SEGMENTAL RESECTION IN THE TREATMENT OF TRACHEAL STENOSIS

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In a retropective analysis, the data of 80 patients, who underwent segmental tracheal resection because of tracheal stenoses, were evaluated. Results of these patients' postoperative course of at least 12 months were available. For 52 of 80 patients, a tracheoscopy was performed 1 year after the operation. Altogether tracheal segments of 2 to 5.5 cm were resected with consecutive end-to-end anastomosis. Seventy-three patients were without complications in the immediate postoperative course. Seven patients with problems after the surgery had to undergo a second intervention, which was successful in all cases. At least 1 year after the segmental resection in 74 of the 80 patients, no tracheal pathologies were detected. Three patients reported dyspnea during heavy physical exertion. In two of these in whom very long tracheal segments had been resected, recurrent stenoses were found with a restriction of 30% to 40%. A third patient suffered from a bilateral vocal cord paralysis with normal tracheal lumen. In another three patients, dyspnea at rest was observed in which a 20% to 30% tracheal restriction led to dyspnea only in combination with a simultaneously diagnosed glottic stenosis. Using the technique of segmental tracheal resection, tracheal stenoses up to a length of 6 cm can be cured safely and with lasting results.

The factors causing stenoses in the laryngotracheal area are very diverse. In principle, congenital and acquired causes are distinguished. Trauma-induced stenoses have increased in incidence distinctively in the last 10 years. Stenoses after traffic and sports accidents, chemical injury, and burn trauma are considerably lower than iatrogenic restrictions in the laryngotracheal area.[1,2] Iatrogenic damage is the result of long-term intubation (intubation period longer than 24 hours) and tracheotomies on patients that survived thanks to modern emergency and intensive care medicine.

Restrictions of the larynx and cervical trachea as a result of long-term intubation and tracheotomies are reported as 0.11% to 16% in the literature.[3] With appropriate expertise, the complication rate could be lowered to 0.46%. Damage parameters in the laryngotracheal area are caused by improper intubation and/or tracheotomy, irritation by the positioned tube, the duration of the intubation period, and additional infections.[1,4]

However, the formation of a later stenosis is not related to the duration and extent of the primary defect of the tracheal mucosa. Risk factors include circulatory disorders (shock, arterial ligature), exterior cartilage defects, and mucous membrane metaplasia induced by viruses and inclination for keloids.[4]

A precondition for the development of stenoses is a defect in mucociliary clearance, pressure-induced necrosis of the tracheal mucosa down to the basal membrane, followed by the destruction of the tracheal cartilage framework because of a subsequent perichondritis and spreading chondritis.[4]

By this, the defects at the inside of larynx and trachea can extend further than areas of direct manipulation. Large simple mucosa defects have a positive tendency to heal, whereas ulcerations on the cartilage framework lead to restricting differentiation.[4] Next to the diversity of modern diagnostic methods such as magnification endoscopy (Fig 1), flexible fiberoptic examination of the larynx and trachea as well as polytomography (Fig 2) in an anteroposterior direction, the physical status of the patient will determine the time of treatment. Intervention is imperative when the stenosis reaches a critical scale.

During rest or light exercise, the patient notices dyspnea only if the width of the tracheal lumen is restricted by more than 50%. Especially in cases of tracheal stenosis, segmental resection has established itself as a promising and safe surgical method,[5-9] which can be extended to the subglottic area when applying Pearson's method of operation to achieve a partial cricoid resection.[10,11] In the following article, we describe our experience with the segmental resection of the trachea.

OPERATING TECHNIQUE

Our experiences encompass 92 resected stenoses of the cervical trachea and the part of the trachea extending from the cervicomediastinal junction down to the truncus brachiocephalicus. The precondition for resection is a stable process, ie, the changes in the tracheal wall have turned into definite cicatrization. The resection should always be conducted outside of the scarred area, to avoid a restenosis through an infection of the cicatrix. A gastric tube in the esophagus facilitates the preparation of the lateral walls of the trachea and the separation between the anterior wall of the esophagus and the posterior wall of the trachea.

Small stenoses up to a length of 1.5 cm can, in principle, undergo operation under local anesthesia, whereas it is

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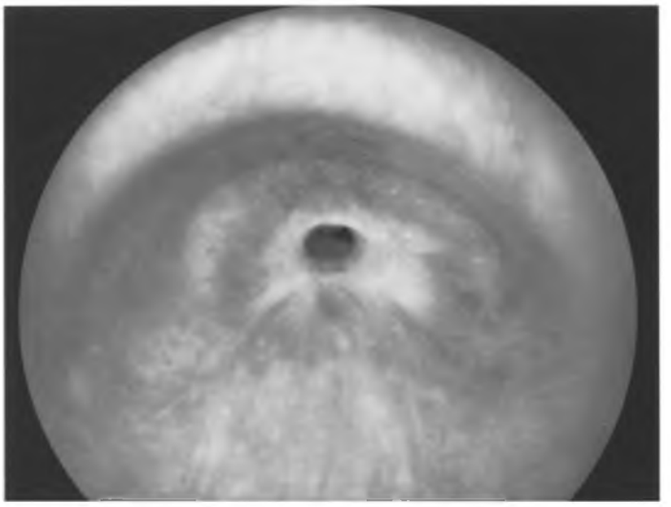

FIGURE 1. Endoscopic aspect of a tracheal stenosis.

necessary to operate alterations larger than 1.5 cm under general anesthesia, because of the mobilization of the trachea and larynx. The larynx and anterior wall of the trachea up to the jugulum are shown with a collar incision in a craniocaudal direction. The preparation should strictly be performed in touch with the lateral wall of the trachea to avoid damage to the nervi laryngei recurrentes.

Therefore, it is not necessary to expose both nerves in the paratracheal cicatrix. Such a preparation would endanger the nerves. Depending on the location of the stenosis, the trachea is incised cranial or caudal to the restrictions and the caudal segment is retained through holding stitches. After preparation of the lateral tracheal wall and the adhesions between the pars membrancea and anterior wall of the esophagus, the pathological segment is resected. If mobilization of the trachea is necessary to attain a position of the edges free of tension, this should be done only between the sternum and trachea and between the trachea and esophagus, ie, at the anterior and posterior wall of the trachea. A circumferential preparation from the surrounding soft tissue interrupts the important lateral arterial supply and endangers the healing process of the anastomosis.

FIGURE 3. Patient immediately after segmental resection of the trachea with removal of a 4.5-cm segment: the head is flexed to the trunk and held in place by a head-thorax cast.

Anastomosis of the cranial and caudal edges of the trachea is performed with several separate full-thickness stitches of 3-0 vicryl. The knots should be placed external to the tracheal lumen and not endoluminal. A tracheostoma or an open furrow being part of the stenosis is usually resected too. If the stoma is located far from the stenosis, it can be left in place.

After closing the soft tissue, the head is flexed to the trunk and held in place by a head-thorax cast (Fig 3). This

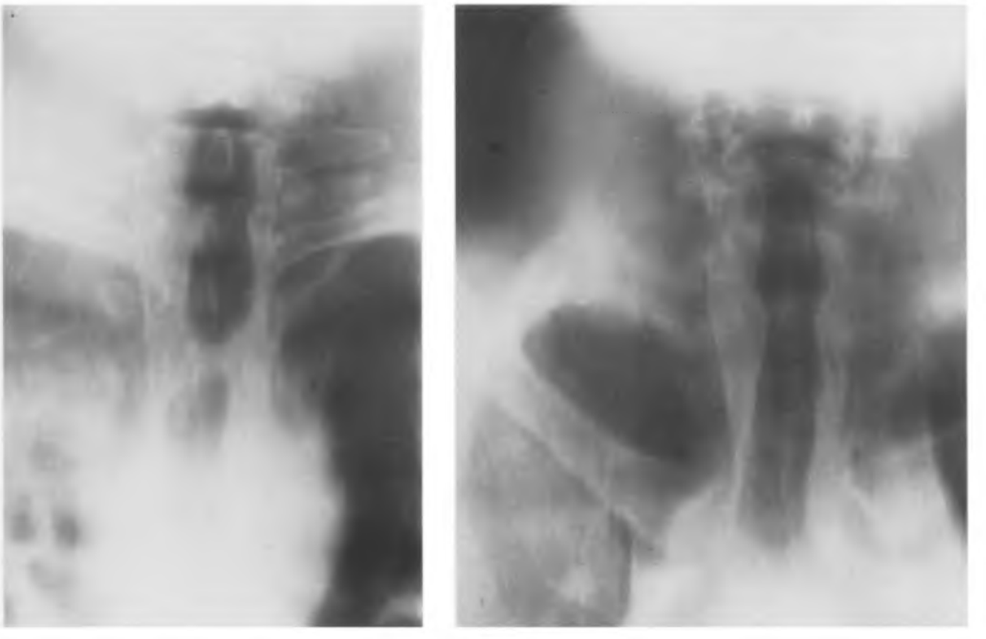

FIGURE 2. Anteroposterior polytomography of a tracheal stenosis before and after tracheal segmental resection.

bending of the chin to the chest at an angle of 30° up to 35° is the most important measure, besides the mobilization of the trachea in caudal direction and the detachment of the connection between larynx and hyoid (laryngeal release) to decrease tension for the anastomosis. The immobility of the head lessens the danger of suture weakening and restenosis, which can arise at high tension on the anastomosis. Depending on the extent of the resection, the head stays fixed in the cast up to 2 to 3 weeks. The patient should immediately be extubated postoperatively and an evaluation of respiration and vocal-cord function should be performed by the surgeon and the anesthesiologist. Treatment with steroids and antibiotics for 3 days as well as gastrogavage for 10 days are further important measures to prevent complications.

The following auxiliary measures after segmental tracheal resection have proven to be worthwhile:

1. Defect length up to 1 cm: Flexion of the chin to the chest for 2 weeks.

2. Defect length of 1 to 3 cm: Mobilization of the trachea in caudal direction and flexion of the chin to the chest for 3 weeks.

3. Defect length of 3 to 5.5 cm: Mobilization of the trachea in caudal direction, laryngeal release and flexion of the chin to the chest for 3 weeks.

PATIENTS

During the observation period, a total of 92 patients suffering from tracheal stenoses underwent operation by segmental resection of the trachea (Fig 4).

Only those patients in the follow-up examinations, for whom immediate postoperative histories as well as the complete histories after a reference period of at least 1 year had been available, were included. Thus, the history of 80 of 92 patients could be evaluated. Four of the 12 patients whose data were insufficient died of causes independent of the tracheal disease (lymphoma, apoplexy, heart attack). No information about the immediate postoperative course could be obtained for the other 8 patients.

Of the remaining 80 patients, 37 were women and 43 were men with an age range of 7 to 77 years at the time of surgery (mean 45.1 years). Tracheal segments measuring 1.0 up to 5.5 cm (mean 2.7 cm) were resected (Table 1).

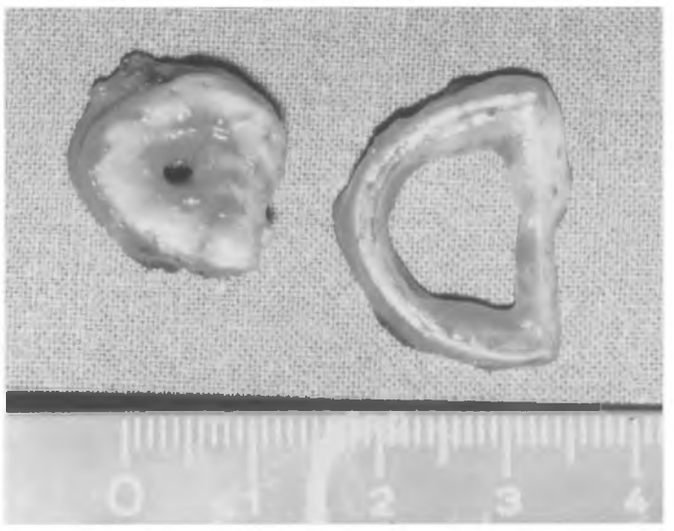

FIGURE 4. Normal and stenotic segments of a human trachea.

TABLE 1. Length of the Resected Segments (n = 80 Patients)

<2 cm	4
2-2.9 cm	46
3-3.9 cm	14
4-4.9 cm	14
≥5 cm	2

The case histories and the immediate postoperative courses were obtained with the help of medical records. For an assessment of the further progress and the present condition, a questionnaire-based survey was performed with these 80 patients in cooperation with the physicians. First, patients and physicians were asked to specify the condition of respiration during the postoperative weeks in comparison with the preoperative condition and to describe the further development. To establish the present condition, we investigated whether respiration was merely rated as sufficient, whether daily exertion like climbing stairs caused dyspnea, or whether hiking and sports could proceed without respiratory difficulties. We also asked if another tracheal operation had been performed after the segmental resection. In addition, all patients were summoned to our outpatient clinic for a follow-up examination. In 52 of the 80 patients, a flexible tracheoscopy was performed in the follow-up examinations.

RESULTS

CASE HISTORIES

In 54 of the 80 patients, a long-term intubation was the main cause of tracheal stenoses; 38 of the 54 patients underwent an additional tracheotomy later on. In 26 cases, the tracheotomy was the primary cause of the stenosis (Table 2).

In 18 patients, correction of the stenoses by open plastic surgery was attempted without success. Ten patients had undergone laser surgery without long-term success. At the time of the segmental tracheal resections, 31 patients had an open tracheostoma or an open furrow. Indications for segmental resection included tracheal stenoses with dyspnea at rest, complaints during moderate physical training, or an open tracheostoma that could not be sealed.

Completed questionnaires were obtained from all 80 patients. With the help of the histories, the questionnaires and the follow-up examinations of 52 of 80 patients, both the immediate postoperative course during the first months after discharge from hospital and the long-term results, ie, the patients' condition 1 year after operation at the earliest, could be assessed. The follow-up period ranged from 1 to 15 years with a mean of 8 years and 6 months.

IMMEDIATE POSTOPERATIVE COURSE

The immediate postoperative course was free of complications for 73 of 80 patients. All of these 73 patients described distinctly improved respiration in comparison

TABLE 2. Causes of Tracheal Stenosis in 80 Patients

Long-term intubation with tracheostoma or open furrow	38
Long-term intubation without tracheostoma	16
Tracheotomy with tracheal collapse	26

with the preoperative condition and the decannulated patients were free of discomfort.

However, several problems occurred within the postoperative period. In one patient, a hematoma developed on the day of the operation. In three further cases, swelling and granulation appeared on the third postoperative day. Furthermore, on the 8th postoperative day granulation around the tracheal sutures was responsible for an acute dyspnea. In these five patients, the tracheal suture was opened anteriorly and a Montgomery T-tube[12] was inserted. After 6 weeks the Montgomery T-tube could be removed in all five cases. The tracheostoma closed spontaneously and respiration was regular.

Another patient with huge swelling and a hematoma in the area of the end-to-end anastomosis complained about acute dyspnea on the seventh postoperative day. Immediately, a revision of the anastomosis was initiated, resulting in an unobstrusive course and sufficient respiration.

Six patients suffered preoperatively from a unilateral paresis and another six patients from a bilateral paresis of the nervi laryngei recurrentes. Four patients sustained a unilateral paresis caused by the operation. In all these cases, several tracheal operations had preceded. Three of these four patients had no respiration complaints postoperatively, however. In one of the four patients, a recurrent unilateral paresis had already existed preoperatively so that the following postoperative dyspnea, which had by that time caused by bilateral vocal cord paralysis, had to be treated by opening the tracheal sutures and inserting a tracheal tube. In the later course, this tube could be removed with unobtrusive suture conditions. The patient was without dyspnea at rest and with a sufficient width of the glottis, despite permanent bilateral vocal cord paralysis. Altogether, we had seven patients with acute postoperative complications that necessitated second interventions, which were successful in all cases.

LONG-TERM RESULTS (TABLE 3)

Sixty patients reported sufficient respiration at rest and during physical exercise. For eight patients, no information about exertional dyspnea could be obtained because of neurological disorders (spastic tetrapareses, paraplegia, encephalopathy), but respiration at rest was sufficient. Six patients with sufficient respiration at rest complained about dyspnea during moderate physical exercise. The dyspnea was of cardial or pulmonary origin in five of these patients. The origin of the dyspnea remained unknown for the sixth patient. All six patients were without pathology in the region of the larynx and trachea.

Three patients complained of dyspnea only after heavy physical exertion. In two of these patients, a thick scar was found in the region of the anastomosis with a lumen stenosis of 30% to 40%. In both cases, tracheal segments of 4 to 5.5 cm were resected. The third patient suffered from a bilateral vocal cord paresis that offered sufficient respiration at rest, but caused dyspnea during moderate physical exercise. The site of the tracheal anastomosis was normal in this patient. Because of the risk of aphonia and the fact that respiration at rest was sufficient, the patient refused a glottis-widening operation (laterofixation).

Three patients had to undergo reoperation because of dyspnea at rest. Two of these patients had similar medical histories. After multiple operations on the thyroid gland, bilateral vocal cord paralysis with paramedian position of both vocal cords occurred that was followed by a tracheotomy. Afterward, laterofixation of one vocal cord was performed and the tracheostoma was closed. A segmental resection with the removal of a 2-cm segment was performed because of dyspnea caused by scarred stenosis. After 9 and 27 months respectively, dyspnea at rest recurred. The trachea was restricted to a diameter 70% of normal by a scar at the site of the resection, with a glottic width of 2 to 3 mm. In one case, the patient had to undergo a renewed tracheotomy, and in the other case the vocal cord was resected and the trachea was bougienaged. The third patient in whom a Montgomery T-tube had been inserted postoperatively and removed 6 weeks later, showed pronounced granulation 13 months later caused by an infection within the tracheal lumen. Endoscopic examination of the anastomosis showed an exposed thread that was removed extratracheally. In addition, the granulation was removed endotracheally and the trachea was enlarged with a bougie. In the further course, both respiration at rest and respiration during moderate physical exercise were satisfactory, so that further measures in case of a residual stenosis of 20% to 30% could be renounced.

The tracheas of the 52 patients examined in the follow-up period, who did not suffer from dyspnea, regularly showed a circular scar at the site of the resection, which was occasionally extended anteriorly in the shape of a sickle. Thirty-four of these patients had a low lumen restriction of less than 10%. Eighteen patients had lumen restriction of 10% to 20% of no clinical relevance.

TABLE 3. Long-Term Results (>12 Months Postoperative) After Tracheal Transverse Resection in 80 Patients

No dyspnea at rest and no exertional dyspnea	60
Sufficient respiration at rest and nonevaluable exertional dyspnea	8
Sufficient respiration at rest and exertional dyspnea caused by other disease	6
Sufficient respiration at rest and exertional dyspnea caused by recurrent tracheal stenosis and/or glottis stenosis	3
Dyspnea at rest and revisional surgery required	3

DISCUSSION

Long-term intubation can lead to tracheal stenosis, a condition in which not only the intubation period, but also the general condition of the patient and local factors within the trachea are important.[4] Furthermore, an improperly performed tracheotomy or an infected tracheostoma may also cause tracheal stenosis.[3] Such types of stenoses may represent indications for surgical measures, if they lead to dyspnea at rest, exertional dyspnea, or if an open tracheostoma cannot be closed. For these procedures, different options exist. One possible treatment is the intermittent or permanent widening of the trachea, but permanent success is achieved only in exceptional cases.[6] Laser surgical excisions of tracheal stenoses have been recommended,[13,14] but to our experience the success rates were temporary at best. In 10 of our patients who were treated by segmental resection, laser surgery had been performed before to no avail. In our opinion, merely short desmoid stenoses, so-called "webs," can be successfully removed with the laser. Stenoses that have developed from changes within the cartilage framework cannot be successfully managed with endoluminal laser therapy.

The construction of an open furrow and the following plastic reconstruction of the tracheal wall represents a therapy for tracheal stenoses, bearing the disadvantage of

a long treatment period and the burden of several surgeries.[2] The transversal resection enables the removal of the stenosis in a single operation.[6,9] It facilitates the safe and lasting creation of a tracheal lumen sufficient for respiration with rapid epithelization. It entails little cicatrization and ensures fast rehabilitation of the patient.

Within the frame of segmental resection of the trachea, cervical tracheal stenoses up to a length of 6 cm are resectable via a collar approach.[9] However, it has been shown that defects of 4 cm and more require an extended mobilization of the trachea to obtain an anastomosis free of tension. This mobilization of the larynx, in which the muscular and membraneous connections between larynx and hyoid are severed, should be the last measure of defect bypass because of the danger of dysphagia.

A sternotomy may be necessary if the stenoses are localized in the thoracic part of the trachea. The transversal resection should always be performed outside the scarred tracheal segment after a minimum interval of about 6 months after the injury to avoid a restenosis of the possibly infected cicatrix. A particular problem is the incorporation of the cricoid cartilage into the stenosis. A segmental resection including the partial removal of the cricoid cartilage and the application of a thyrotracheal anastomosis can result in some of these cases. This surgical procedure, first described by Pearson,[10,11] has in the meantime been successfully applied by our group even in the treatment of subglottic stenosis, in which it has largely replaced laminotomy as originally described by Rethi.[15]

In our experience, the postoperative course after a segmental resection is accompanied by very few complications. Immediate life-threatening incidents were not observed, and complications in some rare cases could be treated successfully without influencing the overall results. A special problem is the avoidance of pareses of the nervi laryngei recurrentes. In accordance with other investigators,[6,16,17] we usually do not dissect the nervus laryngeus recurrens but try to avoid damage to the nerve by strict preparation along the lateral tracheal wall. It is only in the case of extremely scarred masses after multiple previous operations that we consider it a useful measure to identify and preserve the nerve by appropriate electrophysiological monitoring.

Besides the immediate results, the question whether surgical success will last over a longer period of time is of particular interest. According to our patients' subjective statements, respiration is satisfactory after segmental resection even over a longer period of time. Only a small number of the patients complained about exertion dyspnea during physical activity, but had no problems while at rest.

In most of these cases, this could be attributed to factors not related to the trachea. A distinct restenosis occurred in only two patients. In both cases, segments clearly exceeding the average length had been resected. It needs to be assumed that the two tracheal edges had been anastomosed under excessive tractional strain, so that a restenosis occurred because of the collapse of the flexible lateral and posterior tracheal wall. This occurs with every flexible tube when too much strain is imposed on it. Such complications can be avoided by moving the larynx caudally after severing the musculi thyrohyoidei and the membrana thyrohyoidea (laryngeal release)[18] and by placing the patient in a cast designed to bend the head to the chest.[9]

In 3 of the 80 patients, a second operation was required after 9, 13, and 27 months because of basal respiration dyspnea, even though respiration had been sufficient in the immediate postoperative period. In two patients, a small restenosis in the trachea developed in which additional stenosis of the glottis was present as a result of bilateral vocal cord paralysis, despite preceding laterofixation. Both the trachea and the glottis seemed to be sufficiently wide, but the airway resistance values in the trachea and larynx had obviously added up to yielding a large combined overall resistance.

Another patient with glottic stenosis and inconspicuous, ie, wide, trachea had no complaints of dyspnea while at rest. In principle, in the case of simultaneously occurring glottic stenoses, it appears to be useful, however, to perform both a maximally possible widening operation of the glottis and a segmental resection.

Because of the good functional results and the short treatment period of maximally 3 weeks, the segmental resection with end-to-end anastomosis is superior to all other tracheal widening methods in the case of limited tracheal stenosis up to a length of 6 cm. However, the presented positive results of segmental resection cannot obscure the fact that there may still be indications in severe stenoses for constructing an open furrow.

Possibly, transplantation surgery will open new perspectives in the treatment of tracheal stenosis. Preliminary experiments involving the transplantation of preserved homologous tracheas[19] or total tracheal replacement[20] could lead to new prospects under the precondition that the anticipated immunological host-versus-graft reactions can be controlled.

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