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Original Article

Tracheal and laryngotracheal resections and reconstructions—a single-centre experience

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Background: Surgical resection has proven to be the most effective long-term treatment in managing airway stenoses and has shown to decrease the risk of tumor recurrence and mortality in patients with tumor infiltration to the airways. However, there are only a few Nordic reports on the results of a tracheal resection (TR) and cricotracheal resection (CTR). This study aimed to evaluate the volume and short-term outcome of TR and CTR at our institution.

Methods: Retrospective review of patients who underwent TR or CTR between 2004 and 2019 at the Helsinki University Hospital (Helsinki, Finland).

Results: Forty-four patients were included, of which 21 (47.7%) underwent surgery for a tumor, whereas 23 (52.3%) were operated for a benign stenosis. The most common tumor type was thyroid carcinoma with tracheal invasion (15.9%). The distance between the upper margin of the stenosis or tumor infiltration and the vocal cords was in median 3 [interquartile range (IQR), 2–5] cm and the median length of resection 2.5 (IQR, 2–3.5) cm. Overall success rate was 75% (no need for reoperation or postoperative intervention). Complications occurred in 20 (45.5%) patients, of which 10 patients were operated for a tumor, and 10 for a benign stenosis.

Conclusions: Tracheal and CTRs were effective in treating tracheal and subglottic stenoses with variable etiology. However, complications were common especially following cricotracheal tumor resections. These procedures show a clear need for further centralization due to their complex nature and should therefore be performed primarily at institutes with highly experienced multi-professional teams.

Keywords: Tracheal resection (TR); cricotracheal resection (CTR); tracheal stenosis; surgery

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Introduction

Tracheal resection (TR) and cricotracheal resection (CTR) are most commonly performed either to manage acquired benign tracheal stenosis and laryngotracheal stenosis or to remove a malignant tumor. Acquired benign tracheal stenosis and acquired benign laryngotracheal stenosis are rare, yet potentially life-threatening conditions that present with various symptoms, most importantly dyspnea and stridor. The most common etiology for benign conditions is an iatrogenic trauma caused by previous prolonged intubation and/or tracheostomy (1-5). Endoscopic interventions, such as dilatation, stenting and laser coagulation are used in the management of early-stage symptoms, but these procedures most of the times provide only temporary relief, and they are associated with high rates of recurrence and need for reinterventions. However, when surgery is contraindicated, endoscopic interventions may provide an acceptable way of treating acquired benign tracheal stenosis and acquired benign laryngotracheal stenosis (1-3,6,7).

Surgical resection has proven to be the most effective long-term treatment in managing airway stenoses, with at its best reported success rates of up to 95% with minimal morbidity, as it provides the opportunity of re-establishing a healthy airway by removing the pathologic section (8-13). TR and CTR are utilized in the treatment of primary tracheal and subglottic tumors. Other indications include tumor infiltrations to the airways from nearby tissues, as well as idiopathic stenoses of the trachea or subglottic region (14-17). TR and CTR have shown to decrease the risk of tumor recurrence and mortality in patients with tumor infiltration to the airways (17).

A survey of TRs and CTRs in Nordic countries in 2019 found that TR and CTR are performed annually at 15 centers in this area (18). There are only a few Nordic studies on the volume and outcome of patients undergoing these operations (13,18-20). Therefore, the current study was carried out with the purpose of evaluating the volume and clinical outcome of TR and CTR performed at our institution, with a focus on the surgical complications involving the trachea and larynx following these procedures. We present the following article in accordance with the STROBE reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-21-1963/rc).

Methods

We conducted a single-centre retrospective cohort study. All patients who underwent a TR, CTR or carinal resection at the Helsinki University Hospital (Helsinki, Finland) between November 2004 and August 2019 were included in the study. Data collection was performed by reviewing electronic patient records. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study protocol was approved by the Institutional Review Board of Helsinki University Hospital (IRB No. HUS/141/2020). The requirement for patient consent was waived due to the retrospective nature of the study.

The collected data included patient characteristics [age, gender, body mass index (BMI), smoking status, alcohol consumption, comorbidities], previous oncological treatment, tracheal or laryngotracheal interventions, characteristics of the stenosis, information of the tumor, prior treatment, preoperative symptoms, site, grade, surgical access, length of resection, pre- and postoperative tracheostomy, extubation, length of intensive care and hospitalization, complications and follow-up findings. The site of stenosis was measured from vocal cords in centimeters (cm). The severity of the stenosis was retrospectively graded using the Cotton-Myer classification (21).

Preoperative evaluation of all the patients diagnosed with stenosis included a computed tomography scan of the thorax and most of them also underwent a flexible bronchoscopy well in advance in order to classify the characteristics of the stenosis. As this study also included patients who underwent a TR due to conditions other than stenosis (e.g., trauma, malignant tumor, infection), a bronchoscopy was not conducted on all patients preoperatively but at the time of surgery. The data for postoperative complications were collected by reviewing records from the date of surgery until the last follow-up visit related to the airway resection. The complications were retrospectively graded using the Clavien-Dindo classification (22). Postoperative success was defined as the patient not requiring reoperation or postoperative interventions.

Statistical analysis

Continuous data are expressed as median and interquartile range (IQR), as none of the variables were normally distributed. Categorical data are summarized as proportions and percentages. Differences between two groups in continuous variables were compared with the Mann-Whitney U test and in categorical variables with the Chi-squared test. Statistical analyses of patient and stenosis characteristics as well as treatment factors were performed

to identify potential factors predicting treatment failure or high incidence of complications. Data were analyzed using IBM SPSS Statistics (version 25; IBM Corporation, USA).

Surgery

TR and CTR

A transverse cervical incision either with or without partial sternal split was the standard approach for both TR and CTR. Then the dissection was performed directly on the trachea in order to avoid the recurrent laryngeal nerves. Circumferential dissection of the trachea was performed only at the level of pathology and carried a centimeter or two in superior and inferior direction, depending on pathological condition. Two large traction sutures were used to decrease tension on the anastomosis laterally on both sides. The anastomosis was performed with interrupted absorbable sutures tied such that the knots were extraluminal. If possible, the anastomosis was covered anteriorly with a strap muscle flap from the adjacent tissues to enhance the volume of vital tissue and blood supply in that area and to decrease the risk of air leakage. Release maneuvers were utilized when needed. In CTR cases the anterior part of cricoid cartilage was resected with or without resection of cricothyroid membrane depending on the case.

General anesthesia

In most cases, a rigid small caliber (4–4.5 mm) endotracheal tube could be passed through the stricture or placed immediately above it, thus ensuring appropriate ventilation until division of the trachea. Patients with pre-existing tracheostomy were intubated via the stoma, which was later removed *en bloc* with the stenotic segment. Once the anastomotic sutures were placed and before the laryngeal and the tracheal ends approximated, the crossfield intubation was removed and an orotracheal tube was advanced beyond the suture line by the anesthesiologist resuming ventilation. In some cases, in order to avoid local conflict of intubation tube with the surgical equipment, high frequency jet ventilation was utilized. In those cases, the injection catheter was placed at a supraglottic, transglottic or endotracheal level thus minimizing the coverage of the operative field at the time of reconstruction.

Results

During the study period, 44 patients (22 men and 22 women) underwent surgery. The operations were performed by one of three thoracic surgeons in collaboration with an otorhinolaryngologist-head and neck surgeon. Patient characteristics are depicted in *Table 1*.

In total, there were 21 (47.7%) patients with a tumor and 11 (52.3%) of them had stenosis of the airway, which was the most common cause of stenotic airway (11 out of 44) in this series. Histology, indications for surgery, and details of the stenosis are specified in *Table 2*.

Twenty-five patients (56.8%) had a previous bronchoscopic intervention in their medical history, of which eleven patients underwent more than one intervention. These interventions included tracheostomy in 17 (38.6%) patients, dilatation in 9 (20.5%), and stent placement in 4 (9.1%). One patient underwent a laser coagulation. Of the 17 patients who previously had a tracheostomy performed, 4 were tracheostomy dependent on the day of surgery.

There were 7 (15.9%) patients who required a permanent tracheostomy postoperatively. Of these 7 patients, 2 presented with a tracheostomy before surgery, 2 patients required the tracheostomy to be installed during surgery and 3 patients required the tracheostomy postoperatively.

Overview of stenosis, surgery and treatment characteristics are presented in *Table 3*. The distance between the upper margin of the stenosis or tumor infiltration and the vocal cords was in median 3 (IQR, 2–5) cm. The most common surgical access was the neck approach either alone or combined with partial sternotomy, as these were used for 40 (90.9%) patients. The median length of resection was 2.5 (IQR, 2–3.5) cm. One patient required a laryngeal release to reduce tension due to a 5-cm-long resection. Thirty-two (72.7%) of the patients were extubated in the operating room right after surgery. The median length of postoperative intensive care was 1 (IQR, 1–3) days and the median length of postoperative hospitalization was 8.5 (IQR, 7–14.5) days. Nine (20.5%) patients did not require any intensive care.

Although statistical analyses were performed, they did not show any reliable results due to the low volume and heterogenic cohort of patients. Therefore, these analyses were deemed insignificant and were not included in the study.

Complications

Twenty (45.5%) out of the 44 patients suffered from some type of a complication. All the complications are classified in *Table 4*. The patients suffering from complications were categorized into two groups: patients operated for a tumor

Table 1 Patients' characteristics (n=44)

Characteristics	N (%)
Gender	
Female	22 (50.0)
Male	22 (50.0)
Age at surgery (years)	
Median [IQR]	58.5 [48–65]
BMI (kg/m^2)	
Median [IQR]	25.97 [23.25–33.28]
Missing data (patients)	3
Comorbidities	
Yes	28 (63.6)
None	16 (36.4)
Smoking	
Yes	7 (15.9)
Previous (>10 pack years)	14 (31.8)
No	23 (52.3)
Excessive alcohol consumption	
Yes	6 (13.6)
No	38 (86.4)
Oncological treatment for previous cancer	
Yes	9 (20.5)
No	35 (79.5)
Previous interventions	
None	19 (43.2)
Tracheostomy*	13 (29.5)
Dilatation	9 (20.5)
Stent placement	4 (9.1)
Laser coagulation	1 (2.3)
Preoperative airway symptoms	
Cough	7 (15.9)
Coughing up blood	5 (11.4)
Stridor	24 (54.5)
Dysphonia	6 (13.6)
Dyspnea	32 (72.7)
Sleep apnea	6 (13.6)

*, patients were decannulated before undergoing resection. IQR, interquartile range; BMI, body mass index.

Table 2 Indication for surgery, etiology of stenosis and histology of tumor

Indication for surgery	N (%)
Benign stenosis, etiology	23 (53.3)
Tracheostomy	10 (22.7)
Idiopathic	4 (9.1)
Goiter	3 (6.8)
Prolonged intubation	3 (6.8)
Infection of polypropylene mesh*	1 (2.3)
Inflammatory	1 (2.3)
Trauma	1 (2.3)
Histology of tumor	21 (47.7)
Adenoid cystic carcinoma	5 (11.4)
Follicular thyroid carcinoma	5 (11.4)
Squamous cell carcinoma	4 (9.1)
Chondrosarcoma	2 (4.5)
Papillary thyroid carcinoma	2 (4.5)
Carinal carcinoid tumor	1 (2.3)
Glomangioma	1 (2.3)
Papilloma	1 (2.3)

*, placed 20 years prior due to tracheomalacia.

(n=21), and patients operated for a benign stenosis (n=23).

In 12 (27.2%) of the patients, the complications were Clavien-Dindo grade IIIa or higher (22), most of which occurred in patients that underwent a CTR (8 out of 12 patients). Seven (15.9%) of the patients suffering from a grade IIIa or higher complication were in the tumor group, whereas 5 (11.3%) were in the benign stenosis group. Grade IVa was the highest complication grade and occurred in one patient who underwent a pharyngolaryngectomy because of an esophageal tumor infiltration. In both groups, the 30-day mortality was zero. Overall success rate was 75% (no need for reoperations or postoperative interventions).

In the group of patients operated for a tumor, 10 patients suffered from complications. Most common complications were infection (n=4) and dysphonia (n=4) (*Table 4*). Five patients required a permanent tracheostomy postoperatively. In total, 10 of the patients operated for a tumor suffered from a varying degree of either a unilateral (n=7), or bilateral (n=3) recurrent laryngeal nerve paralysis. However, in these cases, the recurrent laryngeal nerve had to be sacrificed, or was damaged

Table 3 Overview of stenosis, surgery and treatment characteristics

Characteristics	N (%)
Localization of the stenosis/tumor	
Subglottic	16 (36.4)
Tracheal	27 (61.4)
Carina	1 (2.3)
Grade of stenosis	
Grade I, ≤50%	18 (40.9)
Grade II, 51–70%	9 (20.5)
Grade III, 71–99%	16 (36.4)
Grade IV, 100%	1 (2.3)
Surgical access	
Neck approach	29 (65.9)
Neck + partial sternotomy	11 (25.0)
Sternotomy	2 (4.5)
Thoracotomy	2 (4.5)
Length of resection (cm)	
Median [IQR]	2.5 [2–3.5]
Tracheostomy in relation to surgery	
Preoperative	4 (9.1)
Emergency tracheostomy	1 (2.3)
Postoperative	4 (9.1)
Extubation in operating room	
Yes	32 (72.7)
No	12 (27.3)
Intensive care (days)	
Median [IQR]	1 [1–3]
Hospitalization (days)	
Median [IQR]	8.5 [7–14.5]
Missing data (patients)	2

IQR, interquartile range.

Table 4 Complications in 44 patients undergoing TR or CTR

Complications	Tumor	Stenosis	Total (%)
Recurrent laryngeal nerve paralysis	0	1	1 (2.3)
Granuloma at site of anastomosis	0	1	1 (2.3)
Anastomotic leakage	0	1	1 (2.3)
Pneumonia	1	3	4 (9.1)
Infection	4	1	5 (11.4)
Bleeding	1	0	1 (2.3)
Recurrent stenosis	0	3	3 (6.8)
Crusting	0	1	1 (2.3)
Subcutaneous emphysema	2	0	2 (4.5)
Dyspnea	1	4	5 (11.4)
Dysphagia	2	0	2 (4.5)
Dysphonia	4	3	7 (15.9)
Permanent tracheostomy	2	2	4 (9.1)
Reoperation	6	5	11 (25.0)
Total	10	10	20 (45.5)

TR, tracheal resection; CTR, cricotracheal resection.

due to tumor infiltration. In 3 of the patients requiring permanent tracheostomy in this group, the tracheostomy was placed due to the nerve paralysis Therefore, these conditions were not considered complications, but rather consequences of the treatment. R0 resection was achieved in all but one of these patients. Six patients required reoperations in this group. These operations included a pharyngolaryngectomy due to an esophageal tumor infiltration and an additional TR because of an adenoid cystic carcinoma (residual tumor in margin). Three patients required a percutaneous endoscopic gastrostomy (PEG) tube insertion because of laryngeal dysfunction postoperatively with one of these patients also requiring a wound revision under anesthesia due to a wound bacterial infection. The remaining patient was the only one who underwent a carinal resection through a thoracotomy and required reoperation due to dehiscence of the thoracotomy wound.

In the group of patients operated for a benign stenosis there were also 10 patients who suffered from variable complications. Dyspnea (n=4), recurrent stenosis (n=3) and pneumonia (n=3) were the most prominent complications in this group (*Table 4*). Recurrent stenosis occurred in 3 patients, 2 of which were operated for an idiopathic stenosis and one operated for immunoglobulin G4 (IgG4)-related disease. All these patients also underwent various postoperative dilatations due to the recurrent stenosis. Although the decision to perform a resection was primarily aimed at securing a patent airway, one of the idiopathic stenosis patients and the patient with IgG4-related disease ultimately required a permanent tracheostomy. Five patients underwent reoperations, including the

dilatations (n=3). The remaining (n=2) operations were a removal of a granuloma at the site of the anastomosis by electrocoagulation and an endoscopic laser surgery for a postoperatively developed subglottic web.

Discussion

In this study we reviewed our institutional data of the patients that underwent TR or CTR either for a malignant or benign indication in the last 15 years to evaluate the indications and outcomes of these operations. We found that surgical resection was an effective treatment for airway stenosis with a low recurrence rate (6.8%). Radical resection of tracheal tumors was successful in almost all cases (85.7%). Overall success rate in our cohort was 75% (no need for reoperations or postoperative interventions).

All operations in the present series were single-stage TRs or CTRs with primary end-to-end anastomosis. This procedure is relatively rare in the Nordic countries, with a median of only five annual patients at those centers performing these operations (18). This is in line with the reported rare occurrence of these operations, as we found that only 44 operations were performed during a 15-year time period at the Helsinki University Hospital catchment area. This area has a total population of over two million people (36% of Finland's population), which further highlights how infrequently this surgery is performed. Therefore, due to their rare nature, these surgical procedures should be further centralized, as they require a multidisciplinary approach and are associated with a significant complication rate (1,3,8,10-14,23).

The aim of a successful TR or CTR is the removal of the pathologic section of the (laryngo)trachea and reestablishment of a functioning airway, as well as achieving a tension free anastomosis (1-3,12-17). We consider the maximum length of a safe resection to be about 5 cm, or half of the tracheal length. Reported success rates in the literature for TR and CTR range from 65% to >95% (8-14,19,23,24). In our cohort, 33 (75%) patients did not require reoperations or postoperative interventions, which falls in the range of previous reported success rates. In addition, our study had a cohort of patients with many different indications for surgery, such as inflammatory, idiopathic and neoplastic stenoses, as well as tumor infiltration without stenosis. Therefore, the present series differs from many previous studies focusing on a single etiology (8-12,14,24). This should be taken into consideration, as it worsens the postoperative outcomes and the overall success rate.

Our postoperative treatment protocol includes the use of steroids, diuretics and racemic adrenalin but not the use of heliox therapy. We do not use T-tubes in the routine treatment of these patients. However, T-tubes may offer an option to avoid tracheostomies. Even though our resections were effective, there were also many complications. In our cohort, 20 (45.5%) patients suffered from complications. Similar complication rates have been reported, ranging from 30% to 56% (3,10-13,24). Interestingly, the incidence of permanent tracheostomies was rather high in our study (15.9%), as previous studies report rates of only 5% or lower (10-12,14). This high rate of permanent tracheostomies could be explained by the heterogenic nature of our cohort, as most of these were presented in patients who underwent surgery for a tumor (5 out of 7). As only 4 out of the 13 patients with a previous tracheostomy experienced a postoperative complication, we could not find a clinically significant correlation between these factors. Laryngeal recurrent nerve paralysis and dysphonia were also prominent in our cohort. Most patients suffering from these conditions were also patients treated for a tumor. This is likely because in the radical resection of a tumor or a tumor infiltration involving the subglottic region, laryngeal recurrent nerves are typically sacrificed to obtain surgical radicality, which was the case in our cohort for 10 (22.7%) patients. Similarly, in three of the patients requiring permanent tracheostomy, the tracheostomy was due to the nerve paralysis. Therefore, in these cases, the laryngeal recurrent nerve paralysis and the permanent tracheostomies were not considered complications, as they were a part of treating the tumor. Previous literature reports on a strong association between surgical management of airway tumor infiltration and high rates of laryngeal recurrent nerve paralysis (15,17). For patients who needed a tracheostomy, the Otorhinolaryngology-Head and Neck Surgery team always considered the possibility of a vocal cord lateralization before performing a permanent tracheostomy.

CTR has been associated with a higher risk of major complications in comparison with TR, due to the complex anatomy of the subglottic region, as it is a narrow space involving the branches of the laryngeal recurrent nerve, vocal cords and the arytenoid cartilages (11,12,25). In line with previous studies, our patients who underwent CTR also suffered from several complications.

Laryngeal mask ventilation has recently been proposed as the standard ventilation technique in surgery of patients with laryngotracheal stenosis, in order to avoid

postoperative complications (26). At our institution, we have utilized the proposed method of anesthesia. However, regardless of this, the incidence of complications was significant. This further highlights the need to centralize these operations to centres with high experience.

In our study, the occurrence of patients treated for a malignant disease was high. This could partly be a consequence of the fact that in Finland, a number of the benign stenoses are not referred to the university hospitals for an evaluation of surgical management but are rather treated at central hospitals with a tracheostomy or bronchoscopic interventions. In contrast, tumors of the trachea and subglottic area are carefully discussed in a multidisciplinary meeting after which, if a resection is considered to be possible, surgery is the first-line treatment. These factors should be taken into account as they make the proportion of patients treated for a malignant disease relatively high in the present series

This study has its limitations. Our series is retrospective, small and heterogenous. Because of the rarity of these procedures in our institution we combined both benign and malignant cases in the same cohort. This leads to the difficulty to compare our results to the other series which report these results separately. On the other hand, because of the low number of cases there was no point in separating different indications.

In conclusion, TR and CTR were a safe and efficient way of treating both benign stenoses and tumors of the trachea and subglottic region in our institution, with zero 30-day mortality and acceptable outcomes. However, TR and CTR are complex procedures with complications and mortality (8,10,11). Our study clearly showed the spectrum of typical complications after these procedures.

We can learn from this study that thorough preoperative investigations and careful planning, as well as preventive measures at the time of surgery are needed in order to avoid these complications. Therefore, these operations should be further centralized into centres of excellence with highly experienced multi-professional teams. Many of our patients had several previous bronchoscopic treatments before their surgical treatment, which in some cases might have made the surgery more difficult. Therefore, in our opinion the optimal treatment of these patients should be decided by the multidisciplinary team in the beginning of the treatment because surgery can offer a permanent solution for well-selected patients.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://jtd.amegroups.com/article/view/10.21037/jtd-21-1963/rc

Data Sharing Statement: Available at https://jtd.amegroups.com/article/view/10.21037/jtd-21-1963/dss

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://jtd.amegroups.com/article/view/10.21037/jtd-21-1963/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study protocol was approved by the Institutional Review Board of Helsinki University Hospital (IRB No. HUS/141/2020). The requirement for patient consent was waived due to the retrospective nature of the study.

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