Factors Associated With Staged Reconstruction and Successful Stoma Closure in Tracheal Resection and End-to-End Anastomosis

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Background: By analyzing the rate of successful decannulation in patients who underwent tracheal resection and end-to-end anastomosis, we tried to find the factors affecting the surgical outcome of tracheal stenosis. We also tried to discover the factors affecting the need for staged reconstruction.

Design and Setting: Retrospective study in a tertiary care center.

Patients: From 1988 to 2001, 117 tracheal resections and primary end-to-end anastomoses in 110 patients were carried out. The statistical analysis was done from the data of 81 patients in whom the stenosis was caused mainly by internal trauma such as long-term intubation or tracheostomy.

Main Outcome Measures: The success of surgery was defined as successful stoma closure; staged reconstructions were defined as cases in which the stoma was left open intentionally during the end-to-end anastomosis.

Results: The stoma could be successfully closed primarily in 67 (83%) of the 81 cases, and staged reconstructions were needed in 22 (26%) of the patients. Older patients (>60 years) and patients with a higher grade of stenosis showed a significantly lower success rate. Staged operations were more frequently needed in cases with total stenosis and with combined stenosis of the trachea and the subglottis.

Conclusions: In patients older than 60 years or with severe stenosis, the rate of successful stoma closure was low. A staged operation should be considered in cases with severe stenosis or stenosis not confined to the trachea.


The earliest report of tracheal reconstruction by an open staged technique was published in 1927.1 And since the contribution of Grillo2 in the 1960s, tracheal resection and end-to-end anastomosis has been regarded as the treatment of choice for isolated tracheal stenosis.

The reported success rate of circumferential tracheal resection and end-to-end anastomosis for postintubation stenosis of the cervical trachea is relatively high, 81% to 96.7%.3-6 There have been some reports on the factors affecting the success rates and complication rates of laryngotracheal reconstructive surgery. Cases involving older patients,7 thyrotracheal anastomosis,8 and impaired glottic function9 have demonstrated lower operative success rates.

The use of various release techniques for gaining additional tracheal length for primary closure is also an important issue in tracheal resection. Dysphagia after use of a release technique is the most commonly discussed problem. Although postoperative dysphagia after suprahynoid release is not very frequently encountered,10 dysphagia cannot be completely avoided when this releasing technique is used.

In patients with a long stenosis or excessive tension after anastomosis, staged reconstruction of the airway using fenestration or the trough method may provide a safe airway and have the additional benefit of avoiding the use of aggressive releasing techniques. It also provides excellent visualization of the airway and state of healing. The risk of postoperative air leakage or rupture of the anastomosis can be avoided by using this method. A longer stenosis (≥4 cm); stenoses involving the glottis, subglottis, and/or trachea; and cases of previous attempts at repair by open surgery have been suggested as indications for staged reconstruction.11 Investigation into the factors that affect the rate of successful stoma closure and the need for staged reconstruction of intubation- and/or tracheostomy-induced...
airway stenoses will help surgeons predict preoperatively the chances of primary surgical success and the likelihood of the need for a staged operation.

**METHODS**

**PATIENTS**

From July 1988 to December 2001, 117 tracheal resections and end-to-end anastomoses were carried out on 110 patients with airway obstructions caused by tumors or stenoses at the Department of Otolaryngology–Head and Neck Surgery, Seoul National University Hospital, Seoul, Korea. Two of us performed all of the operations (K.H.K. and M.-W.S.). The medical records were retrospectively analyzed, and 81 cases of airway stenosis caused by internal trauma (eg, long-term intubation or tracheostomy) were included. Patient age at the time of the operation ranged from 1 to 72 years (mean age, 34.5 years). There were 52 male and 29 female patients. The average follow-up was 12 months.

Success was defined as successful stoma closure with no dyspnea or dyspnea tolerable for daily life thereafter. Staged reconstruction was defined cases in which the stoma was left open intentionally by fenestration or the trough method during end-to-end anastomosis.

The cause of stenosis was mainly either intubation or tracheostomy. However, in 39 cases (48%), intubation had been maintained for about 1 week to 10 days, and then a tracheostomy tube was placed before the airway stenosis was detected. These cases were classified as *mixed cause*. We categorized the patients into 3 age groups: younger than 15 years; 15 to 60 years; and older than 60 years.

The resected length of trachea ranged from 1 to 8 cm (mean length, 3 cm). The degree of stenosis was graded using the Myer-Cotton system in which grade 1 indicates up to 50% obstruction; grade 2, 51% to 70%; grade 3, 71% to 99%; and grade 4, no detectable lumen. We compared the rate of successful stoma closure and the chances of the need for staged reconstruction by age at operation, grade of stenosis, anastomosis site, stenotic portion, cause of stenosis, and length of resection. The Pearson $\chi^2$ test was performed using SPSS (SPSS Inc, Chicago, Ill) for Windows 10.0 (Microsoft Corp, Redmond, Wash).

**OPERATIVE TECHNIQUES**

With dual intubation via stoma and orotrachea, a long horizontal or U-shaped incision was made. After exposure of the tracheal wall, the isthmus of thyroid was transected. The tracheal dissection was performed close to the tracheal wall to avoid injury to the recurrent laryngeal nerve. Usually, the nerve was not identified during the operation. The margin of resection was determined by multiple cutting of the trachea from the stenotic portion. For safe repair, the posterior mucosal wall was left as thick as possible, and after the suture of the posterior wall, the anesthesia tube inserted through the stoma was exchanged. Anastomosis of the trachea was done with 3-0 Vicryl single-layer submucosal suture (Ethicon Inc, Somerville, NJ) including a 1-mm margin of mucosa.

The suprathyroid release technique was used in only 2 cases, both in the beginning of the study period. In many cases, the end-to-end anastomosis could be accomplished without excessive tension, using only finger dissection of the trachea along the surgical field and flexion of the neck and no sutures between the chin and chest wall. In cases of single-stage reconstruction, extubation was done in the next day.

When single-stage anastomosis was difficult, the trough method was used for staged reconstruction of the airway. Suturing of the posterior wall was usually possible in the most extensive cases, but suturing of the anterior wall was difficult in cases of longer stenoses. The stoma and anterior wall were reconstructed in a later stage with a local skin flap (Figure 1) or with a composite skin-and-cartilage graft after mucosal healing.

**CASE 1**

A 22-year-old man involved in a motorcycle crash became quadriplegic in September 1991. After long-term ventilator care with a tracheostomy to manage pneumonia, tracheal stenosis developed. On laryngoscopic examination in May 1993, the subglottic area was patent down to 1.5 cm below the true vocal cord. There was no cartilage support around the tracheostoma site, and the total length of the stenosis was about 7 to 8 cm. In July 1993, tracheal resection and thyrotacheal anastomosis of the posterior wall were undertaken, and a trough was

![Figure 1. A, Design of the incision for a local flap; B, the lateral margin of the skin flap attached to the stoma is approximated in the midline; and C, closure of the defect along a horizontal line after undermining.](http://archotol.jamanetwork.com/pdfaccess.ashx?url=/data/journals/otol/18333/ on 06/04/2017)
formed. Four months after the primary operation, the tracheal lateral wall was augmented by inserting a costal cartilage graft in both sides (Figure 2A and B).

In July 1994, stoma closure was attempted with miniplate support, but tracheal fenestration was required again because of dyspnea 3 days postoperatively. In August, a composite graft of septal cartilage was placed in the upper chest for banking (Figure 2C), and after a 2-week banking period, the stoma was closed, leaving only a small window for observation of the tracheal lumen by rotational flap with banked cartilage (Figure 2D). A skin graft was applied to the donor site. After 1 month, the small tracheocutaneous fistula was closed. Throughout follow-up, the patient experienced no dyspnea or troublesome crust formation (Figure 2E).

CASE 2

A 26-year-old man had a clothesline injury in December 1992. He underwent partial reconstruction of the thyroid cartilage with the costal cartilage in February 1993. In June 1993, cricoid splitting and augmentation with costal cartilage was performed for reconstruction of the subglottic airway. In September, a trough was made superior to the stoma site and a skin graft was placed at the posterosuperior tracheal wall (Figure 3A). The tracheal resection with end-to-end anastomosis and trough formation was performed in June 1994. After 3 months, the tracheal anterior wall was reconstructed with a composite graft of septal cartilage (Figure 3B and C), and the stoma was successfully closed after a 4-month observation period (Figure 3D and E).

**RESULTS**

Successful stoma closure was possible in 67 (83%) of 81 patients. **Table 1** lists the success rate of single-stage vs multiple-stage airway reconstruction. In 22 patients (27%), the tracheostoma could not be removed during the tracheal resection and anastomosis operation, and a staged reconstruction of the trachea was required. In 2 (3%) of 59 single-stage reconstructions, the procedure failed and the patients died. One death was due to the disruption of the anastomosis site 1 week after surgery, and the other was due to the innominate artery rupture.

![Figure 2](http://archotol.jamanetwork.com/pdfaccess.ashx?url=/data/journals/otol/18333/) A 22-year-old man with tracheal stenosis due to long-term ventilator care. A, Augmentation of the tracheal lateral wall by costal cartilage grafting on both sides; B, the skin overlying the cartilage is sutured; C, a composite graft of septal cartilage is placed for banking and to improve blood supply; D, stoma closure with banked septal cartilage leaving a small observation window; and E, final follow-up after successful stoma closure.
In 10 (46%) of 22 cases of staged reconstruction, the normal airway was restored. Seven of the 12 unsuccessful cases required additional surgery for reconstruction of the airway. Rib cartilage grafting was performed in 3 patients with subglottic stenosis. Revision tracheal resection and end-to-end anastomosis was performed in 3 cases to treat restenosis, and repeated bougienage was performed in 1 case. In 2 cases, closure of the stoma was abandoned owing to other problems: hemiplegia and paranoia in the one case and severe aspiration due to bilateral vocal cord palsy in the other. The remaining 3 cases are now under observation at our outpatient clinic.

Table 2 lists the factors analyzed and the success rates of stoma closure and the rate of staged reconstruction. Age at the time of surgery was the most important predictive factor for the success of tracheal resection and end-to-end anastomosis ($P = .03$). In the 11 patients older than 60 years, normal airway was restored in only 6 (55%) compared with at least 13 (87%) of 15 in the younger age groups. Patients older than 60 years seemed to fare better undergoing staged surgery, although this higher success rate did not reach statistical significance.

The success rates analyzed by cause of tracheal stenosis, history of neck surgery, or anastomosis site showed no differences between groups. Staged reconstruction was needed in 50% of thyrotracheal anastomoses, but owing to the small number of these cases, this figure has no statistical meaning. The grade of stenosis was significant in predicting both successful stoma closure and the need of staged operation. The success rate in grade 2 cases was 93%, and that of grade 4 cases was 65% ($P = .05$). In terms of the staged operation, only 17% of grade 2 cases and 18% of grade 3 cases needed staged operations, but in patients with grade 4 stenosis, 59% kept the tracheostoma postoperatively ($P = .005$). Patients whose stenotic portions were not confined to the trachea showed higher

<table>
<thead>
<tr>
<th>Type of Reconstruction</th>
<th>No. (%) of Cases</th>
<th>No. (%) of Successful Outcomes</th>
<th>$P$ Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-stage</td>
<td>59 (73)</td>
<td>57 (97)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Staged</td>
<td>22 (27)</td>
<td>10 (46)</td>
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</tbody>
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*Pearson $\chi^2$ test.
The central aim of this study was to find a way to better predict surgical outcomes and the need for staged reconstruction. Tension at the suture line mainly depends on the length of the resection, however, tension is not always proportional to the resection length. At the beginning of our series, we used a tracheal release technique in 2 cases, but we did not use it after we had some experience with tracheal resection. In some young patients, gaps of up to 7 cm could be successfully anastomosed without the use of the release technique. In some older patients, however, it was hard to finish the anastomosis in spite of a short length of resection. Thus, the need for a staged operation could not be predicted by imaging or by preoperative endoscopic examination of the stenotic site.

The larynx is suspended by many muscles and is not a fixed organ. It can be pulled down enough for anastomosis without cutting the muscles. If a strong anastomosis can be achieved, the chances of separation are not high, and it is not necessary to dissect the skin flap up to the submental region. To perform a thoracotomy to achieve release from the main bronchus level, as Grillo describes, is a very difficult technique and carries the risk of severe complications. Therefore, instead of performing such an aggressive releasing technique, we chose the staged operation, using either anastomosis of the posterior wall and suture of the skin to the margin of the anterior wall to form the trough, or fenestration in cases in which we could not get approximation at the anterior wall. This opening could be easily closed by using a local skin flap after the mucosa healed, as shown in Figure 1. If the anterior-posterior distance is too short owing to lack of the cartilage lateral wall, it can be augmented by a free cartilage graft, as shown in Figure 2. If the opening is too large, a composite graft from nasal septum is helpful to reconstruct the anterior wall, as shown in Figures 2 and 3. Closing the trough cannot be achieved in 1 stage. Some trial and error may be necessary in this kind of difficult airway reconstruction.

The advantage of staged reconstruction using the trough method, as Biller and Lawson described, is that it offers a method of repair for an extensive defect of the cervical trachea or combined stenosis. Also, by suturing the skin flap to the tracheal wall, tracheostomy cannulas can be removed. Patient comfort level will be much higher, and the mucosa will heal better when the cannula is not in the trachea.

The present report reviews cases not only in terms of the rate of successful stoma closure but also the chance of the need for staged reconstruction in tracheal resection and anastomosis. Because factors associated with the need of staged reconstruction are also relevant in predicting the clinical course of patients preoperatively, they will influence the counseling of patients and their families.

Gavilan et al have reviewed the prognostic factors in patients with laryngotracheal stenosis treated mainly by laryngotracheoplasty. They reported that subjects older than 40 years had a significantly lower rate of decannulation than younger patients. Hartnick et al also reported that laryngotracheal reconstruction in children with Myer-Cotton grade 3 or 4 disease yielded a lower success rate. The subjects of these reports represent cases of laryngotracheoplasty using rib cartilage graft or hyoid bone graft.

We analyzed tracheal resection and anastomosis cases only. Age older than 60 years and a Myer-Cotton grade of 4 were associated with significantly decreased success rates of surgery. For patients older than 60 years, successful stoma closure was achieved only half the time. This may be due to the loss of elasticity in the trachea or surrounding tissues of older patients. For the same reason, staged reconstruction might be necessary more often in older patients.

Staged reconstruction was also frequently necessary in patients with Myer-Cotton grade 4 stenoses or with stenoses involving the subglottis and/or glottis. In cases with combined stenosis in the trachea and subglottis or glottis, laryngofissure or cricoid splitting with cartilage graft augmentation was additionally required and these patients had a complex course of treatment. In these cases, increased chances of staged surgery might be expected, but there was no significant difference in terms of success rate.

In contrast to the former report about the indications of staged reconstruction, we found that a history of open reconstruction of stenosis did not affect the rate of success or the chances of staged reconstruction. The indications for staged reconstruction derived from the present study are age more than 60 years, Myer-Cotton grade of 4, and stenosis involving the subglottis and/or glottis.
The 2 failed cases of single-staged reconstruction in the present series were both mortality cases. One death was due to delayed rupture of the anastomosis site and the other to the rupture of an innominate artery. The patient in the first case, a pediatric patient treated by a relatively inexperienced surgeon, died of delayed tracheal separation. Probably the tracheal wall in this patient was shaved too thin, or not enough tissue was taken for suturing the anastomosis site. In the second case, the anastomosis site was in direct contact with the innominate artery, and the arterial wall may have been eroded by the suture knot. In cases where the anastomosis site contacts the great vessels, it is absolutely necessary to separate the suture line from the artery by interposition of soft tissue.

In conclusion, the age of the patient and grade of stenosis seem to be important prognostic factors for predicting successful outcome in tracheal resection and end-to-end anastomosis. Patients with grade 4 stenosis have a higher chance of a need for staged reconstruction than patients with moderate stenosis. Patients with airway stenosis involving the subglottis or glottis need more complicated course of treatment than those with tracheal stenosis, but the surgical success rate does not differ.

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