GENERAL THORACIC SURGERY

REOPERATIVE TRACHEAL RESECTION AND RECONSTRUCTION FOR UNSUCCESSFUL REPAIR OF POSTINTUBATION STENOSIS

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Objective: Our objective was to analyze characteristics and results of redo tracheal resection and reconstruction. **Methods:** Seventy-five patients were operated on between 1966 and 1997 after unsuccessful initial repairs for postintubation tracheal stenosis. **Results:** Sixteen of these patients came from a group of 32 patients with unsuccessful repair among the 450 primary resections and reconstructions performed at our institution. Fifty-nine patients were referred to us after unsuccessful initial repair elsewhere. Initial management was a T-tube or tracheotomy in 39 patients. The length of repeat resection ranged from 1.0 cm to 5.5 cm (mean 3.5 cm). A laryngeal release was used in 19 patients (25%) to reduce anastomotic tension. Complications occurred in 29 patients (39%) and were most frequent in the group requiring laryngeal release (12/19, 63.2%). Overall outcome was good in 59 patients (78.6%) and satisfactory in 10 (13.3%). The repair was unsuccessful in four patients (5.3%), and two patients died (2.6%). **Conclusions:** Despite difficulties encountered in reoperative surgery after failed tracheal reconstruction for postintubation stenosis, successful outcome may be achieved in a large number of cases. (J Thorac Cardiovasc Surg 1997;114:934-9)

Postintubation tracheal stenosis continues to occur because of cuff injuries and stomal injuries.¹ Successful management can be achieved in most patients by resection and reconstruction.² Attention to the principles of tracheal surgery is important to successful outcome.³ Precise dissection to avoid injury to the lateral blood supply and recurrent laryngeal nerves is essential. Careful judgment must be exercised to determine how much of the trachea to resect to ensure that reapproximation is safely feasible and that all diseased trachea is removed.

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The use of fine absorbable sutures has all but eliminated anastomotic granulations so common with permanent sutures.² Traction sutures, dissection of the pretracheal plane, neck flexion, and laryngeal release are all important to minimize anastomotic tension.

Although restenosis probably results often from failure of operative technique, it may occur despite attention to the technical details. Early restenosis poses a difficult challenge for surgeons. If a critical stenosis exists, a plan must be developed to ensure a stable airway for a sufficient period of time to allow inflammation and fibrosis to subside before attempted resection.

Our experience with 75 patients who were reoperated on after failure of primary resection and reconstruction forms the basis of this report. Fifty-nine patients underwent the initial operation in other institutions.

Patients and methods

From 1965 to 1992 we performed 450 primary tracheal resections and reconstructions for postintubation stenosis.² From 1966 to 1997 we performed 75 reoperations for restenosis of the trachea owing to failure of the initial

operation. Fifty-nine were referred after prior surgery elsewhere.

The group comprised 42 male and 33 female patients aged 11 to 71 years (mean 40 years). Hospital and office records were reviewed for each patient. Follow-up was obtained by direct patient contact and from office records. Follow-up was obtained in all patients from 1 month to 13 years and averaged 3.1 years.

Patient evaluation. All patients underwent tracheal x-ray studies to determine extent of involvement of the trachea, integrity of the vocal cords, and presence or absence of tracheomalacia. The technique of these radiographs has been reported previously and in our opinion remains the best way to evaluate postintubation tracheal disease roentgenographically despite recent advances in imaging techniques.⁴ Tracheal fluoroscopy, tomograms, and filtered views of the trachea allow for assessment of malacia and vocal cord paralysis in addition to extent of stenosis and linear amount of normal airway remaining. Otolaryngologists should be involved in the evaluation of patients in whom either laryngeal involvement or vocal cord paralysis is suspected. All patients require careful endoscopic examination of the larynx and trachea. This can be done at the time of planned surgical repair, and it is our preference. A stenosis can be dilated at this time with a combination of woven dilators and rigid bronchoscopes (pediatric size 3.5 to adult size 7 or 8). Dilatation of tracheal stenosis requires coordination between surgeon and anesthesiologist.⁵ Attention should be paid to the state of the tracheal mucosa to assess whether excessive inflammation is present. The extent of involvement and amount of remaining trachea is determined by measurement with a rigid bronchoscope.

Operative technique. Great concern exists about reoperative tracheal surgery. Less trachea is available for reconstruction and potential for increased anastomotic tension increases. A sufficient period of time (a minimum of 4 and preferably 6 months) should be allowed for inflammation and fibrosis to subside. This provides maximum mobility of the airway for reconstruction and reduced probability of excessive cicatrization after the operation.

The technique of tracheal resection and reconstruction differs little from that previously described for primary resection and reconstruction.³ A single-stage repair has been used for those lesions involving the subglottic larynx.⁶⁻⁸ A membranous wall flap may be required to resurface the posterior cricoid if circumferential subglottic scarring is present. The recurrent nerves and esophagus may be densely adherent to the trachea after the initial operation, and injury to these structures must be carefully avoided by keeping the dissection strictly on the trachea or the scar that replaces it. Judgment, in major part based on experience, is critical in knowing how much trachea to resect and still be able to perform a sufficiently tension-free anastomosis. A balance is often struck between the length of resection that will permit safe anastomosis and the desire to achieve normal mucosa and structure of the trachea. It is important to remove all areas of malacia or stenosis. The two ends of the trachea may be slightly thickened, but the mucosa should be as nearly normal as possible and the cartilages should be in good condition.

Table I. Initial surgical procedures in addition to a tracheal resection and reconstruction

Procedure	No.
TEF closure	5
Laryngoplasty	4
Multiple TRR	3
Hyoid grafting	2
Neck exploration	2
External splinting	1

TEF, Tracheoesophageal fistula; TRR, tracheal resection and reconstruction.

Absorbable suture material (4-0 Vicryl polyglactin 910, Ethicon, Inc., Somerville, N.J.) for the anastomosis is essential to reduce the incidence of postoperative anastomotic granulations.² Traction sutures (2-0 Vicryl), neck flexion, and a chin stitch to prevent postoperative hyperextension of the neck are standard.

It is important to understand the techniques to reduce anastomotic tension after reoperative tracheal resection and reconstruction. The pretracheal plane is dissected free from cricoid to carina as in primary operations. Special care must be given to the innominate artery, which may be adherent to the anterior surface of the trachea. If the innominate artery must be extensively dissected it is advisable to separate it from the tracheal suture line by a pedicled strap muscle, to minimize risk of trachea-innominate artery fistula. Suprahoid laryngeal release as described by Montgomery⁹ is our preferred method to gain additional mobility of the airway if tension appears excessive. It is rarely necessary or advisable to perform median sternotomy to mobilize the pulmonary hila.

A protecting tracheostomy is rarely required. If concern exists about the lumen of the airway, a small tracheostomy placed at least two rings below the anastomosis can be done, but strap muscle or thyroid isthmus should be sutured over the anastomosis to prevent erosion or contamination of the suture line by the tracheostomy tube. The innominate artery is similarly protected if adjacent.¹⁰

Results

Etiology of original tracheal stenosis. Cuff injury was responsible for the stenosis in 42 patients. Stomal injury from tracheostomy was responsible for stenosis in 22 patients. Three patients had a combined injury, and in eight patients the exact cause could not be determined. Sixteen patients had undergone primary tracheal resection and reconstruction at our institution. These patients represented half of the 32 patients with unsuccessful repair in our series of 450 initial operations.² Fifty-nine patients were referred after resection and reconstruction at other institutions.

Original operations. Fifty-nine patients underwent a primary tracheal resection and reconstruction without additional procedures. Sixteen patients

Table II. Complications

Complication	No.	Incidence (%)
Anastomotic granulations	15	20
Retained secretions	5	6.7
Wound	5	6.7
Dysphagia	4	5.3
Anastomotic dehiscence	3	4
Deep venous thrombosis	1	1.3
Pneumopericardium	1	1.3

had other procedures performed in addition to tracheal resection and reconstruction (Table I).

Etiology of restenosis. The exact cause of restenosis was often difficult to determine. In those patients without granulations, excessive tension and devascularization were thought to be the main causes for restenosis. This was seen in approximately half of the patients. In those patients who had exuberant granulations, the type of suture material was important. Granulations developed in 11 of 27 patients (40%) in whom permanent sutures were used and in only four of the 48 (8%) in whom absorbable suture material was used.

Necrosis of cartilage rings or tracheal separation could also result in anastomotic granulation. Five patients had prior operations for tracheoesophageal fistula. Three had recurrent fistulas in addition to tracheal stenosis, and two patients had recurrent tracheal stenosis despite successful management of the fistula.

Airway management. In our experience postoperative airway stenosis usually manifests itself clinically within 1 to 2 weeks after the operation. Approximately 50% (39/75) of patients in our experience could be managed with observation or dilation until an appropriate time for reoperation. In those patients who required intervention, a T-tube ($n = 17$) or tracheostomy ($n = 15$) was used. We prefer to use a T-tube whenever possible.¹¹ A T-tube is less reactive and easier to manage, and it preserves voice.¹² Because of the importance of conserving as much viable trachea as possible for future reconstruction, the tracheostomy or T-tube was inserted through the most damaged or stenotic portion of the trachea when accessible in the neck. We prefer to replace the T-tube with a tracheostomy tube 3 to 7 days before reoperation to allow the subglottic larynx to recover from the irritation caused by the proximal end of the T-tube.

Interval from initial operation to reoperation. Timing of reoperation is critical to success. We believe that 4 to 6 months should elapse from the initial operation to allow for inflammation and

fibrosis to subside. This length of time may improve mobility of the tissues and lessen anastomotic tension at the time of reoperation, and it will reduce recurrence of granulation and scarring. The interval from primary operation to reoperation in the 16 patients initially treated at our institution was 8.2 months. This length of time was influenced by many factors including deferral of operation to await subsidence of inflammation.

Level of recurrent stenosis. The recurrent stenosis was primarily located in the trachea in 61 patients. The stenosis extended into the subglottic larynx in 14 patients. The level was identified by careful endoscopic evaluation with rigid bronchoscopes and magnifying Storz telescopes (Karl Storz Endoscopy-America Inc., Culver City, Calif.).

Incisions. An anterior operative approach was used in 73 of 75 patients. In 53 patients, a cervical collar incision was used exclusively. In 18 patients, a partial upper sternotomy was added for additional exposure. A transthoracic approach was used in two patients, both of whom were operated on early in our experience. Both would likely be treated through an anterior approach today.

Length of specimen resected. The length of specimen resected may be misleading. In patients in whom slow separation occurs, what is resected is often scar tissue with little actual trachea. In patients with tracheal necrosis or ischemia, actual tracheal tissue is lost. The range of resected specimen was 1.0 cm to 5.5 cm (mean 3.5 cm).

Release procedures. Anastomotic tension was excessive in 19 patients and a laryngeal release was performed. Early in our experience a thyrohyoid release¹³ was performed ($n = 4$). Subsequently suprahyoid release ($n = 15$) was performed because of apparent increased laryngeal dysfunction and aspiration after thyrohyoid release.⁹ Two additional patients had a release procedure with their initial operation elsewhere.

Mortality. Two deaths occurred in this series (2.7%). Both were related to dehiscence of the trachea and subsequent mediastinitis.

Morbidity. Thirty-three major complications occurred in 29 patients (39%) (Table II). This figure compares with a major complication rate of 15% after primary tracheal resection and reconstruction. The most common complication was anastomotic granulations in 15 patients. This complication was greatly influenced by the use of permanent sutures in 11 patients. The problem has been virtually

eliminated in primary repairs by the use of absorbable sutures.² Wound complications were present in five patients including three who had a sternal infection and one who had a separation. Dysphagia was present in four patients, all of whom had a laryngeal release. One patient required prolonged enteral feeding via a gastrostomy because of persistent aspiration.

Complications occurred more often in patients undergoing laryngeal release (12/19, 63.2%). Granulations were present in six patients. Vocal cord dysfunction was present in three patients but ultimately improved in two of them. Two patients were unable initially to clear secretions and required repeated treatments with a flexible bronchoscope. A sternal infection developed in one.

Functional outcome. Outcome was judged *good* if there was no limitation in activity and good voice was present. Outcome was deemed *satisfactory* if the patients had symptoms of dyspnea on exertion and had an adequate voice. *Failure* was determined by the need for a permanent tracheostomy tube or T-tube. A good or satisfactory outcome was achieved in 91.9% of patients (Table III). This result compares very favorably with results after primary resection and reconstruction. *Satisfactory* results were more common in the reoperation group (13.3%) than in the group having primary resections (4.7%), indicating a less optimal expectation in secondary repairs. The failure rate was very similar between reoperative cases (5.3%) and primary reconstructions (7.5%).

Discussion

Restenosis of the trachea after failure of tracheal resection poses a difficult challenge. The margin for error is small if successful reconstruction is to be achieved. A second failure may well condemn a patient to a life-long tracheostomy with an impaired voice.

At our institution the failure rate for first-time resection and reconstruction was 7.1% (32/450). Sixteen (50%) of these 32 patients underwent reoperation. It is often difficult to determine the cause of failure of primary operation. Anastomotic tension is a leading cause for failure. Ischemia, poor technique, and inadequate resection of diseased trachea at the initial operation are contributing factors but often difficult to prove. Associated illnesses such as diabetes, connective tissue disorders, and poor nutrition may play a role but are even harder to prove. Whatever the cause of failure, conditions must be

Table III. Comparative results of tracheal resection and reconstruction

	Primary (n = 450)		Reoperation (n = 75)	
	No.	%	No.	%
Good	387	86	59	78.6
Satisfactory	21	4.7	10	13.3
Failure	32	7.1	4	5.3
Death	10	2.2	2	2.6

optimal to achieve successful reconstruction in a repeat operation.

Sufficient time must elapse after the first operation to allow resolution of inflammation, edema, and fibrosis so that tissues are pliable and mobile to a maximum degree. Four to 6 months is probably sufficient, but the interval averaged 8 months in our patients whose original operation was at our institution. About half of the patients in our series had a satisfactory airway that precluded the need for temporary tracheostomy or T-tube. This is the preferred option. If a tracheostomy or T-tube is required, the tube should be inserted through the most damaged portion of the airway to preserve as much viable trachea as possible for future reconstruction. Sixteen of 32 patients with failed primary tracheal resections at our own institution underwent reoperation. If the restenosis is very distal and inaccessible directly through the neck, a stoma may be placed at the level of the second or third ring and a long T-tube passed through the stenosis distally.

Almost all repeat operations for tracheal stenosis can be done through a cervical incision, with a partial upper sternotomy for added exposure if needed. Because of the increased adherence of the innominate artery, recurrent nerves, and esophagus to the trachea, great care must be used to avoid these structures by staying as close as possible to the trachea during the dissection. Great judgment is required to know how much of the diseased airway to resect. Structural integrity of the cartilage and a healthy mucosa are important, but the two ends of the airway may not be entirely normal. The technique of anastomosis is the same as described for primary reconstruction.³

Anastomotic tension is an even greater concern in reoperations. Usually, less airway is available and the tissues are less mobile. Laryngeal release was used in 25.3% of the patients in our series compared with only 6.4% in more than 450 patients undergoing primary resection and reconstruction.² We have preferred the Montgomery suprahyoid laryngeal re-

lease because laryngeal dysfunction and aspiration are less prevalent than with the thyrohyoid release. Complications were more common in the subset of patients requiring laryngeal release (63.2%), but despite that a good (91%) or satisfactory (4.5%) result was achieved in these patients, with only one failure (4.5%).

Complications are more common in patients undergoing reoperation (39%) than in patients undergoing primary reconstruction (15%).² This implies a greater degree of difficulty in this group of patients. The most common complication seen in our series was anastomotic granulations. This problem has become less common in this series because we have abandoned permanent sutures (40%) in favor of absorbable sutures (8%).

A dreaded complication after tracheal reconstruction is dehiscence of the airway. This occurred in three patients and accounted for the only two deaths. Poor tissue and excessive tension are the leading causes of this problem. The importance of minimizing tension and using laryngeal release, when appropriate, cannot be overemphasized. If in the surgeon's mature judgment resection would lead to unacceptable anastomotic tension, appropriate management may be a permanent T-tube.¹¹ Thus 16 of 32 patients with restenosis after reconstruction in our hospital were not subjected to a second reconstruction.

Despite the increased difficulties encountered in reoperation for tracheal stenosis, successful outcome is still possible. Only about half of patients whose primary repair was unsuccessful are suitable for reoperation. Experienced judgment is required to determine who is a suitable candidate. Once the patient is identified as a suitable candidate, however, successful restoration of the airway and preservation of voice can be achieved in more than 90% of cases.

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Discussion

Dr. F. Griffith Pearson (Toronto, Ontario, Canada). Dr. Donahue, you and your colleagues are reporting on approximately 30 years of experience with these postintubation injuries and have synthesized your experience with the most difficult problems in management, which involve reoperation. Ronald Belsey used to state that the most difficult operation in thoracic surgery was the management of an unsuccessful antireflux operation. By the same token, the most difficult operation in upper airway surgery, as you state, is reoperation. Its complexity and magnitude are indeed completely different from those of the initial operation.

Your 75 patients have had outstandingly good results, with only four unsuccessful repairs and two deaths and with 90% of patients extubated. Furthermore, you dealt with a number of difficult associated problems, such as tracheoesophageal fistula. We have a similar, though smaller, experience over the same three decades, with about 30 reoperations, 10 of which were at the subglottic level and four at the level of the larynx.

Identifying the cause of failure has been problematic. I do not believe that dehiscence resulting from tension has been a common problem. Often the complications developed in patients who had had rather short resections. We have seen some instances of local infection, and that has been associated with a poor result and restenosis. I believe infection has occurred most commonly in patients with diabetes; we have always been concerned when treating these patients who have been on a long-term program of steroid therapy.

What prophylaxis would you recommend to prevent infection? When the rare wound infection occurs, do you reopen the wound widely with the patient under anes-

sia? What do you do about the patient who is on a high-dose steroid regimen?

Dr. Donahue. Thank you, Dr. Pearson. We were fortunate that our infection rates were fairly low. Early in our experience infections in the sternotomy wound developed in three patients but, fortunately, only one necessitated debridement. The others were managed with antibiotic treatment.

Eight patients in this series were referred to us while on a program of systemic steroids. We were able to successfully wean five of them from the steroid therapy, and the other three underwent their procedure while receiving steroid therapy. Two were treated successfully, and the third died.

Of the primary operation group, patients who under-

went only first-time operations, 13 had been receiving steroid therapy in the preoperative period and could not be weaned from the drugs; 12 of those had a good outcome.

Many factors play a role in outcome: the patient's body habitus, the length of trachea that is resected, and the mobility and flexibility of the patient's tissues certainly have an effect, in addition to other more systemic factors such as steroids and diabetes. However, we have not been able to clearly identify any causal factors.

Dr. Pearson. Do you use prophylactic antibiotics in the first-time operations?

Dr. Donahue. We typically use cefazolin sodium (Ancef) for the first 2 days.

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