The Journal of Laryngology & Otology (2017), ***131***, *447–454*.

doi:10.1017/S0022215117000378

MAIN ARTICLE

End-to-end anastomosis in the management of laryngotracheal defects

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Abstract

Objective: To present clinical experience and surgical outcomes of end-to-end anastomosis in the management of laryngotracheal stenosis and tracheal defects following invasive thyroid malignancy resection.

Methods: A retrospective analysis was performed of 14 patients with laryngotracheal stenosis and tracheal invasive thyroid malignancy. All patients underwent tracheal or cricotracheal resection and primary end-to-end anastomosis.

Results: Length of stenosis was 1.7–4 cm. Stenosis was classified as Myer and Cotton grade II in 4 patients, grade III in 6 and grade IV in 2. Surgical procedures included tracheotracheal end-to-end anastomosis ($n = 4$), cricotracheal anastomosis ($n = 2$) and thyrotracheal anastomosis ($n = 6$). Patients with invasive thyroid malignancy underwent segmental resection of the involved segment with tumour-free margins, and tracheal or cricotracheal end-to-end anastomosis. Successful decannulation was achieved in 13 patients (93 per cent). Post-operative complications were: wound infection ($n = 1$), subcutaneous emphysema ($n = 1$), temporary unilateral vocal fold palsy ($n = 1$), granulation tissue development ($n = 1$), and restenosis ($n = 2$).

Conclusion: End-to-end anastomosis can be used safely and successfully in the management of advanced laryngotracheal stenosis and wide laryngotracheal defects. Greater success can be achieved using previously described surgical rules and laryngotracheal release manoeuvres.

Keywords: Airway Obstruction; Tracheal Stenosis; Acquired Subglottic Stenosis

Introduction

Laryngotracheal stenosis is defined as a partial or complete cicatricial narrowing of the endolarynx and trachea.[1] The larynx has a complex structure and function, and thus the surgical management of laryngotracheal stenosis is very complex and has been a major challenge for surgeons. The increasing incidence of this pathological condition may be related to the use of nasal or orotracheal intubation.[2] The management strategy may include endoscopic dilatation, stent placement, laser treatment, tracheostomy, and surgical resection of the stenotic segment and reconstruction. Following the works of Grillo and Pearson, surgical resection of the stenotic segment with primary anastomosis is considered the procedure of choice because of its high success rate (71–95 per cent) and minimal morbidity.[3,4]

In this retrospective study, we report our reconstruction experience of laryngotracheal defects following stenosis and invasive thyroid carcinoma resections. The major goal of these management practices is to provide a free airway without tracheostomy.

Materials and methods

Patients

This study involved a retrospective analysis of patients who underwent open laryngotracheal surgery between January 2011 and December 2014 at the Department of Otorhinolaryngology, Head and Neck Surgery, Cerrahpasa Medical Faculty (Istanbul, Turkey). Fourteen patients were included in the study, eight males (57 per cent) and six females (43 per cent). The average age of patients was 29.9 years (range, 3–67 years) (Table I). All patients in the study were referred to our advanced head and neck clinics with laryngotracheal stenosis or thyroid malignancy that invaded the laryngotracheal framework. The patients were evaluated pre-operatively and a surgical plan was made accordingly.

Pre-operative evaluation

The clinical pre-operative evaluation included a detailed history and physical examination. Data on previous treatments were collected. The patients were

Accepted for publication 1 December 2016 First published online 13 March 2017

TABLE I
GENERAL CHARACTERISTICS OF STUDY POPULATION

Pt no.	Age (years)	Gender	Aetiology	Stenosis duration (months)	Intubation duration (days)	Stenosis Myer & Cotton grade	Stenosis length (cm)	Distance to vocal folds (cm)	Vocal fold mobility	Operation	Time to decannulation (days)	Post-surgery complications or symptoms	Previous laryngo-tracheal operations
1	11	F	Intubation	16	16	III	2	3	Unilateral paralysis	Tracheal resection	5	Subcutaneous emphysema	None
2	66	F	Intubation	8	21	II	1.9	3	Bilateral mobile	Tracheal resection	15	None	None
3	3	M	Intubation	24	75	II	2.2	1	Bilateral mobile	Cricotracheal resection	4	Wound infection, dysphonia	Laser
4	17	F	Intubation	6	9	III	3	3	Bilateral mobile	Tracheal resection	5	Granulation	None
5	28	F	Intubation	23	19	II	2.4	2	Bilateral mobile	Cricotracheal resection	23	Dysphonia	None
6	36	M	Intubation	6	12	III	3.2	2	Bilateral mobile	Tracheal resection	1	None	Dilatation
7	10	M	Intubation	6	10	II	3	2.4	Bilateral mobile	Cricotracheal resection	0	None	None
8	67	F	Intubation	8	13	III	1.8	1.2	Bilateral mobile	Cricotracheal resection	20	Dysphonia	None
9	7	M	Intubation	72	40	III	3.5	0.3	Bilateral mobile	Cricotracheal resection	3 following 2nd operation	Restenosis, dysphonia	Laser
10	20	M	Intubation	36	16	III	1.7	3.3	Bilateral mobile	Tracheal resection	8	Positional dyspnoea	None
11	45	M	Intubation	12	45	IV	4	2.3	Bilateral paralysis	Tracheal resection	Not decannulated	Restenosis	Laser
12	19	M	Intubation	8	16	IV	2.6	2.8	Bilateral mobile	Cricotracheal resection	3	Temporary unilateral vocal fold palsy	None
13	48	F	Tracheal resection for thyroid malignancy	None	None	None	4	1.3	Unilateral paralysis	Cricotracheal resection	42	None	None
14	42	M	Tracheal resection for thyroid malignancy	None	None	None	3.5	3	Bilateral mobile	Tracheal resection	33	None	None

Pt no. = patient number; F = female; M = male

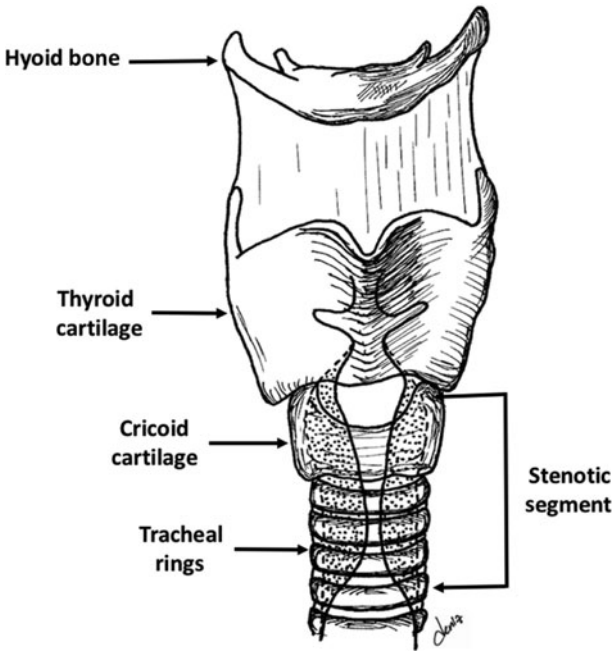

FIG. 1
Examination of the airway to evaluate the stenotic segment.

evaluated endoscopically and using computed tomography (CT), in order to determine the length of the stenotic segment, distance to vocal folds and mobility of the vocal folds. The stenosis was graded in accordance with the Myer and Cotton grading scale. This system classifies stenosis severity on the basis of airway obstruction, as follows: grade I = 0–50 per cent obstruction; grade II = 50–70 per cent obstruction; grade III = 70–99 per cent obstruction; and IV = complete obstruction.[5]

Patients with suspected thyroid malignancy with laryngotracheal invasion were admitted to our clinic with symptoms of dyspnoea and swelling on the anterior region of the neck. Following ultrasonography imaging, fine needle aspiration biopsy was performed to confirm invasive thyroid malignancy.

Surgical procedure

The surgical procedure for the laryngotracheal stenosis was selected according to stenosis location, cricoid cartilage involvement and vocal fold mobility. All patients underwent surgery under general anaesthesia. Orotracheal or endotracheal intubation was performed under general anaesthesia and the patients were positioned with their neck hyperextended. Before surgery, all patients were re-evaluated to confirm the location and grade of stenosis.

A cervical collar incision was performed and skin flaps were elevated for exploration. Strap muscles were dissected from the midline to visualise the larynx and trachea. The vertical incision was performed on the side of the stenotic segment and the laryngotracheal lumen was entered. Airway examination was

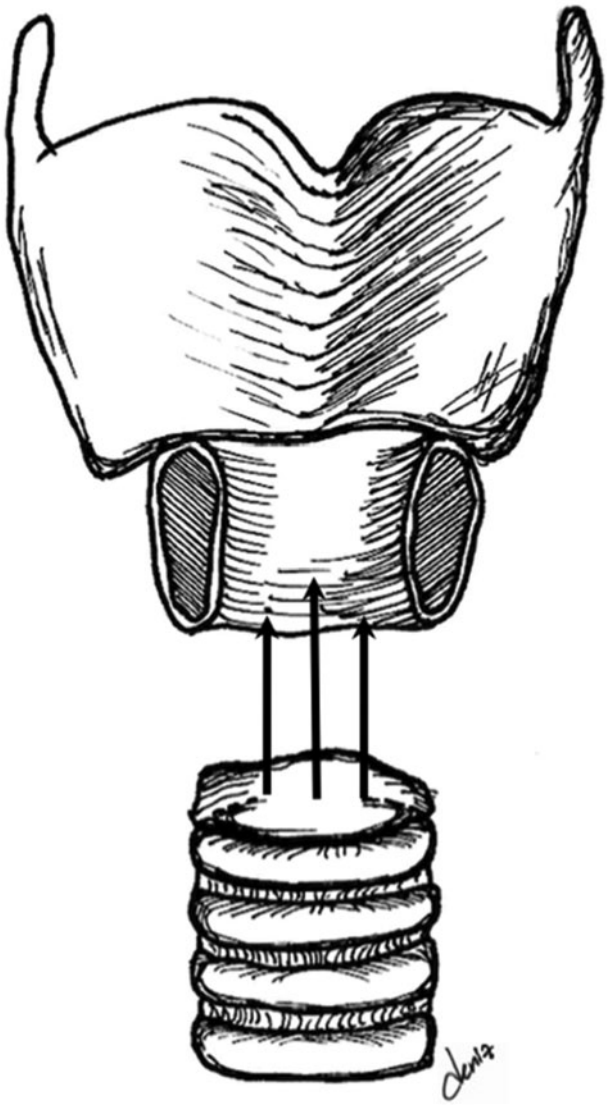

FIG. 2
Pearson-type operation; the anterolateral cricoid cartilage was resected and posterior cricoid cartilage was preserved to protect recurrent laryngeal nerve function.

performed for re-evaluation of the stenotic segment and cricoid cartilage (Figure 1).

If the stenosis involved only the tracheal mucosa inferior to the cricoid cartilage, segmental tracheal resection that included the stenotic segment and primary anastomosis of the proximal and distal ends of trachea were performed. If the stenosis was in the subglottic region and involved the mucosa of the cricoid cartilage, the surgical techniques described by Pearson *et al.*[6] or Grillo[7] were applied. For lesions that involved the mucosal surface of the anterior cricoid cartilage, a Pearson-type operation was performed. In this procedure, the anterolateral cricoid cartilage was resected, thus preserving the posterior cricoid plate to protect recurrent laryngeal nerve function (Figure 2). If the subglottic stenosis was circumferential and affected the posterior wall of the larynx, a Grillo-type operation was preferred. In this procedure, the involved mucosa and submucosa over the posterior

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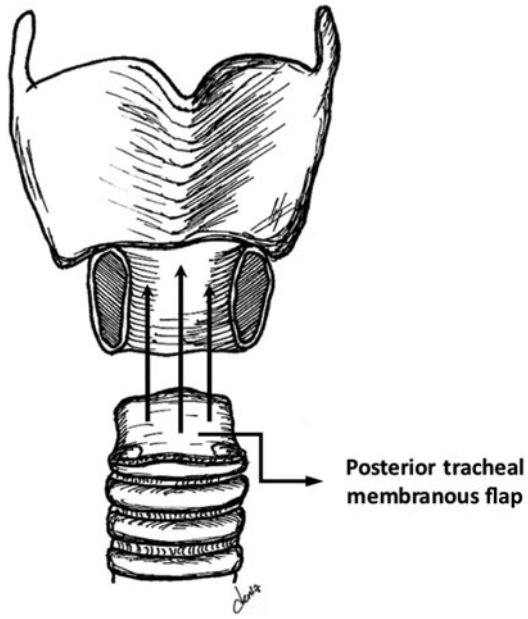

FIG. 3
Grillo-type operation; the involved mucosa and submucosa over the posterior lamina of cricoid cartilage were resected, and cartilage of the posterior lamina was preserved. A tracheal membranous flap was prepared.

lamina of cricoid cartilage was resected, thereby preserving the cartilaginous framework of the posterior lamina (Figure 3).

A tracheal membranous flap was prepared to provide complete mucosal coverage, and thyro-tracheal anastomosis was performed (Figures 4 and 5). For a tension-free anastomosis, tracheal release was carried out using blunt dissection. If tracheal mobilisation is not sufficient to provide tension-free anastomosis, laryngeal release manoeuvres may be performed by releasing the suprahyoid or infrahyoid muscles.

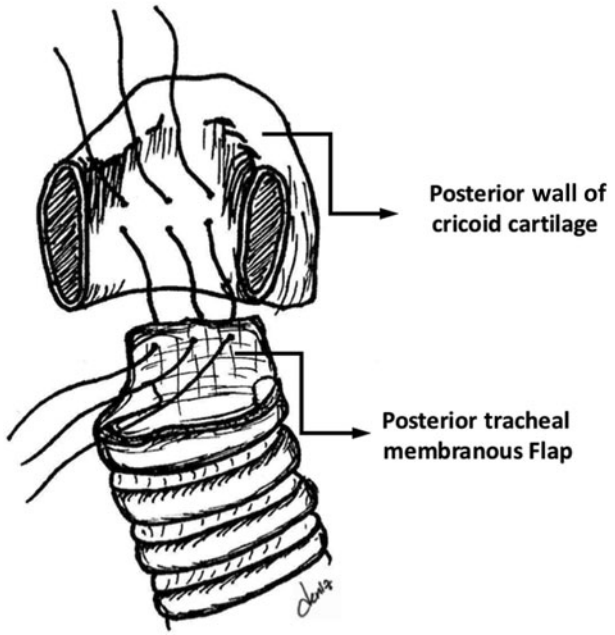

FIG. 4
A tracheal membranous flap was tailored to the posterior lamina of the cricoid cartilage.

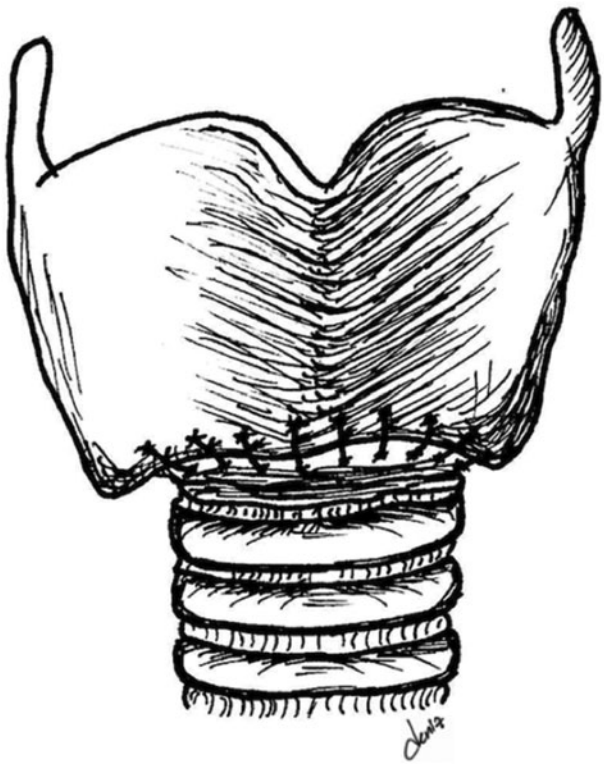

FIG. 5
Anastomosis was performed.

After stenosis resection and release manoeuvres, anastomosis was carried out with 4–0 absorbable sutures.

For patients with advanced thyroid malignancy, appropriate surgery was performed for the malignancy. Invasion areas in the cricothyroidal and tracheal region were resected with tumour-free margins. After resection, the trachea was released from its adjacent tissue. Cricotracheal anastomosis was conducted in one of the patients and thyrotracheal anastomosis was performed in the other.

In the post-operative period, prophylactic systemic antibiotherapy for aerobic and anaerobic pathogens was administered to all patients for 7 days, and flexible endoscopic follow-up examinations were performed.

Results

Table I presents the general characteristics of the study population. The indication for surgery in 12 patients (86 per cent) was laryngotracheal stenosis. The remaining two patients (14 per cent) underwent laryngotracheal resection because of tracheal invasive thyroid malignancy. In the patients with laryngotracheal stenosis, the most common aetiological factor was prolonged tracheal intubation in the intensive care unit, because of trauma (in eight patients (67 per cent)) and respiratory tract infection (in two patients (17 per cent)) (Table II). The duration of intubation in the

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TABLE II
CAUSES OF PROLONGED INTUBATION

Cause	Patients (*n*)
Trauma	8
Respiratory failure	2
Stroke	1
Status epilepticus	1

intensive care unit ranged from 9 to 75 days (average of 24 days). All patients with stenosis had previously undergone tracheostomy because of severe dyspnoea.

At the initial evaluation, vocal fold mobility was normal in all but three cases, two of which had unilateral paralysis and the other had bilateral vocal fold paralysis.

One patient had previously undergone endoscopic dilatation and three patients had undergone endolaryngeal laser treatment for the stenosis.

In our series, stenosis was classified as Myer and Cotton grade II in four patients (33 per cent), grade III in six (50 per cent) and grade IV in two (17 per cent). The stenosis length was less than 2 cm in three patients (25 per cent), and between 2 and 4 cm in nine patients (75 per cent). The stenotic segment was located at the cricotracheal region in six patients and at the trachea in six patients. The distance of the stenotic segments from the vocal folds ranged between 0.3 and 3.3 cm, with an average distance of 2.2 cm. The length of stenosis varied between 1.7 and 4 cm, with an average length of 2.7 cm.

Tracheal resection and cricotracheal anastomosis ($n = 2$) or tracheotracheal anastomosis ($n = 4$) were performed in six patients with tracheal stenosis. Cricotracheal resection and thyrotracheal anastomosis were performed in six patients with subglottic laryngeal and upper tracheal stenosis. In three of these patients, the stenosis involved the anterior and lateral arcs of the cricoid cartilage, and a Pearson-type operation was performed. The remaining three patients had circumferential cricoidal and tracheal stenosis, for which a Grillo-type operation was performed. In one of these patients, the stenotic segment was observed (during surgery) to involve the lower part of the thyroid cartilage. In this case, the fibrotic area was excised and thyrotracheal end-to-end anastomosis was performed, thus preserving the posterior lamina of the cricoid cartilage. In the post-operative follow-up period, restenosis was detected; segmental resection from the thyroid cartilage, 2 mm below the vocal folds, was performed in the revision surgery along with thyrotracheal re-anastomosis. In another patient who had bilateral vocal fold palsy pre-operatively, laser arytenoidectomy was simultaneously performed during thyrotracheal anastomosis.

In cases with invasive thyroid malignancy, CT scans demonstrated tracheal invasion (2.6 cm) in one patient and cricotracheal invasion (3.1 cm) in another who had unilateral vocal fold palsy pre-operatively. The involved laryngotracheal segments were located 3 cm and 1.3 cm from the vocal folds, respectively. These patients were treated with segmental resection of the involved segment, with tumour-free margins, and tracheal or cricotracheal end-to-end anastomosis was performed.

The post-operative complications of the patients were: wound infection ($n = 1$), subcutaneous emphysema ($n = 1$), temporary unilateral vocal fold palsy ($n = 1$), granulation tissue development ($n = 1$) and restenosis at the site of anastomosis ($n = 2$) (Table III). Inhaled and systemic steroids were successfully used for the treatment of granulation tissue. One of the patients with restenosis was re-operated on and revision end-to-end anastomosis was performed. The patient was successfully decannulated after the second operation.

Successful decannulation was achieved in 93 per cent of the patients. One patient who had pre-operative bilateral vocal fold palsy remains tracheostomy-dependent because of restenosis. Seven patients were decannulated within 5 days of surgery, and decannulation was delayed between 8 and 42 days in the remainder. The two patients who underwent surgery for thyroid malignancy were successfully decannulated after radioactive iodine treatment (after 33 and 42 days).

After an average of six months after decannulation, nine patients (64.2 per cent) remained asymptomatic, four (28.5 per cent) had dysphonia and one (7.1 per cent) had positional dyspnoea with head hyperflexion; no patients required tracheostomy or revision surgery.

Discussion

Laryngotracheal stenosis is one of the most difficult conditions to manage in the field of otolaryngology. Its diagnosis and treatment remains a challenge. Management of these patients requires a multidisciplinary approach by experienced centres. The disease process is complex, and treatment must be tailored according to factors such as the degree, length and location of stenosis, the presence of tracheomalacia, and laryngeal function. Treatment options for laryngotracheal stenosis include endoscopic procedures such as dilatation, laser and stents, and open surgical procedures such as resection and end-to-end anastomosis, or the application of different grafts. In cases with an

TABLE III
POST-OPERATIVE COMPLICATIONS

Complications	*n*
Early complications	
– Subcutaneous emphysema	1
– Wound infection	1
– Temporary unilateral vocal fold palsy	1
Late complications	
– Granulation tissue	1
– Restenosis	2

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appropriate indication, end-to-end anastomosis is one of the most successful treatments, with high decannulation rates.[8] In this study, we report a series of 14 patients who underwent tracheal or cricotracheal resection and end-to-end anastomosis for the treatment of laryngotracheal stenosis and thyroid malignancies invading the laryngotracheal region. We achieved a 93 per cent successful decannulation rate in our study population.

Laryngotracheal stenosis most frequently occurs secondary to prolonged intubation. Although the rates tend to decrease with the use of endotracheal tubes with low pressure, stenosis is still a major problem in intensive care units. Tracheal stenosis mostly develops around the cuff of the tube. The incidence of stenosis after tracheostomy or laryngotracheal intubation ranges from 0.6 to 21 per cent.[2,3,4,9] Some recent studies reported that other common causes of laryngotracheal stenosis were blunt cervical injury, strangulation and penetrating injuries of the neck.[10,11] Consistent with previous reports, the most common aetiological factor of laryngotracheal stenosis in our series was prolonged intubation. Intubation duration in our study group ranged from 9 to 75 days. There is no exact evidence about the timing of tracheostomy for intubated patients. Most authors who work in laryngeal reconstruction agree that 7–10 days of intubation is enough for laryngotracheal injury.[11,12] Ninety-two per cent of our patients were intubated for more than 10 days. Our findings support the idea that 7–10 days is the optimal maximum period for tracheostomy. According to our clinical experience, patients who have a tracheostomy at the correct anatomical location and appropriate cuff monitoring develop laryngotracheal stenosis less frequently.

Pre-operative detailed clinical, endoscopic and radiological evaluation of patients provides the basis for the surgery. Our pre-operative evaluation of the patients included flexible endoscopic examination of the larynx and CT imaging of the neck, to define the location and grade of the stenosis, the vocal fold mobility, and the distance of stenosis to the vocal folds. Radiological imaging confirms the exact location and length of the stenosis, aids assessment of cartilaginous structures, and enables evaluation of the larynx and trachea in patients with thyroid malignancies.

Surgical management of stenosis depends on different factors such as grade, site and duration of stenosis. Patients with grade I–II, recent stenosis and a strong cartilaginous framework can be treated endoscopically.[13] Conservative treatment options may be dictated in some situations, such as when the stenosis is shorter than 1 cm in length with no circumferential scarring, or if the patient has poor general medical health.[14] Advanced stenosis or previous unsuccessful treatments may indicate open surgery. However, some studies suggest that surgical treatment may actually increase the degree of stenosis.[15] Open surgery conducted following the failure of endoscopic or conservative treatment modalities may be challenging.

The timing of the surgery is also important to achieve successful results. Surgery should be delayed in clinically stable patients until inflammation has regressed and the scarring process has stabilised.[16] Generally, appropriate indications and optimal timing of surgery are important predictors of outcome.[17] In our series, none of the patients underwent surgery earlier than 6 months following stenosis onset, with an average 19-month history of stenosis. In addition, as per our protocol for advanced stenosis management, we preferred open surgery that included resection of the stenotic segment, with end-to-end anastomosis.

Single-stage resection of the stenotic segment with concomitant end-to-end anastomosis is a complex procedure. The recurrent laryngeal nerves must be protected during dissection, and the anastomosis should be performed with minimal tension. This can be achieved by laryngeal release and/or mobilisation of the trachea. Our first aim was to perform secure and tension-free anastomosis through mobilisation of the trachea using blunt dissection, because laryngeal release may cause post-operative swallowing problems. We successfully achieved tension-free anastomosis in all our patients. Tracheal mobilisation without the need of laryngeal release was successfully accomplished because the average length of stenosis in our patients was relatively short.

The most common complication of excessive tension at the anastomosis site is the formation of granulation tissue, which may result in restenosis. The other complication of excessive tension is dehiscence at the anastomosis site. Thus, surgical release manoeuvres for the trachea and larynx, such as blunt mobilisation of the trachea, cervical flexion and suprahyoid release, have crucial importance for surgical success. The length of the resected tracheal segment is also important for tension-free anastomoses. A study performed on cadavers to determine the upper limit of safe tracheal resection in humans reported that a 6.68 cm resection of the trachea can be achieved safely.[18] Grillo *et al*. reported that the maximum length of tracheal resection with safe anastomosis was 6.4 cm.[19] Consistent with these studies, we resected an average of a 2.7 cm segment in our patients, and there was no suture dehiscence or other findings of excessive tension.

The location of stenosis or laryngotracheal defect is also important for the success of the anastomosis and decannulation. The management of subglottic or glottic stenosis is more challenging than that of tracheal stenosis, because the larynx has a more complex structure and function than the trachea. Preserving the recurrent laryngeal nerves is more difficult during subglottic stenosis surgery and needs more careful dissection because the recurrent laryngeal nerves enter the larynx at the thyrocricoid junction. Preserving the posterior cricoid plate during surgery has crucial importance for protecting the recurrent laryngeal nerves. Pearson *et al*. described the removal of the anterior

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and lateral cricoid arch, thus preserving the cricoid plate to protect the recurrent laryngeal nerves in patients when the stenosis involved tracheal mucosa at the cricoid cartilage level, with a normal laryngeal ventricle and mobile vocal folds.[6] In our series, three patients had anterolateral cricoid stenosis; resection of stenotic segments was performed by preserving the posterior lamina of the cricoid cartilage.

Grillo, a pioneer in laryngotracheal surgery, successfully treated 80 patients by performing an oblique resection of the cricoid cartilage and preparing a membranous tracheal wall flap to resurface the cartilage.[7] In this procedure, Grillo described a method in patients with circumferential cricoid stenosis in which an anterior and lateral arc of the cricoid was resected and extended over the mucosa of the posterior cricoid lamina, thereby preserving the posterior plate. The bare cartilage plate was resurfaced using a membranous flap prepared from the distal end of the trachea. This procedure was performed in three of our patients with laryngotracheal stenosis. We believe that preserving the posterior cricoid plate is crucial to achieve a strong cartilaginous framework and stable larynx, and it protects the laryngeal nerves.

In our series, seven patients (six with laryngotracheal stenosis and one with thyroid malignancy) were treated with partial cricoidectomy with cricotracheal resection. The average distance of the defect from the glottis in these patients was 1.4 cm, ranging from 0.3 to 2.3 cm. In patients with stenosis that affects the cricoid cartilage, the cricoid resection should be advanced in the subperichondrial plane to secure the recurrent nerves. Partial thyroid cartilage resection was performed during revision surgery in one patient who underwent cricoid resection during the primary surgery.

Release manoeuvres should be performed to achieve tension-free anastomoses. This can be achieved via mobilisation of the trachea, larynx or both. Tracheal mobilisation can be conducted using careful blunt dissection. Laryngeal release can be performed by resecting the infrahyoid or suprahyoid muscles. The suprahyoid release technique described by Montgomery in 1974 is a surgical method in which the genioglossus, mylohyoid and geniohyoid muscles are detached above the hyoid bone.[20] Dedo and Fishman's laryngeal release technique involves dividing the thyrohyoid muscle and membrane.[21]

Laryngeal release manoeuvres may cause swallowing and phonation problems in the post-operative period. For these reasons, our first choice was to perform tracheal release using blunt dissection. In selected patient groups with relatively short defects, the release and mobilisation of the trachea should be performed, with prevention of laryngeal mobilisation, instead of hyoid and laryngeal release, to protect laryngeal function. In patients who have longer defects for which tracheal release is not sufficient, laryngeal mobilisation is unavoidable and can be performed, while keeping in mind the potential for adverse effects.

When the glottis is involved, surgical interventions to restore or protect a normal airway and glottic functions (including phonation, swallowing and respiration) are required; one of the mainstays in such cases is the protection of at least one recurrent laryngeal nerve. Some authors have used laryngeal stents after scar resection of the interarytenoid region; however, this technique is not enough to provide sufficient glottic space in patients with cricoarytenoid ankylosis.[22] We believe that in patients with advanced stenosis, partial cricoid as well as partial thyroid cartilage resection and end-to-end anastomosis is a viable option, and patients can be successfully decannulated.

End-to-end anastomosis offers decannulation rates ranging from 74 to 97 per cent.[13,16,23,24] This technique is also applicable in cases of laryngotracheal defects following resection of invasive thyroid carcinoma, with high success rates. In our study, the success rate of the operations was 92 per cent in patients with laryngotracheal stenosis and 93 per cent in all patients (n = 14), which included both laryngotracheal stenosis cases (n = 12) and patients with tracheal invasive thyroid malignancy (n = 2), which is consistent with those rates reported in the literature.

- **End-to-end anastomosis is a treatment option for laryngotracheal defects**
- **Detailed pre-operative evaluation and strict compliance with surgical techniques are mandatory for successful outcomes**
- **Tracheal release manoeuvres are important for successful swallowing following end-to-end anastomosis**

Although the surgical results were satisfactory, there are various complications associated with this operation. The most common complications are wound infection, recurrent laryngeal nerve palsy, laryngeal oedema, subcutaneous emphysema, granulation tissue at the anastomosis site and restenosis. In the literature, some studies reported that the most common complication of the procedure was granulation tissue along the suture line.[15,16,25] The complications detected in our series were: subcutaneous emphysema (n = 1), wound infection (n = 1), temporary unilateral recurrent laryngeal nerve palsy (n = 1), granulation tissue at the anastomosis site (n = 1) and restenosis (n = 2) (Table III).

Inappropriate surgical techniques may result in restenosis and the development of excess granulation tissue at the anastomosis site.[3,4,25] Delicate surgical techniques such as release manoeuvres of the larynx and trachea (for decreasing tension of the anastomosis), preserving a disease-free mucosal layer, and suturing the mucosal layer with absorbable materials are crucial for successful results.

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Conclusion

The larynx has a complex structure and function, which complicates the surgical management of laryngotracheal stenosis. End-to-end anastomosis can be safely and successfully used in cases of advanced laryngotracheal stenosis and wide laryngotracheal defects. Greater success can be achieved using previously described surgical rules and laryngotracheal release manoeuvres. This type of surgical approach results in minimal morbidity and high success rates.

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Dr E Karaman takes responsibility for the integrity of the content of the paper
Competing interests: None declared