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Research Article

Long-term results after 110 tracheal resections

Langzeitergebnisse nach Trachearesektion bei 110 Patienten

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Abstract

Objective: Among the many therapeutic options for treating tracheal stenosis (e.g. bouginage, laser resection and stenting), segmental resection and reconstruction with end-to-end anastomosis is the method of choice. We verified this in an analysis of clinical material.
Patients and methods: We retrospectively evaluated 110 tracheal sleeve resections performed between 1985 and 2001. Data before and after resection were analyzed, and the patients were interviewed.
Results: The aetiology of stenosis was mainly postintubation injury (n = 92) (83.6%), followed by goiter with malacia (n = 8) (7.3%) and tumor (n = 6) (5.5%). There were a few other causes (n = 3) (2.7%). 48 patients (43.6%) had undergone prior conservative or surgical treatment other than sleeve resection. A cervical approach was used in 93 (84.6%), a cervicomediastinal in 15 (13.6%), and a transthoracic in two. Healing of anastomosis was uncomplicated in 101 patients (91.8%). Major and minor complications occurred in 29 patients (26.4); there were 4 dehiscences (3.6%), 3 restenoses (2.7%), 2 suture line granulations (1.8%) and 4 vocal cord dysfunctions (3.6%). The 30-day mortality rate was 0.9%. 77 patients were interviewed after surgery (median 80.1 months); 93.5% (n = 72) were satisfied with the surgical treatment.
Conclusions: Resection and reconstruction offer the best treatment for tracheal stenosis. Lethal complications were due to severe comorbidity. Many patients today still undergo unsuccessful conservative treatment before being referred to surgery.

Zusammenfassung

Im Rahmen einer retrospektiven Untersuchung wurden die Ergebnisse von 110 Tracheasegmentresektionen, die zwischen 1985 und 2001 durchgeführt wurden, untersucht. Die Datenerhebung erfolgte anhand der Krankenakten und einer Nachbefragung der Patienten. Die Ätiologie der Stenose war in 83.6% durch einen Postintubationsschaden begründet, in 7.3% durch eine Struma und in 5.5% durch einen Tumor. Bei 48 Patienten wurden vor der definitiven Resektion zum Teil mehrfache konservative und chirurgische Therapieversuche durchgeführt. Der Zugang zur Trachearesektion bestand in 84.6% in einem Kragenschnitt, in 13.6% war eine zusätzliche partielle Sternotomie erforderlich und bei 2 Patienten mit einer tiefen Stenose wurde eine Thorakotomie durchgeführt. Die primäre Anastomosenheilung war in 91.8% problemlos. Kurzzeit- und Langzeitkomplikationen traten in 26.4% auf, bei 4 Patienten kam es zu einer Anastomosendehiszenz, in 3 Fällen trat eine späte Restenose auf und bei 4 Patienten eine Recurrensparese. Die 30-Tage Letalität betrug 0.9%. 77 Patienten mit einer medianen Nachbeobachtungszeit von 80.1 Monaten konnten direkt befragt werden; 93.5% waren mit dem Ergebnis der Trachearesektion zufrieden.
Zusammenfassung: Die Tracheasegmentresektion ergibt die besten Langzeitergebnisse in der Therapie der Tracheastenose. Die postoperative Letalität war in allen Fällen auf schwere Begleiterkrankungen zurückzuführen. In nicht geringem Umfange werden konservative Therapieversuche unnötig oft durchgeführt.

Introduction

Tracheal surgery has developed primarily in the last two decades. Although segmental tracheal resection was described as early as 1881 and 1885 by Glück and Colley [1], [2], attention was not turned again seriously to this method until 1950 with Belsey [3]. Grillo and Pearson further developed and refined it in the 1980's [4], [5]. Above all, improvements in absorbable suture materials and new ventilation techniques (e.g. jet ventilation) have now ensured that tracheal segment resection in experienced hands is a safe and successful surgical treatment. Other surgical techniques such as laryngofissure or tracheal replacement and reinforcement with cartilage or rib grafts rightfully belong to the past. Surgical treatment of tracheal stenosis has now become confined to a few medical institutions. In the last 10 years, only a few authors have reported experiences with large numbers of patients.

Methods

The present retrospective study encompassed 110 patients (45.5% female) with a mean age of 51 years (3-86 yrs.) who underwent segmental resection of the trachea between January 1985 and August 2001 due to tracheal stenosis. Patients with tumors of the tracheal bifurcation and the main bronchi were not included in this study.

Table 1: Aetiology of tracheal stenosis

	Patients	%
Stomal lesion	60	54.5
Cuff lesion	30	27.3
Recurrent goiter	8	7.3
Tumor	6	5.5
Others	3	2.7
Short time intubation	2	1.8
Radiotherapy	1	0.9
Total	110	100

Aetiology and prior treatment

60 patients (54.5%) had previously undergone tracheotomy and 30 (27.3%) long-term intubation. In eight cases (7.3%), recurrent goiter and tracheomalacia were the causes of constriction. Six patients (5.5%) had the following tumors respectively: 1 lipoma, 1 granular cell blastoma, 1 pseudotumorous mucosal hyperplasia, 1 hemangiosarcoma, 1 mucoepidermoid carcinoma, and 1 fibrosarcoma. Stenosis after brief intubation narcosis occurred twice, and the cause remained unknown in three patients (Table 1). Stridor when resting was noted preoperatively in 91 patients (82.7%). 104 patients (94.6%) breathed spontaneously preoperatively and required no oxygen when resting. Three patients (2.7%) required oxygen when resting, three others were intubated and ventilated orotracheally.

48 patients (43,6%) had already been treated at other hospitals. Of these, 22 patients (20%) had been treated only once, whereas the other 26 (23.6%) had been treated either several times with various methods or repeatedly with the same method. In one case, laser removal of the stenosis had been attempted 20 times. Four patients had been tracheotomized distally from the already existing stenosis. In one other case perforation of the tracheal wall occurred following laser removal of a mucosal polyp. In three patients, recurrent stenoses developed following previous resection surgery of the trachea (Table 2). The time between prior treatment and resection varied from 1 to 228 months, with a mean of 27 months.

Table 2: Overview of 107 presurgical treatments in 48 patients

	1x	2x	3x	4x	5x	20x
Laser	13	3		1	1	1
Bouginage	8	2	2		2	
Stenting	7			1		
Tracheostomy	4					
Laryngofissure	2				1	
Tracheal resection	3					
Splinting	2					
Montgomery tube	2					
Reintubation	2					

Surgical technique and anesthesia

All patients underwent preoperative flexible bronchoscopy in order to determine the diameter and length of the stenosis and its distance from the vocal cords. In case of stenosis with scarring, indication for surgery depends on the degree of dysfunction. A reduction in the transverse diameter of 50-70% with stridor or stress dyspnea is regarded as an indication for tracheal resection.

Collar incision is the standard access to the upper and middle trachea. When the stenosis is distal located, additional partial sternotomy gives a good view as far as below the bifurcation. Right-side thoracotomy is the access for stenosis of the lower third of trachea and bifurcation, particularly in case of tumors.
The trachea is exposed above and below the isthmus of the thyroid. In most cases, isthmus is transected. In case of malacic stenosis, the tracheal wall is usually deformed and embedded in fibrotic scar tissue. The subsequent circular surgical exposure of the trachea is then extended to a maximum of 1 cm distal to the resection line in order to preserve vascular blood supply. The trachea is retracted with a holding suture distal to the stenosis and circumferentially transected. Lifting up the trachea in proximal direction the rear wall can now easily be prepared free from lateral tissue with the recurrent nerves and the esophagus to the proximal resection line. In case of malignant tumor frozen sectioning examination of the resection line is used. In subglottic stenosis, we use the technique of partial ventral cricoidectomy with primary thyreotracheal anastomosis first described by Pearson in 1975 [6]. The end-to-end anastomosis is created by means of a single-layered pericartilaginous suture technique with extraluminally tied interrupted sutures (Figure 1). We always use absorbable, 3.0 to 5.0 gauge sutures of Polydioxanon (PDS)®. Continuity resection of the trachea with end-to-end anastomosis without mobilization manoeuvres is possible to a resection length of 3-4 cm. Digital mobilization of distal trachea and bifurcation yields 1.5 cm, and of the larynx another 2 cm. The gain of different mobilization manoeuvres was described in an earlier publication [7]. We have found it unnecessary to fix the neck in place by means of a chin-thorax suture or a plaster cast.
Intraoperative oxygenation was carried out with high-frequency jet ventilation from 1986 on in all patients (n=104; 96.4%). Here the ventilation tube is retracted during tracheal resection, and a slender catheter is inserted over the operative field into the distal trachea. This much improves the view of the operative area. We use an Accutron Co. "Universal-Jet-Ventilator". This pressure-controlled unit is equipped with an automatic pressure cut-off. The ventilation frequency is 200 to 300 per minute; the tidal volume is between 20 and 80 ml, and the pressure is 1.5 to 2.5 bar. We ventilate with pure oxygen. Sedation is carried out with intravenous anesthesia using for example Midazolam or Propofol, and analgesia using Fentanyl or Alfentanyl.

Clinical course

Anamnestic, clinical and surgical data were gathered retrospectively from the clinical files, the reports of surgery, and the histological findings and were put into a spread sheet program. Data was then gathered from all surviving patients in telephone interviews in February 2002 by means of a questionnaire containing standardized questions. Questions were put concerning hoarseness, stridor, repeat treatment and satisfaction with the results.

Results

Surgical procedures

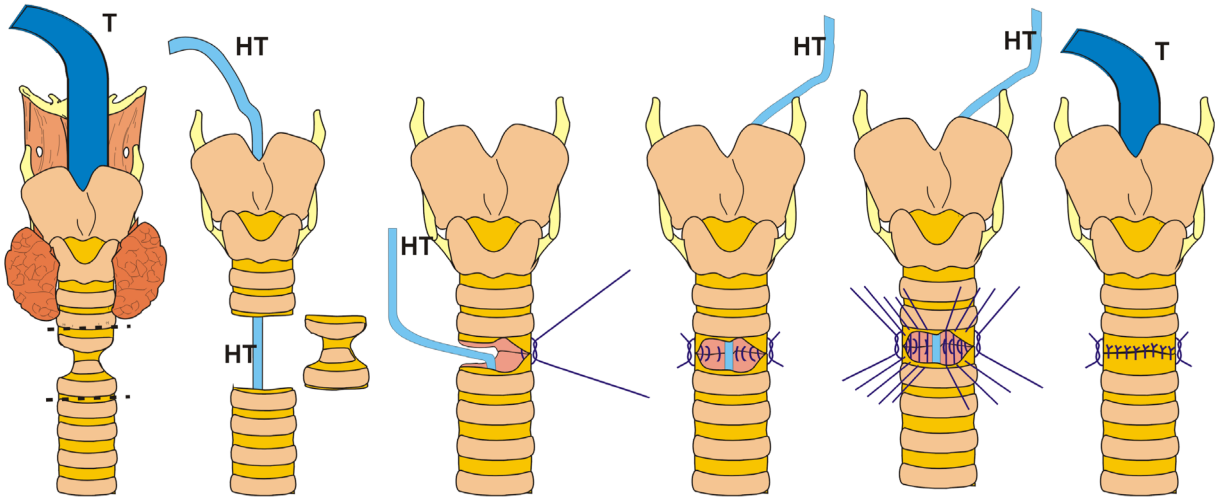
Surgical access was achieved in 93 of the 110 patients (84.6%) via collar incision. In 13 patients (11.8%) extension was required via partial sternotomy. In two cases (1.8%) right-side thoracotomy in the 4th intercostal space was selected for access and in two cases (1.8%) a complete median sternotomy (Figure 2).
In 98 cases (89.1%) tracheal segmental resection was carried out with end-to-end anastomosis. 12 subglottic stenoses (10.9%) were removed with Pearson-type partial cricotracheal resection. Tracheal segments with a length of 2 to 6.5 cm (mean: 3.5 cm) were resected (Table 3). In six cases (5.5%) digital mobilization of the entire larynx was required. None of the patients required the mobilization technique of Dedo or Montgomery as described in the literature [8], [9]. Unilateral resection of goitre was carried out 11 times (10%) and bilateral subtotal goitre resection 12 times (12.7%). The procedure was expanded by esophageal surgery to close esophagotracheal fistulas in three patients (2.7%).

Table 3: Length of resected tracheal segment

Length (cm)	No.
2.0	7
2.5	6
3.0	27
3.5	16
4.0	25
4.5	9
5.0	13
5.5	3
6.0	3
6.5	1
Median 3.5	110

Complications

Intraoperative or postoperative complications developed in 29 patients (26.4%); the 30-day mortality rate was 0.9% (n=1), the in-hospital mortality rate was 5.4% (n=6). Two patients died from re-infarction, one from re-stroke.



T = Tube; HT = High frequency jet ventilation tube

Figure 1: Step by step of tracheal segmental resection and end-to-end anastomosis

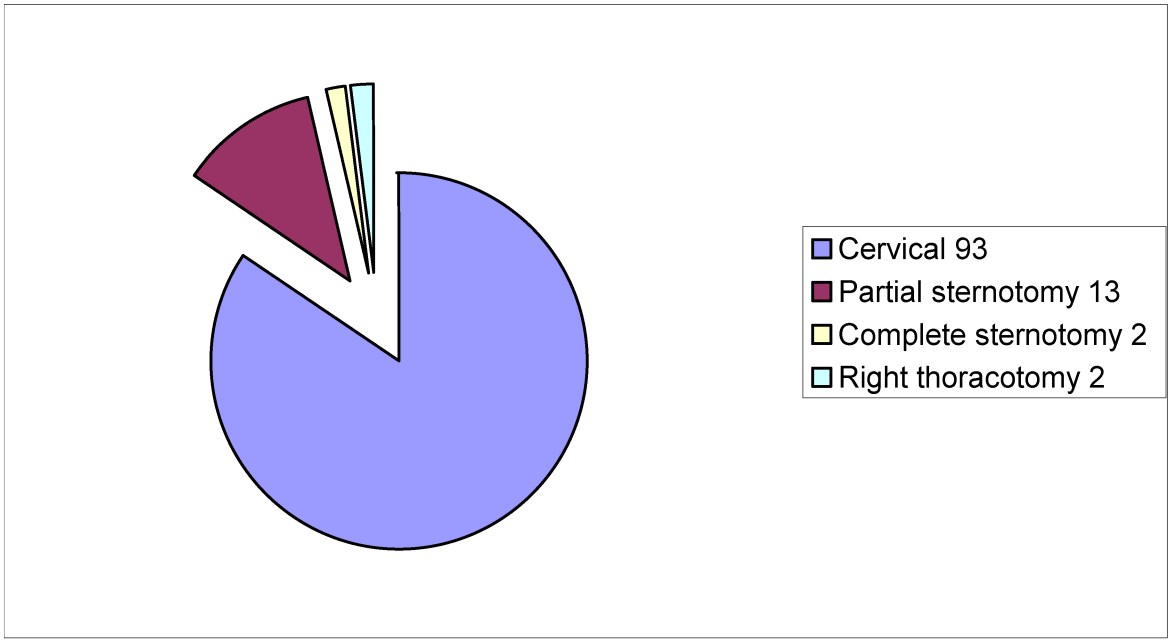


Figure 2: Surgical access

Two patients previously ventilated died of postoperative pneumonia. In one patient, irreversible ventricular fibrillation occurred intraoperatively (Table 4). Consequently, the causes of death were only indirectly connected with surgery and were not a result of the surgical technique.

Recurrence of stenosis and suture failure. In 101 patients (91.8%) the anastomosis healed primarily without complications. Re-stenoses appeared during the hospital stay in three patients (2.7%). In one of these the cause was foreign-body reaction to suture material, in another keloid of the anastomosis. A second resection was performed in one patient, and he was thereafter free of discomfort. Prosthetic support and re-tracheotomy were required respectively in the two others. In the latter patient, a woman in whom a Morbus Wegener was found one year after surgery required a Montgomery tube and 9 years later a stent. In two cases (1.8%), granulation of the anastomoses was successfully removed endoscopically. Four patients had suture dehiscence (3.6%). One of these healed after revision. Two small dehiscences were treated antibiotically and healed without re-stenosis. The fourth patient was reoperated.

Laryngeal dysfunction. In six patients recurrent nerve paralysis occurred. In two patients, vocal cord function was restored at the time of discharge from hospital; in the four others, paresis remained permanently (3.6%). One case of aphony after cricoid cartilage excision (0.9%) was resistant to therapy. It was not possible to preserve the posterior part of the deformed and largely destroyed

Table 4: Complications after tracheal resection and end-to-end anastomosis

	No.	%	Therapy / Results
Recurrent nerve paralysis	6	5.5	2 temporary, 4 permanent
Pneumonia	4	3.6	3 antibiotic, 1 died
Dehiscence	4	3.6	2 antibiotic, 1 revision, 1 died
Pneumothorax	3	2.7	3 chest tubes
Restenosis	3	2.7	1 resection, 1 stent, 1 tracheotomy
Granulations	2	1.8	2 laser resection2
Myocardial infarction	2	1.8	2 died
Hemorrhage	2	1.8	1 artery repair, 1 coagulation
Ventricular fibrillation	2	1.8	1 resuscitated,1 died
Restroke	1	0.9	1 died
Tracheomalacia	1	0.9	1 tracheotomy
Aphonia	1	0.9	permanent

cricoid cartilage due to high stenosis of rheumatic origin in the subglottic space.

Pulmonary complications. Pneumonia occurred four times (3.6%) postoperatively. All four patients were treated antibiotically. The course was thereafter uneventful in two patients. Two patients died, one of them after revisional surgery due to suture dehiscence. These two patients had been ventilated in the past due to lung emphysema. Three cases of pneumothorax (2.7%) occurred: in one case during tracheal resection under jet ventilation, in another during ventilation on the intensive care unit and in the last case during revisional surgery due to suture dehiscence under ventilation via an orotracheal tube. Postoperatively in one patient (0.9%) there was complete atony of the tracheobronchial system, so that a tracheostoma for ventilation was required.

Haemorrhaging. There were two cases (1.8%) of postoperative hemorrhage; in one case, due to arrosion of the brachiocephalic artery, and the second was a diffuse hemorrhage. Following surgical revision the further course was uneventful in both patients.

Cardiovascular complications. Two patients (1.8%) who had been reanimated due to myocardial infarction in the past again experienced postoperative myocardial infarction and died. Two patients (1.8%) developed intraoperative ventricular fibrillation; one of them was successfully resuscitated, the other died later on the intensive care unit. One patient (0.9%) with a past history of stroke and reanimation suffered a new stroke and died.

Long-term results

In February 2002 we conducted a follow-up study and were able to gather data on the further course of 92 (88.5%) of the 104 patients who had been discharged from our care. We were able to reach and interview 77 of these patients by telephone. The follow-up period ranged from 12 to 226 months (mean: 80.1 months). 15 of the 92 patients had died, one of these 11 months after surgery from local recurrence of a hemangiosarcoma of the trachea and another 45 months after surgery due to diffuse lung metastases of mucoepidermoid carcinoma of the trachea. In one patient progressive neurological disease occurred, making renewed tracheotomy necessary; he died from arrosion hemorrhage from the tracheostoma. The other 12 patients died of illnesses unrelated to tracheal surgery (Table 5).

Table 5: Cause of death in 15 patients in the long-term follow-up

	No
Cardiopulmonary disease	7
Malignant tumor	5
Hemorrhage from tracheostomy	1
Unknown	1
Sjögrens – Syndrom	1

Of the 77 patients reached by telephone at the time of the interviews, 72 (93.5%) reported satisfaction with the results of surgery; 58 (75.3%) were without discomfort. Nine patients (11.7%) reported occasional hoarseness, seven patients (9.1%) reported stridor under exercise. Three recurrent stenoses appeared which required renewed surgery. The causes were suture dehiscence, foreign body granuloma, and localized recurrence of mucoepidermoid carcinoma. Five patients (6.5%) were unsatisfied with the results of surgery (Table 6). The reasons given were hoarseness and persistent stridor under exercise.

Table 6: Long-term results of 77 interviewed patients

	No	%
Content	72	93.5
No complaint	58	75.3
Hoarseness	9	11.7
Stridor under stress	7	9.1
Restenosis	3	3.9

Discussion

In the treatment of tracheal stenosis, there is basically a competition between conservative methods like laser resection, bouginage, cryosurgery, and stents with tracheal segment resection. Multi-stage methods like laryngofissure and stiffening operations with rib or cartilage substitutes rightfully belong to the past. Laser resection is indicated in case of web-shaped, short stenosis as a primary remedy for recurrences, and resection is preferable in all other forms of short, scarred stenosis. Above all, laser resection is superior in the palliative recanalization of tumors. Stents are indicated for long tracheomalacic stenosis and for inoperable patients and as a temporary measure for patients in poor condition until resection can be carried out [10].

We have reported here on 110 patients who were treated over a period of 16 years with tracheal segment resection.

Cause of stenosis

Long-term intubation or tracheostoma was the cause of tracheal stenosis in 90 (81.8%) of the 110 patients in this study. During prolonged ventilation via a tube, the perfusion of the tracheal mucosa with blood can be so severely reduced by the cuff that constrictive perichondritis occurs due to mucosal necrosis; after tracheotomy, highly fibrotic scarring then leads to ring-shaped tracheal stenosis [11]. In two female patients in our series, we were unable to find any other cause of the stenosis than respective, brief intubation anesthesia carried out for 35 minutes in the one and 4 hours in the other. Whether percutaneous dilatational tracheostomy results in less scarring as in conventional tracheotomy, has not been evaluated up to now [12].

Prior treatment

48 patients in the present study had been previously treated one or more times for tracheal stenosis. In most of these cases, bouginage and laser therapy had been carried out. In similar serial studies of other authors, numerous patients were also found who suffered recurrences after endoscopic therapy. The figures given for recurrences after laser therapy extend range from 23% to 43% [13], [7], [14]. Paris reported 78% of recurrences after dilatation therapy of circular tracheal stenoses [15]. On the other hand, Grillo found no negative effect after tracheal resection in 45 patients previously treated by laser. However, he found a high rate of re-stenosis and/or suture insufficiency after previous cartilage dilatation procedures [13]. Most authors today are unanimous in regarding endoscopic procedures as useful primarily for bridging in the presence of active inflammation or for patients whose general health does not yet permit tracheal resection [13] . To date, however, few examples of integrated treatment concepts exist in the literature.

Anesthesia

We have used high-frequency jet ventilation since 1986 for all tracheal resection procedures. In our opinion, this form of ventilation decisively improves the overview in the operating area during resection and end-to-end anastomosis [16]. In the presence of severe stenosis, we dilatate directly before surgery with a rigid bronchoscope, intubate the patient, and carry out the resection. In this way it is possible to avoid a long preoperative phase of preparation with repeated dilatations [17]. In one case a pneumothorax occurred under jet ventilation. The frequency of intraoperative pneumothorax is given in the literature as being between 0.6% and 8.8% [13], [18].

Surgical access and resection lengths

Out of reports published after 1990 it is obvious that the cervical or cervicomediastinal access is not only adequate but also preferred for benign tracheal stenosis [13].

84.6% of the tracheal stenoses in our patient collective could be resected via collar incision. 11.8% of the cases required extension via partial sternotomy. Right thoracotomy offers an excellent overview in precarinal stenoses.
The length of the resected tracheal segments ranged from 2 to 6.5 cm, with a median length of 3.5 cm. In the largest patient collective studied to date, resections of 1 to 7.5 cm were carried out with an average resection length of 3.3 cm [13]. It should be pointed out that longer segments can be resected in taller patients with a longer neck and in younger patients with a more elastic trachea [19].

Restenosis

The anastomosis healed primarily in 101 patients (91.8%); in two others, anastomosis healed after endoscopic resection of granulation tissue. Grillo has reported on a 93.7% primary success rate of anastomosis healing [13].
During hospital stay, three patients (2.7%) developed recurrent stenoses; three others (2.7%) experienced recurrences after discharge from hospital. This corresponds to a 5.4% long-term recurrence rate of stenosis. Grillo has reported a stenosis recurrence rate of 7.1% after 503 resections [13]. Other authors report rates between 3.8% and 8% [19], [14], [7]. The causes of recurrence are only partly known. Pronounced anastomotic tension, ischemia, incomplete resection of the diseased tracheal segment, diabetes mellitus, rheumatic disease, and malnutrition appear to be unfavourable factors [20]. The recurrence rate of stenosis is dependent on the choice of suture material. In our own study we found granular tissue in 70.5% of the anastomoses using non-absorbable sutures but 0% using absorbable sutures [21]. These results were confirmed by Grillo [13].

Suture dehiscence

Four cases (3.6%) of suture dehiscence occurred; two of these healed spontaneously. Rates of dehiscence ranging from 5.7% and 7.5% have been reported in the literature [13], [22]. Smaller dehiscences can heal spontaneously. The causes of suture insufficiency are still not clear. Excessive circular dissection of the trachea, disrupting the blood supply of the anastomosis, has been discussed as a possible cause [22], [13]. In addition, it is likely that a high level of tension due to lack of mobilization or following extensive resection can also endanger the healing process [23]. We never used chin-to-thorax sutures. Other authors regard this as necessary to protect the anastomosis in children and patients who cannot cooperate due to neurological disease, at least in the case of extensive resection [13], [19].

Other complications

Recurrent nerve paralysis occurred in six patients; in two of these, vocal cord function was again normal at the discharge from hospital corresponding to a vocal cord paralysis rate of 3.6%. In view of our patient collective, including three malignant tumors, 10 patients who had previously undergone surgery for tracheal stenosis, and seven patients previously operated on for goitre this rate is low. The recurrent nerve was not exposed intraoperatively. The frequency of postoperative vocal cord paralysis in the litera-ture is ranging between 0% and 5% [22], [14], [24], [25].
In one of our patients there was an arrosion hemorrhage from the brachiocephalic artery on the 2nd postoperative day. After immediate reoperation the further course was uneventful. The frequency of this complication in the literature is ranging from 1 to 2.5% [13], [15].

Postoperative mortality

Six patients died postoperatively. This corresponds to an overall mortality rate of 5.5%. The 30-day mortality rate was 0.9% (n=1).
Figures given in the literature on overall mortality in comparable patient collectives range between 2.5% and 18% [22], [13], [7], [14], [24], [25], [15]. In five of the six patients who died, we registered severe comorbidity. The otherwise relatively minor procedure of tracheal resection is associated with a very high risk in particular for patients who have been reanimated in the past due to cardiovascular or pulmonary disease.

Patient interviews

77 patients were reached by telephone interviews. 93.5% were satisfied with the surgical treatment and had no complaints. 9.6% were hoarse on occasion, 7.4% experienced stridor during physical exercise; only 6.5% of the patients voiced dissatisfaction with the surgical result. In subsequent interviews published by other authors, up to 92% of patients also voiced satisfaction with the surgical results [7], [25], [15]. The high number of satisfied patients is certainly explicable among other things by the severe preoperative impairment experienced from tracheal stenosis. Many patients also had repeated treatments with laser, insertion of stents, etc.

Conclusions

The results of this study show in agreement with reports in literature that long-term ventilation by means of an orotracheal tube or a tracheostoma is the main cause of tracheal stenosis. The high rate of previously treated patients permits the conclusion that these therapeutic measures were ineffective. Prior treatment is mostly unnecessary, since intubation, in combination with bouginage if necessary, is always possible during the surgical

procedure. Most patients can be operated on via collar access which can be extended if necessary by means of a partial sternotomy. In case of a supracarinally located stenosis right-side thoracotomy is preferable. The procedure of tracheal resection carries a risk for patients who have already been reanimated due to cardiovascular or pulmonary disease. Resection of the trachea extending up to 7 cm followed by end-to-end anastomosis including mobilisation of the larynx if necessary is possible. Absorbable suture material reduces the anastomosis complications. The results of this study show that segmental resection is the method of choice for treatment of tracheal stenosis.

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