily required in patients with distal TS. Two patients with distal tracheal involvement underwent a transternal-transpericardial approach, while partial sternotomy was performed in selected cases requiring additional surgical exposure due to distal location or extended resection length.

In our series, intraoperative nerve monitoring was not used in any patient for identification of the recurrent laryngeal nerve. Safe dissection was achieved by maintaining a plane close to the trachea. In cases where LMA was used, flexible bronchoscopy was performed to identify the stenotic segment.

In selected patients with subglottic involvement, additional airway expansion procedures were performed to achieve adequate airway caliber and facilitate reconstruction. Posterior cricoid split was performed in 5 patients, while anterior cricoid split was performed in 3 patients according to the anatomical extent of the stenosis.

Following resection, adequate mobilization was achieved, and tracheal anastomosis was performed. The posterior wall of the anastomosis was typically sutured using a continuous technique with 3-0 or 4-0 PDS, while the anterior wall was closed with interrupted 3-0 Vicryl sutures. Additional Vicryl sutures were placed at both lateral edges of the anastomosis.

After completion of the anastomosis, it was evaluated using flexible bronchoscopy. A leak test was performed by instilling saline over the anastomotic line and applying positive pressure ventilation. During the awakening phase, vocal cord movements were assessed bronchoscopically.

Results

Patients who underwent surgical treatment for TS at our institution (n=110) were retrospectively reviewed. Patients operated for tracheoesophageal fistula (n=25), malignancy (n=18), and those with incomplete follow-up data (n=5) were excluded. A total of 62 patients with benign TS were included in the study. The most common etiology of TS was post-intubation TS. The mean age was 37 years (range: 4-83). A total of 34 patients had associated comorbidities. Indications for intubation varied, and 6 patients had a history of intubation due to COVID-19. Demographic and preoperative characteristics of the patients are presented in Table 1.

A total of 23 patients (37.1%) entered the operating room with a preoperative tracheostomy. Among these, 9 patients (39.1%) were decannulated intraoperatively and left the operating room without a tracheostomy, while 14 required continued tracheostomy at the end of surgery. An exmaple of the resected tracheal specimen including the stenotic segment with the tracheostomy cannula *in situ* is shown in Figure 1.

Among the patients who were decannulated intraoperatively, 2 required re-tracheostomy on postoperative day 1 due to respiratory distress, and both were successfully managed and discharged following appropriate airway stabilization. No patients without a preoperative tracheostomy required a new tracheostomy at the end of surgery. T-tube placement was performed in 5 patients as an airway management strategy, particularly in cases requiring extended resections, and these patients included both individuals with and without preoperative tracheostomy. T-tube size selection was individualized based on intraoperative findings; in our

series, 10 mm T-tubes were used in 3 patients and 12 mm T-tubes were used in 2 patients. Overall, 21 patients required postoperative airway support, including tracheostomy or T-tube. Perioperative tracheostomy status and airway management strategies are summarized in Table 2.

Surgical characteristics, including incision type, resection type, median length of hospital stay, number of restenosis cases, and other procedural details, are presented in Table 3.

Analysis of patients with complications revealed that the risk of restenosis and other complications was higher in those who underwent extended resections. Nearly all patients who developed wound infection had preoperative tracheostomy. Among these, 5 patients had type 2 diabetes mellitus, and 2 patients had a history of coronary artery disease requiring clopidogrel (Plavix) therapy.

Of the 9 patients who developed restenosis, 8 had undergone upper-level tracheal surgery. All cases of restenosis were successfully managed with dilatation, and no patient required repeat resection. The characteristics of patients with restenosis are presented in Table 4.

Vocal cord edema was observed only in patients who underwent subglottic surgery. The characteristics of postoperative complications are presented in Table 5. No complications related to LMA placement or its intraoperative use were observed.

Table 1. Patient characteristics

Characteristics		n	%
Age (years), median (range)		37 (4-83)	
Gender	Male	38	61.3
	Female	24	38.7
	COVID-19	6	9.6
Indication for intubation	Myocardial infarction	6	9.6
	Trauma	22	35.4
	Intoxication	3	4.8
	Other	25	40.3
Comorbidities	Present	34	54.8
	Absent	28	45.2
Preoperative tracheostomy		23	37.1
Number of preoperative dilations, mean (range)		1.4 (1-7)	

COVID-19: Coronavirus disease-2019.



Figure 1. Resected tracheal segment with the tracheostomy cannula *in situ*.

Discussion

Tracheal resection and reconstruction (TRR) is the standard treatment modality for benign tracheal stenosis (BTS) in experienced centers, with low mortality and acceptable morbidity rates.[9] In our series of 62 patients, no mortality was observed, and the overall complication rate

Table 2. Perioperative tracheostomy and airway management

Variable	n	%
Preoperative tracheostomy	23	37.1
Intraoperative management		
Decannulated	9	39.1
Continued tracheostomy	14	60.9
Airway management strategies		
T-tube placement	5	8.1
Postoperative outcome		
Re-tracheostomy (postoperative day 1)	2	3.2
Overall		
Patients requiring postoperative airway support	21	33.9

Table 3. Characteristics of surgical procedures

Characteristics		n	%
Ventilation method	LMA	37	59.6
	ET	25	40.4
Type of resection	Extended	28	45.2
	Standard	34	54.8
Surgical incision	Collar incision	54	87.1
	Collar+p.sternotomy	6	9.7
	Sternotomy (TSTP)	2	3.2
Level of resection	Upper 1/3 of trachea Distal 1/3 of trachea Subglottic Two-level	46 5 10 1	74.2 8.1 16.1 1.6
Mean resection length (cm), mean ± SD		2.79±0.9 cm	
	T-tube	5	8.1
Procedures in extended resections	Mold	4	6.4
	Split	8	12.9
	Suprahyoid release	1	1.6
Restenosis		9	14.5
Rigid dilation for restenosis, median (range)		4 (1-10)	

SD: Standard deviation; LMA: Laryngeal mask airway.

Table 4. Characteristics of patients with restenosi

Complications	N	Resection level	Comorbidity	Preop tracheostomy	Complex resection	Management
Restenosis	9	Upper 1/3 (n=7) Distal 1/3 (n=1) Subglottic (n=1)	6	4	7	Rigid bronchoscopy
Wound infection	7	Upper 1/3 (n=6) Subglottic (n=1)	7	6	4	Wound care and antibiotic therapy
Vocal cord edema		Subglottic (n=2)	2	2	2	Medical treatment

Table 5. Complications and their characteristics

Case	Resection level	Perioperative tracheostomy	Technical features	Resection length (cm)	Complex resection	Comorbidity	LOS (days)	Bronchoscopic dilation (n)	Reoperation
1	Distal 1/3 Trachea	Absent	-	3.2	Yes	CAD	14	10	No
2	Upper 1/3 Trachea	Absent	-	2.5	No	None	32	4	No
3	Upper 1/3 Trachea	Present	-	2	No	DM	12	5	No
4	Subglottic	Present	T-tube	2.5	Yes	CAD	6	1	No
5	Upper 1/3 Trachea	Absent	-	3.5	Yes	None	13	5	No
6	Upper 1/3 Trachea	Present	T-tube, posterior cricoid split	1.5	Yes	DM	5	1	No
7	Upper 1/3 Trachea	Absent	Anterior cricoid split and mold	5	Yes	DM	16	4	No
8	Upper 1/3 Trachea	Present	Anterior cricoid split and mold	2	Yes	DM	14	7	No
9	Upper 1/3 Trachea	Absent	Suprahyoid release and T-tube	2	Yes	None	30	1	No

DM: Diabetes mellitus; LOS: Length of stay; CAD: Coronary artery disease.

was 20.9%. This rate is consistent with the 18-44% range reported in the literature.[1,9] Our findings indicate that complications were associated with the level of resection and the need for extended surgical procedures.

The most common etiology in our study was post-intubation stenosis (80.6%), followed by post-tracheostomy stenosis (19.4%). These findings are consistent with previous reports identifying prolonged intubation and tracheostomy as the leading causes of BTS.[1,2,6] The underlying pathogenesis is primarily related to mucosal ischemia leading to fibrotic healing and airway narrowing.[4,5]

In our cohort, 61.3% of patients were male and 38.7% were female. This distribution is in line with the literature, which suggests a higher incidence of BTS in males due to increased rates of trauma and intensive care unit admissions.[1,7]

During preoperative evaluation, patients underwent rigid bronchoscopy an average of 1.4 times (range: 1-7). This is particularly important in complex stenosis cases for accurate airway assessment and surgical planning. The literature also supports the repeated use of rigid bronchoscopy for both diagnostic and therapeutic purposes.[12-14]

In recent years, COVID-19-related TSs has emerged as a significant clinical problem. In our series, 9.6% of patients had a history of intubation due to COVID-19. These patients generally required longer segment resections, and in some cases, additional interventions such as T-tube placement (8.1%), mold application (6.4%), and suprahyoid release (1.6%) were necessary. Mangiameli et al.[15] reported longer stenotic segments, increased inflammation, and a higher need for release procedures in the COVID-19 group.

Similarly, Yousef et al.[12] demonstrated that the mean resection length in post-COVID patients could reach up to 4 cm and emphasized the importance of careful surgical planning to prevent complications. In post-COVID pathology, mucosal ulceration, cartilage necrosis, and intense inflammation have been reported. [15]

In our study, the mean tracheal resection length was 2.79±0.9 cm, and 45.2% of patients underwent extended resections. It should be noted that extended resection in this study was not limited to subglottic involvement, but also included long-segment resections and cases requiring additional surgical maneuvers. The majority of resections were performed at the upper third of the trachea (74.2%), while 16.1% involved the subglottic region. When the patient with multi-level involvement is included, approximately 17-18% of procedures involved the cricoid cartilage or extended above it. Subglottic stenosis is technically challenging due to the complex laryngotracheal anatomy and its proximity to the glottic structures, and postoperative complications may include vocal cord dysfunction or dysphonia.[13,16] Only one patient underwent a two-level resection, which is considered rare in the literature.[11]

These findings support the observations of Hecker and Volmerig, [11] who reported that resections exceeding 3.5 cm increase surgical complexity. Young and Bigcas [13] demonstrated that techniques such as laryngeal drop and suprahyoid release can allow safe anastomosis for resections up to 6 cm.

In our technique, the posterior wall of the anastomosis was sutured using continuous monofilament absorbable sutures (PDS), while the anterior wall was closed with interrupted absorbable sutures. We preferred absorbable sutures for the anterior wall due to their ease of handling and knot security, particularly in complex or extended resections. Monofilament absorbable sutures such as PDS provide adequate strength while minimizing long-term foreign body reaction. In

our series, we did not observe any suture-related complications, such as excessive granulation tissue formation or calcification.

Restenosis occurred in 9 patients (14.5%), particularly in those undergoing long-segment resections and in patients with comorbidities. Although the overall comorbidity rate was 54.8%, no statistically significant association was found ($p>0.05$). However, larger studies have identified diabetes mellitus and cardiovascular disease as independent predictors of postoperative complications.[3,5,17]

Among patients with preoperative tracheostomy (37.1%), intraoperative decannulation was achieved in 39.1%. However, these patients had higher rates of postoperative tracheostomy (25.8%) and T-tube requirement (8.1%). This finding suggests that scar tissue formation due to prior tracheostomy may predispose to restenosis, as also emphasized in the literature.[18-20] In our study, extended resections, subglottic involvement, and preoperative tracheostomy were associated with higher complication rates. These findings are consistent with previous reports emphasizing the importance of tension-free anastomosis and careful airway assessment.

Ventilation using a LMA was preferred particularly in proximal tracheal surgery and was safely applied in 59.6% of patients. In all cases, flexible bronchoscopy was successfully performed through the LMA, allowing adequate intraoperative evaluation of the anastomosis. The safety and feasibility of this method have also been supported by Adiyeke et al.[21] Celik et al.[22] The use of LMA may provide better surgical exposure and reduce airway trauma compared to ETT, particularly in proximal tracheal lesions.

The median length of hospital stay was 8 days (range: 4-90), which is consistent with previously reported data.[9,15] Vocal cord mobility was preserved in all patients and confirmed bronchoscopically. Although vocal cord edema was observed in a small number of patients, no cases of clinically significant vocal cord dysfunction or permanent vocal cord paralysis were observed.

The limitations of our study include its retrospective design, single-center nature, and the lack of long-term functional outcomes such as voice quality and pulmonary function tests. In addition, detailed long-term evaluation of vocal cord dynamics, including subtle asymmetry, arytenoid positioning, and transient vocal cord immobility, was not systematically performed. The relatively small sample size may also limit the generalizability of the findings. Prospective studies are needed to further evaluate these aspects.

In conclusion, TRR is a safe and effective treatment modality for benign TS. Risk factors such as long-segment resection (>3.0 cm), extended surgical procedures, proximal (upper-level) stenosis, presence of comorbidities, and preoperative tracheostomy should be carefully considered during surgical planning to minimize complications and improve long-term outcomes.

Ethics

Ethics Committee Approval: Following approval from the Local Ethics Committee of Gazi University (date: 13.01.2025, approval number: 2026-70).

Informed Consent: The requirement for informed consent was waived due to the retrospective nature of the study.

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For transparency, the authors note that an artificial intelligence-assisted language model (ChatGPT, OpenAI) was utilized to support language correction. This assistance was limited to linguistic refinement; all scientific content, critical analysis, and final editorial decisions were made exclusively by the authors.

Footnotes

Authorship Contributions

Surgical and Medical Practices: E.V., İ.T., B.A., M.F., A.K.T., İ.C.K., M.S., A.Ç.; Concept: E.V., M.S., A.Ç.; Design: E.V., İ.T., B.A., İ.C.K., M.S., A.Ç.; Data Collection or Processing: E.V., İ.T., B.A., M.F., A.K.T.; Analysis or Interpretation: E.V., İ.T., A.K.T., İ.C.K., M.S., A.Ç.; Literature Search: E.V., İ.T., A.K.T., İ.C.K., M.S., A.Ç.; Writing: E.V., İ.T., B.A., M.F., A.K.T., İ.C.K., M.S., A.Ç.

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