European Journal of Cardio-Thoracic Surgery 2024, 65(2), ezae026
https://doi.org/10.1093/ejcts/ezae026 Advance Access publication 30 January 2024

ORIGINAL ARTICLE

Cite this article as: Mammana M, Verzeletti V, Baldi M, Schiavon M, Dell'Amore A, Rea F. Surgery for tracheal and laryngotracheal stenosis: a historical case series. Eur J Cardiothorac Surg 2024; doi:10.1093/ejcts/ezae026.

THORACIC

Surgery for tracheal and laryngotracheal stenosis: a historical case series

Marco Mammana *, Vincenzo Verzeletti , Matteo Baldi, Marco Schiavon, Andrea Dell'Amore and Federico Rea

Thoracic Surgery Unit, Department of Cardiac, Thoracic, Vascular Sciences and Public Health, University of Padua, Padua, Italy

* Corresponding author. Thoracic Surgery Unit, Department of Cardiac, Thoracic, Vascular Sciences and Public Health, Padova University Hospital, Via Giustiniani 2, 35128 Padua, Italy. Tel: +390498212442; e-mail: marco.mammana@aopd.veneto.it (M. Mammana).

Received 19 September 2023; received in revised form 12 January 2024; accepted 25 January 2024

Surgery for (laryngo-)tracheal stenosis – Outcomes and risk factors for complications

Summary

Surgery for benign (laryngo-)tracheal stenosis leads to low failure rates and acceptable morbidity. Length of the stenotic segment is a risk factor for postoperative complications. In this single center historical series, surgical volume, morbidity rates and success rates were constant over time

Multivariable logistic regression for the risk of postoperative complications

Variable	N	Odds ratio		p
age	186		1.01 (1.00, 1.03)	0.13
stenosis.length	186		1.05 (1.01, 1.09)	0.02
Cotton.Myer.grade				
I to II	109		Reference	
III to IV	77		1.18 (0.58, 2.39)	0.64
preop.dilations				
0	97		Reference	
1	89		1.08 (0.54, 2.15)	0.83
preop.stent				
0	156		Reference	
1	30		1.26 (0.47, 3.19)	0.63
preop.tracheostomy				
No	69		Reference	
Yes	117		1.67 (0.77, 3.76)	0.20
procedure				
Tracheal R/A	129		Reference	
Laryngotracheal R/A	57		1.24 (0.58, 2.57)	0.57

0.5 1 1.5 2 2.5 3 3.5

Legend: R/A, resection/anastomosis

Abstract

OBJECTIVES: Benign (laryngo-)tracheal stenosis is a relatively rare pathology and its surgical treatment is performed only at few specialized centres. This study aims to investigate outcomes after (laryngo-)tracheal resection–anastomosis, to explore potential risk factors for postoperative complications and to assess whether, over a 33-year period, there were major changes in surgical indications, techniques or outcomes.

METHODS: Retrospective, single-centre review of all consecutive patients who underwent tracheal or laryngo-tracheal resection/anastomosis for benign pathologies from 1990 to 2023.

Presented at the EACTS Annual Meeting, Vienna, Austria, 4–7 October 2023.

RESULTS: Overall, 211 patients underwent tracheal (149 patients, 70.6%) and laryngo-tracheal (62 patients, 29.4%) resection–anastomosis. Of these, 195 patients (93.8%) were affected by iatrogenic stenosis, while 13 (6.2%) suffered from idiopathic stenosis. The median length of stenosis was 25 mm (interquartile range 1–3, 20–30). The overall morbidity rate was 27.5%, while major morbidity occurred in 10.5% of cases. One patient (0.5%) died in the postoperative period. Glottic oedema (17 patients, 8.1%), granulations (12 patients, 5.7%) and restenosis (10 patients, 4.7%) were the main complications. The only independent risk factor for postoperative complications was the length of the resected airway ($P = 0.019$). In the latest half of the study period, an older median age was observed, and no patient with idiopathic tracheal stenosis underwent surgery. Postoperative outcomes were comparable between surgical eras.

CONCLUSIONS: Surgical treatment of (laryngo-)tracheal stenosis is challenging and should be performed by specialized centres. In our experience, morbidity and mortality rates were satisfactory, and in most cases, patients could breathe without tracheostomy. The length of the stenosis was the most significant risk factor for postoperative complications.

Keywords: Tracheal resection and anastomosis • Tracheal resection–anastomosis • Tracheal stenosis • Tracheal surgery

ABBREVIATION	
IQR	Interquartile range

INTRODUCTION

Benign tracheal and laryngo-tracheal stenosis are relatively rare pathologies of the upper airway that are most commonly caused by iatrogenic injury (postintubation injury or tracheostomy) [1, 2]. Less common non-malignant causes include idiopathic stenosis, stenosis related to traumatic events or stenosis from granulomatous diseases of the upper airway (i.e. granulomatosis with polyangiitis) [3–5]. The clinical picture is highly variable, ranging from mild dyspnoea to acute respiratory failure; the degree and location of stenosis along with patient's comorbidities are the most important factors that can influence the symptoms [6].

There are no clear-cut guidelines that define the treatment of tracheal stenosis, which could be either endoscopic (e.g. balloon or laser dilations, stent placement) or surgical (tracheal resection–anastomosis) [7]. Surgery for tracheal and laryngotracheal stenosis has been demonstrated to lead to good to excellent outcomes in the majority of cases [8–10]. However, expertise in tracheal surgery is usually available only at few high-volume centres, which may potentially result in a wrong perception of the risks associated with tracheal resection–anastomosis. Moreover, only few studies have investigated risk factors for complications after surgery [9, 11].

We already reported on our experience with surgical treatment of tracheal and laryngo-tracheal stenosis on a consecutive series of 65 patients from 1991 to 2001 [12]. The aims of this study are: to reevaluate on an updated series the outcomes after surgery for tracheal stenosis; to identify, thanks to larger sample size, what are the main risk factors for postoperative complications; and finally, to assess whether there were any differences in surgical indications, operative techniques and outcomes over time.

PATIENTS AND METHODS

Ethics statement

This study received the approval by the Institutional Review Board of Padua University-Hospital (protocol number AOO0058862/2023). All patients signed an informed consent form for the use of anonymized data for research purposes.

Patient selection

This study includes all consecutive patients who underwent tracheal or laryngotracheal resection at the Thoracic Surgery Unit of Padua University Hospital, from January 1990 to March 2023. We excluded patients who had malignant tracheal stenosis, and patients with a concurrent tracheoesophageal fistula.

Data were collected from a prospectively maintained retrospective database including demographic information, history of prior treatments, endoscopic characteristics of the stenosis, operative reports and information about the postoperative course, including follow-up bronchoscopies after hospital discharge.

The degree of airway stenosis, as assessed by preoperative rigid endoscopy, was graded according to the Cotton-Myer classification [13]. Additionally, the stenoses were classified into simple and complex according to an established definition [7, 14]. Simple stenoses were considered those limited to 1 cm in length, absence of tracheomalacia or loss of cartilaginous support, while complex stenoses were represented by lesions longer than 1 cm, with varying degrees of cartilage involvement or circumferential contraction scarring, or those associated with malacia. All airway resections involving any part of the larynx were classified as laryngo-tracheal resections. The resected laryngeal tract typically consisted of part or all of the anterior cricoid arch and its lateral aspects, and/or the mucosa overlying the posterior cricoid plate. Because we felt that there were no clear-cut distinctions between different extents of laryngeal resections, we did not attempt to further classify this procedure. Any resection below the cricoid, including the first tracheal ring, was classified as tracheal resection. Postoperative complications were graded according to the Clavien–Dindo classification, and further grouped into major (Clavien–Dindo IIIa or above) and minor (Clavien–Dindo I–II) [15, 16].

Preoperative evaluation

The preoperative evaluation of patients was almost the same as described in the previous report [12]. All patients underwent accurate endoscopic examination of the larynx and trachea through both flexible and rigid bronchoscopy. The main parameters analysed were: stenosis length and location (proximity to the cricoid and distance from the carina), functional status of the vocal cords, quality of mucosa and the presence or absence of malacia.

Furthermore, neck and chest computed tomography were performed preoperatively in order to gain further information on the status of the airway, of the cartilage rings and anatomical

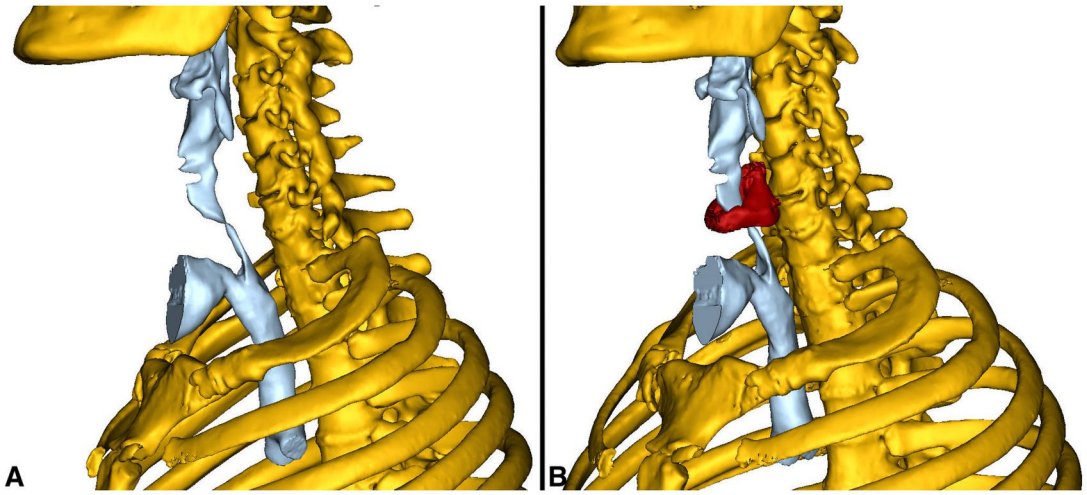

Figure 1: Example of preoperative 3D reconstruction images of a postintubation laryngotracheal stenosis of a young male. In (**A**) the air column shows a near complete subglottic stenosis, which extends caudally to the level of the tracheostomy. In (**B**) the cricoid cartilage has been added to the image, in order to help localize the level of the stenosis relative to the vocal folds.

relationship with nearby structures. In recent years, we have added 3D computed tomography reconstructions to standard bidimensional images. Reconstructions were obtained through a semi-automatic segmentation process, thanks to a commercially available software (Materialise Mimics InPrint, Materialise NV, Leuven, BE). We found 3D reconstructions particularly useful for better estimating the length of the stenotic segment in the case of complete or near-complete stenoses (Cotton-Myer grades III and IV). Furthermore, by visualizing the relationship between the airway and the bony structures, 3D reconstructions helped determine the most suitable surgical approach and whether a sternal split was needed or not (Fig. 1).

Surgery was proposed to patients with acceptable anaesthesiological risk, who were weaned off mechanical ventilation and had no evidence of active inflammation. In this latter case (typically subjects affected by idiopathic tracheal stenosis), we often chose to treat symptomatic patients with endoscopic dilations and postpone surgery, if still required, until inflammation subsided.

Surgical technique

The surgical technique for tracheal and laryngo-tracheal resection–anastomosis is essentially the same as described previously [12]. Briefly, the trachea was accessed by collar incision, cervicotomy with sternal split, full median sternotomy or right thoracotomy, depending on the level of the stenosis. The anterior aspect of the trachea was dissected bluntly for its entire length, while the lateral and posterior aspects were exposed only at the level of the stenotic segment, to avoid injury to the vascular supply and recurrent laryngeal nerves. Additional release manoeuvres (supralaryngeal release or hilar release) were seldom performed and mostly only in case of longer resections. The trachea was cut below the stenotic segment and a cross-field endotracheal tube was inserted into the distal stump. After resection of the stenotic segment, the 2 ends were reapproximated under gentle neck flexion. The membranous trachea was sutured with a running 4–0 polydioxanone (PDS, Ethicon Inc., Somerville, NJ, USA) suture, while the anterolateral ends were anastomosed with interrupted 3–0 Vicryl sutures. Additionally, 2 lateral 2–0 Vicryl traction sutures were placed proximally and distally from the line of resection on each side. These sutures were tied at the end of the anastomosis to reduce tension. In patients undergoing laryngo-tracheal resection, prior to tying the anterolateral sutures, a nasotracheal tube was advanced into the distal trachea under direct vision of the surgeon. The tube was left in place for 24 h and removed under bronchoscopic guidance, as a measure to prevent airway obstruction from glottic oedema. In all other patients, an orotracheal tube was advanced at the moment of the anastomosis and removed at the end of the operation. Similarly, a 'guardian suture', passed between the chin and the sternum to prevent neck hyperextension, was placed only in cases of laryngo-tracheal or longer resections.

Postoperative course

The anastomosis was checked bronchoscopically typically on days 1 and 7 from surgery. Additional bronchoscopies were scheduled according to clinical need. Any patient with known or suspected vocal folds impairment underwent laryngoscopy by an Otolaryngologist and, if needed, subsequent speech and swallow rehabilitation. Patients were followed up regularly in the postoperative period by bronchoscopy during the first 3 months. Additional bronchoscopies were scheduled if clinically indicated.

Statistical analysis

Descriptive statistics were presented as number (%) or median [interquartile range (IQR)]. Analysis of risk factors for postoperative complications was performed by univariable and multivariable logistic regression. The choice of the potential risk factors to include in the analysis was based on clinical judgement and literature data. Categorical variables containing rare values (e.g. aetiology, surgical approach, release manoeuvres) were excluded. Differences between baseline and intraoperative variables were assessed by chi-squared test for categorical variables and the Wilcoxon rank-sum test for numerical variables. Due to the descriptive nature of the comparison, no attempt was made to correct significance values for multiple testing. A *P* value

<0.05 was considered statistically significant. Analyses were performed using R software (R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

Characteristics of the study population

Over the study period, 211 patients underwent tracheal or laryngo-tracheal resection at our centre. Main characteristics are shown in Table 1. In the vast majority of cases, airway stenosis resulted from a iatrogenic injury, which was attributed to a history of prolonged intubation in 129 cases (61.1%) or to a tracheostomy injury in 58 cases (27.5%). The initial cause of prolonged intubation or tracheostomy was varied, and in the latest years, it included 7 patients with previous Covid-19 infection. Idiopathic tracheal stenosis was the only other aetiology, accounting for 14 patients (6.2%). Overall, 177 patients (83.9%) underwent either endoscopic treatments (dilations or stent placement) or tracheostomy for their stenosis. Among the 99 patients who underwent endoscopic dilations, the median (IQR) number of procedures per patient was 2 [1–3]. The median (IQR) length of the stenotic segment was 25 mm (20–30 mm), while 28 patients (15%) had a Cotton-Myer grade IV stenosis (no detectable lumen). Only 6 patients (2.8%) had a simple stenosis, while all others were classified as complex.

Table 1: Baseline characteristics of the 211 patients included in the study

Characteristic	*n* (%) or median (IQR)
Age (years), median (IQR)	41 (24–57)
Gender, *n* (%)	
Male	145 (68.7%)
Female	66 (31.3%)
Aetiology, *n* (%)	
Iatrogenic	198 (93.8%)
Post-intubation	129 (61.1%)
Tracheostomy	58 (27.5%)
Undetermined	11 (5.2%)
Idiopathic	13 (6.2%)
Previous treatments, *n* (%)	
Endoscopic/laser dilations	99 (52.4%)
Endotracheal stents	36 (17.1%)
Tracheostomy	129 (61.1%)
Length of the stenosis (mm), median (IQR)	25 (20–30)
Cotton-Myer grade, *n* (%)	
I	43 (23.0%)
II	66 (35.3%)
III	50 (26.7%)
IV	28 (15.0%)
Surgical approach, *n* (%)	
Cervicotomy	194 (91.9%)
Sternotomy or sternal split	14 (6.7%)
Thoracotomy	3 (1.4%)
Surgical procedure, *n* (%)	
Tracheal R/A	149 (70.6%)
Laryngotracheal R/A	62 (29.4%)
Release manoeuvres, *n* (%)	14 (6.6%)

IQR: interquartile range; R/A: resection–anastomosis.

The surgical approach consisted in a cervicotomy in the majority of patients (91.9%), while a full median sternotomy or a sternal split was needed in 6 and 8 patients, respectively (6.7%). Only 3 patients underwent thoracotomy. Laryngo-tracheal resection was performed in 62 cases (29.4%). Release manoeuvres were needed in 14 patients, including supralaryngeal release in 13 and right hilar release in 1 case.

Postoperative results

The overall morbidity rate was 27.5% (58 patients), including 23 patients who experienced major complications (Clavien–Dindo IIIa or above). Overall mortality was 0.5% (1 patient who died from respiratory failure). Complications are listed in Table 2.

Glottic oedema was the most frequent complication (17 patients): in most cases, it was treated conservatively with steroid therapy, while in 2 cases, it required temporary tracheostomy and T-tube placement. Eventually, both patients were successfully decannulated. Similarly, anastomotic granulations were usually treated with inhaled steroids, and seldom required any further treatment, which consisted in endoscopic laser-assisted ablation in 3 cases. Restenosis was observed in 10 cases: in 9 patients, it was resolved by endoscopic dilations, while 1 patient needed a tracheostomy and long-term T-tube stenting for the occurrence of malacia. Tracheal dehiscence was the most severe airway complication, leading to redo tracheostomy in 6 cases. Only one of these 6 patients was eventually decannulated. Other cases of smaller dehiscence were treated conservatively ($n = 2$) or by endoscopic debridement of necrotic tissue ($n = 1$). Unilateral vocal fold paralysis occurred in 8 patients; it was usually well tolerated and treated with speech and swallow rehabilitation, except 1 patient who required a cordectomy. The median (IQR) postoperative hospital stay was 10 days (8–14 days). Patients experiencing any postoperative complication had a significantly longer hospital stay than patients with a regular postoperative course [median (IQR): 12 days (10–21.5 days) vs 9 days (8–12 days), respectively, $p < 0.001$].

Patients who underwent laryngotracheal resection, compared to those who underwent tracheal resection, were characterized by a trend towards a younger age, a higher prevalence of idiopathic stenosis and a longer airway defect (Table 3). The overall and major complication rates between the 2 procedure types was comparable, although patients who underwent

Table 2: Postoperative complications divided into major (Clavien–Dindo IIIa or above) and minor

Complication type	Overall, *n* (%)	Major	Minor
Glottic oedema	17 (8.1%)	2	15
Granulations	12 (5.7)	3	9
Re-stenosis	10 (4.7%)	10	0
Dehiscence	9 (4.3%)	7	2
Vocal fold paralysis	8 (3.8%)	1	7
Wound infection	6 (2.8%)	0	6
Dysphagia	3 (1.3%)	0	3
Hematoma	2 (0.9%)	1	1
Other medical[a]	7 (3.3%)	2	5

[a]Includes sepsis and respiratory failure (2 cases each), atrial fibrillation, sialorrhea and pulmonary embolism (1 case each).

laryngotracheal resection experienced a higher rate of laryngeal oedema (Table 3).

Risk factors for postoperative complications

Variables with a potential effect on the onset of postoperative complications, based on clinical judgement and literature data, were analysed using univariable and multivariable logistic regression. Analysed variables included age, gender, length of the stenosis, Cotton-Myer grade (grouped into grades I–II and III–IV), preoperative dilations, preoperative stent, preoperative tracheostomy and laryngotracheal (as opposed to tracheal) resection. The results of univariable analysis are presented in Table 4. Of all analysed variables, only the length of the stenotic tract was significantly associated with the onset of postoperative complications ($P = 0.021$), while preoperative tracheostomy was only marginally significantly associated ($P = 0.082$). Similar results were confirmed by multivariable analysis (Table 5).

Table 3: Comparison of baseline, intraoperative and postoperative variables according to the type of resection

Variable	Stenosis location		*P*-value
	Tracheal R/A ($n = 149$)	Laryngotracheal R/A ($n = 62$)	
Age (years), median (IQR)	44 (24–59)	35.5 (24.25–47.75)	0.075
Gender, *n* (%)			1.000
Female	47 (31.5%)	19 (30.6%)	
Male	102 (68.5%)	43 (69.4%)	
Aetiology, *n* (%)			<0.001
Iatrogenic	146 (98.0%)	52 (83.9%)	
Idiopathic	3 (2.0%)	10 (16.1%)	
Length (mm), median (IQR)	24 (20–30)	25 (20–30)	0.043
Cotton-Myer grade, *n* (%)			0.380
I to II	79 (60.8%)	30 (52.6%)	
III to IV	51 (39.2%)	27 (47.4%)	
Preoperative treatments, *n* (%)			
Endoscopic dilations	71 (47.7%)	28 (45.2%)	0.858
Endotracheal stents	28 (18.8%)	8 (12.9%)	0.404
Tracheostomy	83 (55.7%)	46 (74.2%)	0.019
Release manoeuvres, *n* (%)	7 (4.7%)	7 (11.3%)	0.147
Overall morbidity, *n* (%)	39 (26.2%)	19 (30.6%)	0.622
Major morbidity, *n* (%)	15 (10.1%)	8 (12.9%)	0.719
Glottic oedema, *n* (%)	5 (3.4%)	12 (19.4%)	<0.001
Re-stenosis, *n* (%)	7 (4.7%)	3 (4.8%)	1.000
Dehiscence, *n* (%)	6 (4.0%)	3 (4.8%)	1.000
Postop. stay (days), median (IQR)	9 (8–13)	10 (9–14)	0.120
Tracheostomy at last follow-up, *n* (%)	3 (2.0%)	3 (4.8%)	0.503

IQR: interquartile range; R/A: resection–anastomosis.

Analysis of variables by surgical era

Because the study period covers a large time frame, we aimed to assess whether there was any significant change in the indications, surgical techniques and results over time. Figure 2 shows the number of procedures performed each year at our centre. The median (IQR) number of tracheal or laryngotracheal resection–anastomoses per year was 6 [5–9]. Furthermore, we arbitrarily divided the study period into 2 halves; namely from January 1990 to December 2006, and from January 2007 to March 2023. Table 6 summarizes the main baseline, intraoperative and postoperative variables according to the surgical era. From 2007 to 2023, compared to the previous period, the median patients' age was significantly older and there were no patients affected by idiopathic tracheal stenosis. The surgical approach, the proportion of laryngotracheal resection–anastomoses and the use of release manoeuvres did not significantly change. Postoperatively, the overall and major morbidity rates were comparable, while a lower median postoperative stay was observed.

DISCUSSION

Tracheal stenosis is a relatively rare pathology; moreover, its surgical treatment requires strict adherence to rigorous surgical principles [2, 8–10, 12, 17, 18]. As a result, the required technical expertise is only available at few specialized centres, and there is often a wrong perception of the perioperative risks. This may explain why the majority of patients referred for surgery already underwent some form of endoscopic treatment (stent placement, laser or mechanical dilations). Indeed, the treatment of tracheal stenosis is controversial, and highly variable among centres depending on the available expertise and referral pattern

Table 4: Univariable logistic regression for the risk of postoperative complications

Variable	Complications: *n* (%) or median (IQR)		OR (95% CI)	*P*-value
	No = 153 (72.5%)	Yes = 58 (27.5%)		
Age (years)	39 (23–57)	44 (28.25–61.50)	1.01 (0.99–1.03)	0.152
Gender: male	105 (68.6%)	40 (69.0%)	1.02 (0.53–1.95)	0.962
Stenosis length (mm)	23 (20–30)	25 (20–30)	1.04 (1.01–1.08)	0.021
Cotton-Myer grade: 3 or 4	53 (39.3%)	25 (48.1%)	1.43 (0.75–2.73)	0.274
Preop. dilations: yes	72 (52.9%)	27 (50.9%)	0.92 (0.49–1.74)	0.805
Preop. stent: yes	24 (15.7%)	12 (20.7%)	1.40 (0.65–3.03)	0.390
Preop. tracheostomy: yes	88 (57.5%)	41 (70.7%)	1.78 (0.93–3.41)	0.082
Procedure: laryngotracheal R/A	43 (28.1%)	19 (32.8%)	1.25 (0.65–2.39)	0.508

CI: confidence interval; IQR: interquartile range; OR: odds ratio; Preop.: preoperative; R/A: resection–anastomosis.

[7, 19]. Some authors have attempted to define an algorithm based on the characteristics of the stenosis. Simple stenoses may be offered endoscopic treatment only, while complex ones should be evaluated for resection anastomosis 1st [7, 14]. In our series, only a minority of patients had a simple stenosis (2.8%), which is very different from the proportion reported in the case series from interventional endoscopy units [7]. Because the patient populations are so different, it is not possible to compare the outcomes between surgical and endoscopic management of tracheal stenosis based on published case series.

Several reports from experienced centres have shown that tracheal or laryngotracheal resection–anastomosis leads to good to excellent results in the majority of cases. In fact, a surgical failure, which is usually identified with the need for long-term tracheostomy or airway stenting, ranges from 3.7 to 7% in more recent series (Table 7). Therefore, in this study, we rather focused on the occurrence of all postoperative complications. We found an overall complication rate of 27.5%, which is in line with other most recent series (Table 7). As shown in Table 2, the majority of complications involved the airway, but they could be treated conservatively, or endoscopically. The long observation period allowed us to analyse a large patient cohort, so as to identify potential risk factors for complications. A similar analysis was performed by Fiz *et al.* in a multicentre study of 267 patients undergoing tracheal or laryngo-tracheal resection. They found an overall complication rate of 38.2%, and, similarly as in our study, the vast majority of complications were surgery-related [9]. Interestingly, the authors found that the presence of systemic

Table 5: Multivariable logistic regression for the risk of postoperative complications

Variable	OR (95% CI)	*P*-values
Age (years)	1.01 (1.00–1.03)	0.126
Stenosis length (mm)	1.05 (1.01–1.09)	0.022
Cotton-Myer grade: 3 or 4	1.18 (0.58–2.39)	0.641
Preop. dilations: yes	1.08 (0.54–2.14)	0.826
Preop. stent: yes	1.26 (0.49–3.24)	0.628
Preop. tracheostomy: yes	1.67 (0.76–3.68)	0.204
Procedure: laryngotracheal R/A	1.24 (0.59–2.58)	0.570

CI: confidence interval; OR: odds ratio; Preop.: preoperative; R/A: resection–anastomosis.

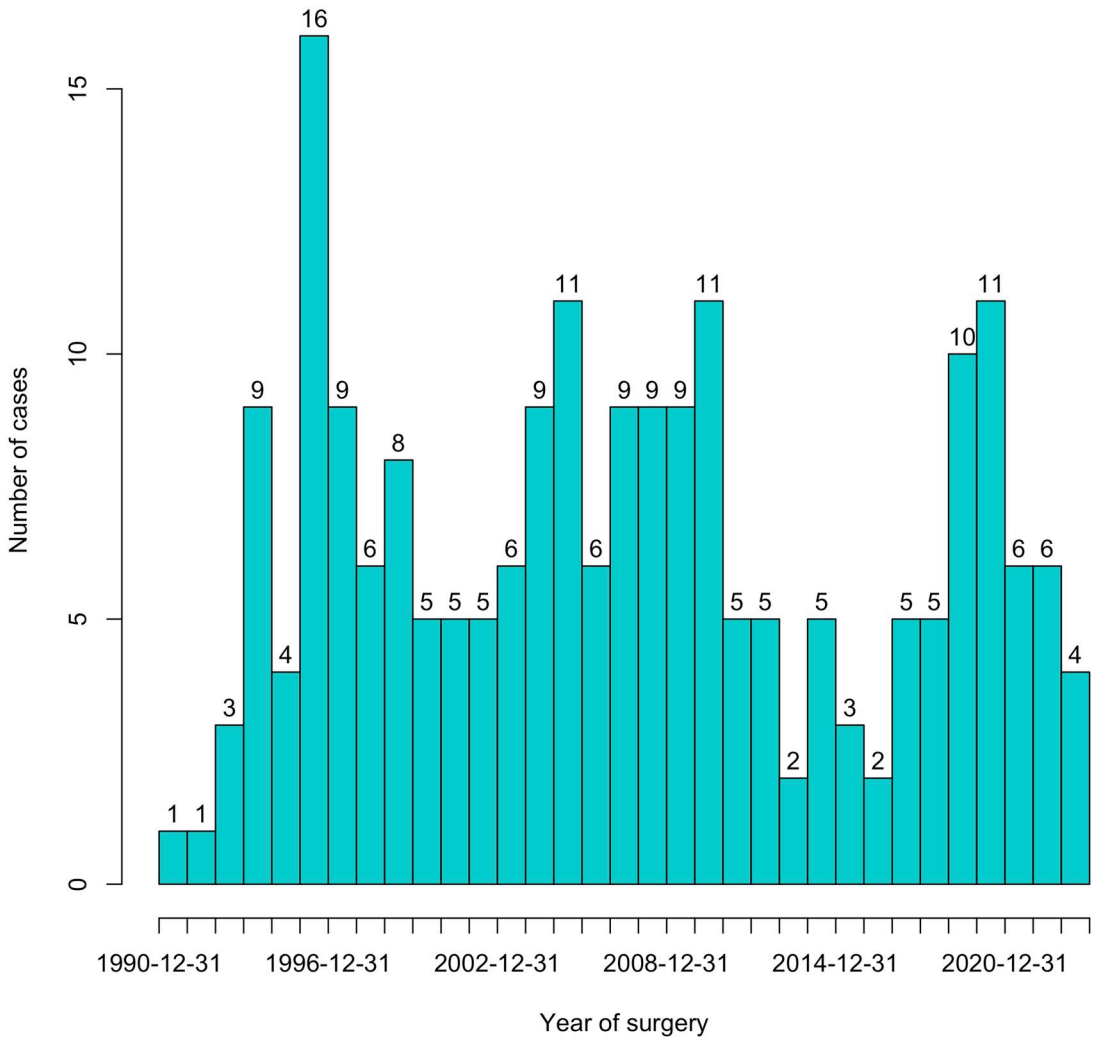

Figure 2: Histogram showing the number of procedures of (laringo-)tracheal resection–anastomosis performed per year at our centre during the study period.

comorbidities, rather than the extent and location of the stenosis, was the only independent predictor of postoperative complications. Unfortunately, because our study covers a long period, we had not enough complete records available to test the effect of systemic comorbidities on the overall complication rate. On the other hand, we found that the length of airway resected was independently associated with an increased risk of postoperative complications (Tables 4 and 5). This finding can be explained by the fact that the length of resection is a well-known risk factor for anastomotic complications [11]. Indeed, anastomotic complications (stenosis or dehiscence) occurred only in a minority of patients in our study (19 patients); however, we postulate that also other surgical complications (oedema, granulations, vocal fold paralysis, wound-related problems) relate more or less directly with the complexity of the procedure and, thus, the length of airway resected.

Another aim of this study was to verify whether there were significant changes in indications, surgical variables or outcomes over the study period. We found that patients tended to be older in the latest part of our experience, which is consistent with similar experience of other authors [9]; and that no patient with idiopathic tracheal stenosis underwent surgery from 2007 to 2023. It should be noted that this finding is not explained by a change in our management strategy of patients affected by idiopathic tracheal stenosis. This has consisted in offering the endoscopic approach with dilations to those patients where there is still evidence of active disease with inflammation, and surgery to those patients with stable disease and a significant, persistent stenosis. Unfortunately, we did not collect data of patients who were referred to our centre for tracheal or laryngotracheal stenosis but did not undergo surgery. However, it is the authors' impression that, during the latest half of our experience, the majority of patients with idiopathic tracheal stenosis eventually stabilized with a sufficient airway lumen after 1 or more endoscopic dilations.

The postoperative results in the 2 halves of our experience, on the other hand, were substantially the same in terms of overall and major morbidity, while median hospital stay was shorter. These results confirm that, in experienced centres, the rate of major complication after (laryngo-)tracheal resection-anastomosis is low, as well as the rate of surgical failures.

Table 6: Comparison of baseline, intraoperative and postoperative variables according to surgical era

Variable	Surgical era		*P*-value
	From 1990 to 2006 ($n = 104$)	From 2007 to 2023 ($n = 107$)	
Age (years), median (IQR)	35 (22–54)	47 (27–60)	0.004
Gender, *n* (%)			0.140
Female	38 (36.5%)	28 (26.2%)	
Male	66 (63.5%)	79 (73.8%)	
Aetiology, *n* (%)			0.001
Iatrogenic	90 (87.4%)	105 (100.0%)	
Idiopathic	13 (12.6%)	0 (0.0%)	
Length (mm), median (IQR)	25 (20–30)	25 (20–30)	0.752
Cotton-Myer grade, *n* (%)			0.911
I to II	51 (57.3%)	58 (59.2%)	
III to IV	38 (42.7%)	40 (40.8%)	
Preoperative treatments, *n* (%)			
Endoscopic dilations	53 (55.2%)	46 (49.5%)	0.519
Endotracheal stents	18 (17.3%)	18 (16.8%)	1.000
Tracheostomy	60 (57.7%)	69 (64.5%)	0.384
Surgical approach, *n* (%)			0.656
Cervicotomy	97 (93.3%)	97 (90.7%)	
Other	7 (6.7%)	10 (9.3%)	
Surgical procedure, *n* (%)			0.135
Tracheal R/A	68 (65.4%)	81 (75.7%)	
Laryngotracheal R/A	36 (34.6%)	26 (24.3%)	
Release manoeuvres, *n* (%)	5 (4.8%)	9 (8.4%)	0.438
Overall morbidity, *n* (%)	30 (28.8%)	28 (26.2%)	0.778
Major morbidity, *n* (%)	10 (9.6%)	13 (12.1%)	0.712
Glottic oedema, *n* (%)	12 (11.5%)	5 (4.7%)	0.114
Re-stenosis, *n* (%)	4 (3.8%)	6 (5.6%)	0.781
Dehiscence, *n* (%)	6 (5.8%)	3 (2.8%)	0.468
Postop. stay (days), median (IQR)	11 (9–16)	9 (8–11)	<0.001

IQR: interquartile range; R/A: resection–anastomosis.

CONCLUSION

Tracheal and or laryngotracheal resection–anastomosis for benign airway stenosis is a safe and effective procedure, when performed by experienced centres, leading to low morbidity and mortality rates. The length of the resected airway segment is an independent risk factor for postoperative complications. Over time, we observed an increase in the median age of patients, while no patient with idiopathic tracheal stenosis was operated on in the second half of our experience. Finally, in this series,

Table 7: Overview of complication and overall success rate in more recent case series of (laringo-) tracheal resection–anastomosis

First author [ref]	Publication year	*n* pts	Laryngotracheal resection (%)	Overall morbidity (%)	Overall success (trach- or stent-free airway) (%)
Wright [8]	2019	392	23	33	93
Schweiger [17]	2021	165	55	18.7	–
Maurizi [10]	2021	228	100	9.6	98.7
Slama [18]	2021	66	45.5	–	100
Fiz[a] [9]	2023	267	64	38.2	96.3
Current study		211	29.4	27.5	97.2

[a]Multicentre study.

there were no major differences in intraoperative or postoperative outcomes over time.

Funding

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Conflict of interest: none declared.

DATA AVAILABILITY

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

Author contributions

Marco Mammana: Conceptualization; Data curation; Investigation; Methodology; Writing—original draft. **Vincenzo Verzeletti:** Conceptualization; Data curation; Investigation; Methodology; Writing—original draft. **Matteo Baldi:** Conceptualization; Data curation; Investigation; Methodology; Writing—original draft. **Marco Schiavon:** Conceptualization; Data curation; Investigation; Supervision; Validation; Visualization; Writing—review & editing. **Andrea Dell'Amore:** Conceptualization; Data curation; Investigation; Supervision; Validation; Writing—review & editing. **Federico Rea:** Conceptualization; Data curation; Investigation; Supervision; Validation; Writing—review & editing.

Reviewer information

European Journal of Cardio-Thoracic Surgery thanks Toru Bando, Juan L. Anton-Pacheco, John R Benfield and the other, anonymous reviewer for their contribution to the peer review process of this article.

REFERENCES

[1] Ravikumar N, Ho E, Wagh A, Murgu S. The role of bronchoscopy in the multidisciplinary approach to benign tracheal stenosis. J Thorac Dis 2023;15:3998–4015.
[2] Piazza C, Lancini D, Filauro M, Sampieri C, Bosio P, Zigliani G et al Post-COVID-19 airway stenosis treated by tracheal resection and anastomosis: a bicentric experience. Acta Otorhinolaryngol Ital 2022; 42:99–105.
[3] Aziz J, Murthy R. Idiopathic tracheal stenosis and hormone receptors. J Thorac Dis 2023;15:4146–7.
[4] Quinn KA, Gelbard A, Sibley C, Sirajuddin A, Ferrada MA, Chen M et al Subglottic stenosis and endobronchial disease in granulomatosis with polyangiitis. Rheumatology (Oxford) 2019;58:2203–11.
[5] Schweipert J, Riediger C, Balandat JE, Bonkowsky V, Kahlert C, Kraus D. The role of local expression of hormone receptors in the genesis of idiopathic tracheal stenosis. J Thorac Dis 2023;15:2948–57.
[6] Timman ST, Schoemaker C, Li WWL, Marres HAM, Honings J, Morshuis WJ et al Functional outcome after (laryngo)tracheal resection and reconstruction for acquired benign (laryngo)tracheal stenosis. Ann Cardiothorac Surg 2018;7:227–36.
[7] Galluccio G, Lucantoni G, Battistoni P, Paone G, Batzella S, Lucifora V et al Interventional endoscopy in the management of benign tracheal stenoses: definitive treatment at long-term follow-up. Eur J Cardiothorac Surg 2009;35:429–33; discussion 933–4.
[8] Wright CD, Li S, Geller AD, Lanuti M, Gaissert HA, Muniappan A et al Postintubation tracheal stenosis: management and results 1993 to 2017. Ann Thorac Surg 2019;108:1471–7.
[9] Fiz I, Filauro M, Sampieri C, Ioppi A, Vallin A, Fiz F et al Analysis of complications in (crico-)tracheal resection anastomosis in adults: a multicenter study. Laryngoscope 2023;133:2910–9.
[10] Maurizi G, Vanni C, Rendina EA, Ciccone AM, Ibrahim M, Andreetti C et al Surgery for laryngotracheal stenosis: Improved results. J Thorac Cardiovasc Surg 2021;161:845–52.
[11] Wright CD, Grillo HC, Wain JC, Wong DR, Donahue DM, Gaissert HA et al Anastomotic complications after tracheal resection: prognostic factors and management. J Thorac Cardiovasc Surg 2004;128:731–9.
[12] Rea F, Callegaro D, Loy M, Zuin A, Narne S, Gobbi T et al Benign tracheal and laryngotracheal stenosis: surgical treatment and results. Eur J Cardiothorac Surg 2002;22:352–6.
[13] Myer CM, O'Connor DM, Cotton RT. Proposed grading system for subglottic stenosis based on endotracheal tube sizes. Ann Otol Rhinol Laryngol 1994;103:319–23.
[14] Dalar L, Karasulu L, Abul Y, Özdemir C, Sökücü SN, Tarhan M et al Bronchoscopic treatment in the management of benign tracheal stenosis: choices for simple and complex tracheal stenosis. Ann Thorac Surg 2016;101:1310–7.
[15] Clavien PA, Sanabria JR, Strasberg SM. Proposed classification of complications of surgery with examples of utility in cholecystectomy. Surgery 1992;111:518–26.
[16] Dindo D, Demartines N, Clavien P-A. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann Surg 2004;240:205–13.
[17] Schweiger T, Evermann M, Roesner I, Frick A-E, Denk-Linnert D-M, Klepetko W et al Laryngotracheal resection can be performed safely without a guardian chin stitch – a single-centre experience including 165 consecutive patients. Eur J Cardiothorac Surg 2021;60:402–8.
[18] Slama A, Zaatar M, Demir M, Okumus O, Mattheis S, Kampe S et al Tracheal resection after previous treatment provides comparable outcome to primary surgery. Thorac Cardiovasc Surg 2022;70:505–12.
[19] Karush JM, Seder CW, Raman A, Chmielewski GW, Liptay MJ, Warren WH et al Durability of silicone airway stents in the management of benign central airway obstruction. Lung 2017;195:601–6.