

## Original Investigation

# Staged Laryngotracheoplasty in Adult Laryngotracheal Stenosis Predictors of Long-term Decannulation

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**IMPORTANCE** This study reviews a single center's experience of performing staged laryngotracheoplasty (LTP) for the treatment of laryngotracheal stenosis with the ultimate goal of attaining long-term airway patency without restenosis.

**OBJECTIVE** To identify staged LTP as an efficacious surgical treatment option for laryngotracheal stenosis.

**DESIGN, SETTING, AND PARTICIPANTS** From January 2000 to January 2012, patients at a tertiary care academic institution presenting with diagnoses of laryngeal or laryngotracheal stenosis were retrospectively identified. Medical records from adult patients were inspected, and patient demographics, clinical data, and clinical outcomes were recorded. All patients undergoing staged LTP were initially included. Patients with history of head and neck malignant neoplasm were excluded.

**INTERVENTIONS** Staged LTP.

**MAIN OUTCOMES AND MEASURES** The primary outcome was long-term decannulation, defined as decannulation for duration of at least 6 months.

**RESULTS** Sixty-one patients were included in this study. The mean (SD) patient age was 47.1 (16.7) at the time of first-stage LTP and had a mean (range) follow-up of 5.32 (0.5-17.3) years from the first-stage reconstruction. Etiology of stenosis included prolonged intubation in 27 patients (44%), autoimmune disease in 9 (15%), idiopathic causes in 11 (18%), blunt laryngeal trauma in 10 (16%), and other causes in 4 (7%). Forty-nine patients (80%) were successfully decannulated, while to date 12 (20%) remain tracheostomy or tympanostomy tube dependent. Univariate analyses showed no significant association between decannulation and age ( $P = .35$ ), sex ( $P = .52$ ), history of intubation ( $P = .22$ ), surgeon ( $P = .20$ ), etiology of stenosis ( $P = .91$ ), or length of stenosis ( $P = .31$ ). Multivariate logistic regression analysis showed a significant inverse relationship between grade of stenosis and probability of decannulation ( $P = .01$ ).

**CONCLUSIONS AND RELEVANCE** Staged LTP is an option for the reconstruction laryngotracheal stenosis. Our experience shows excellent decannulation rates in the selected patients with stenosis, many of whom have failed treatment with other surgical modalities.

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Laryngotracheal stenosis (LTS) in the adult patient is a complex disorder with several treatment options, including endoscopic and open approaches, but without a universally accepted treatment owing to its complexity. Laryngotracheal stenosis is often a result of direct injury to tracheal cartilage or inflammatory granulation tissue causing airway narrowing, most commonly secondary to external or luminal trauma, such as prolonged endotracheal intubation. Other etiologies include Wegener granulomatosis, chemical injury, and gastroesophageal reflux disease.<sup>1,2</sup> Instrumentation of the trachea is by far the predominant cause of LTS in adults, with multiple series reporting intubation or tracheotomy as causes in more than 80% of patients.<sup>3,4</sup>

The length, location, and severity of stenosis must all be considered in the treatment of LTS. Mild LTS may be successfully treated with endoscopic techniques, including balloon dilation, carbon dioxide laser ablation, steroid injection, and antineoplastic agent applications.<sup>5</sup> These are safe and well-tolerated but are associated with high rates of recurrence typically requiring repeated procedures.<sup>2</sup> Alternatively, open surgical approaches can lead to long-term decannulation but carry higher risks of morbidity and mortality.<sup>2</sup> There are 2 general open surgical strategies.<sup>6</sup> The first approach involves full resection of the stenotic segment of trachea, which may or may not include the cricoid ring, with primary anastomosis. The second approach is laryngotracheoplasty (LTP), which describes surgical ablation of the luminal stenosis and scar, along with reconstruction without segmental tracheal resection.

Tracheal or cricotracheal resection with primary anastomosis provides excellent long-term success rates treating adult LTS with high rates of decannulation.<sup>6-8</sup> However, treatment of long-segment stenoses, typically beyond 6 tracheal rings, and stenoses that extend high within the larynx has limited success with primary resection.<sup>1</sup> In such challenging cases, staged LTP has been suggested to produce high decannulation rates.

*Laryngotracheoplasty* is a general term encompassing wide ranges of surgical techniques and protocols. It has been described as including a single-stage or multistage approach to use various types of luminal grafting and differing methods of tracheal stenting.<sup>9</sup> Much of the literature on single-stage LTP is in the pediatric population, but good decannulation rates in adults have been reported as well.<sup>10-12</sup> Laryngotracheoplasty with mesh grafting for anterior tracheal wall reconstruction has been described in 2 small case series by Gaafar et al<sup>13</sup> and Daneshi et al,<sup>14</sup> demonstrating over 90% of patients achieving long-term decannulation. However, there is a relative paucity of large case series describing the clinical variables associated with favorable outcomes of staged LTP in the adult patient with LTS. The present study reviews the largest case series to date of adult airway stenosis treated with staged LTP, describes our surgical technique, and identifies clinical predictors of long-term tracheostomy decannulation.

## Methods

### Study Design

This study protocol was approved by the local medical institutional review board. From a single-institution otolaryngology

patient database, a patient list was gathered by identifying specific *International Classification of Diseases, Ninth Revision (ICD-9)* diagnosis codes (codes 478.74 or 519.19) between 1990 and 2012. A retrospective medical record review was performed for all of the identified patients. Patients who underwent multistaged LTP for LTS were selected. At the current institution (David Geffen School of Medicine at University of California, Los Angeles), LTP was practiced using a consistent and uniform surgical technique beginning in the year 2000; therefore, the current study includes patients undergoing surgery between January 2000 to January 2012. Demographics, clinic notes, operative reports, and follow-up data were recorded. Patients were included in the study if they were 17 years or older and if they completed at least 2 stages of LTP (all surgical procedures were performed at the present institution). Patients were excluded if there was a history of malignant neoplasm within the aerodigestive tract.

### Demographic and Clinical Characteristics

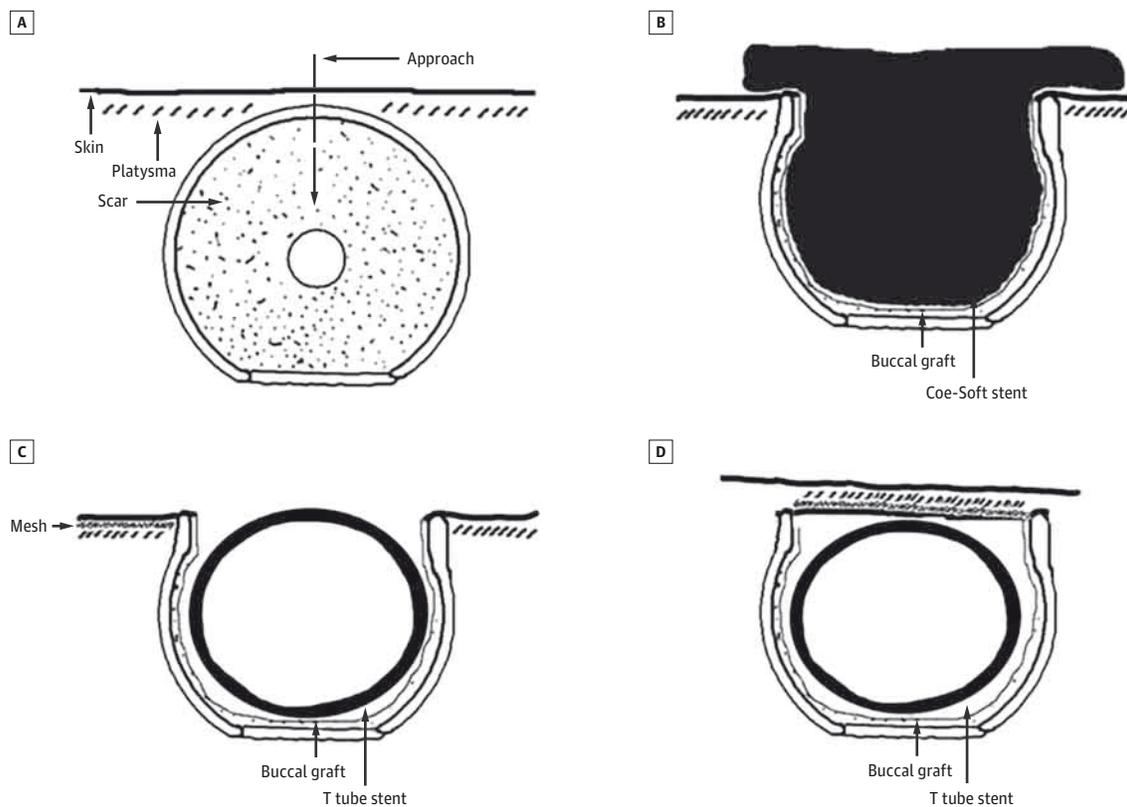
Demographic and clinical data recorded included age at presentation, sex, etiology of stenosis, prior intubation, and smoking history. Prolonged intubation was defined as intubation for more than 24 hours, and symptoms of stenosis were temporally associated. Stenosis was determined to be idiopathic if there was no other underlying cause of pathologic abnormalities, including trauma, diagnosis of autoimmune disease, or history of intubation. Stenosis grade was based on the Myer-Cotton grading system (grade I,  $\leq 50\%$  stenosis; grade II, 51%-70% stenosis; grade III, 71%-90% stenosis; and grade IV, complete stenosis with no detectable lumen).<sup>15</sup> Vertical stenosis length was categorized into short ( $\leq 2$  cm in length) or long ( $> 2$  cm in length) segment. Both grade and length of stenosis were determined based on intraoperative laryngoscopy with tracheobronchoscopic findings at the first stage of reconstruction. The main outcome measure was long-term decannulation, which was defined as continued decannulation at last clinical follow-up.

### Surgical Technique

#### Stage 1

The first LTP stage begins with a diagnostic direct laryngoscopy and bronchoscopy to identify the extent and severity of stenosis. After endoscopic assessment, the neck is prepared and draped for open airway surgery. Rarely, if there is no existing tracheostomy, then a standard tracheostomy is performed, usually while the patient is awake because these patients often cannot be easily intubated. A vertical neck incision is made in the anterior midline, with the inferior extent at the level of the previously placed tracheotomy site and the superior extent to the superior level of airway stenosis. The dissection proceeds deeper in the midline until the larynx and trachea are delineated. Starting at the tracheostomy site, a vertical midline incision is then made into the anterior laryngotracheal wall and airway lumen, and the full extent of the stenosis is exposed (Figure 1A). Cricoid split and laryngofissure is performed if needed to expose the full length of the scar. With the tracheal lumen open and with the stenosis splayed, the scar tissue is removed by excising sharply or by drilling with a 3- to 4-mm diamond burr.

Figure 1. Surgical Technique of Laryngotracheoplasty



A, During the first stage, a vertical incision is made in the neck skin, and the stenotic segment of the airway is exposed. B, The scar is removed and covered with buccal mucosal graft. A custom-made Coe-Soft (GC America) stent is used to stabilize the mucosal graft. C, At stage 2, a mesh is placed in a subcutaneous

pocket and a tympanostomy tube (T tube) is used to stent the stenotic segment. D, At stage 3, an anterior tracheal wall is created by rotating the mesh complex and suturing to the opposite tracheal wall.

The airway is now exposed as a 3-walled trough, with areas of denuded mucosa after stenosis scar removal. The lateral edges of the exposed airway walls are sutured to the skin edges using half-mattress sutures (3-0 or 4-0 Vicryl), creating a vertical open tracheal trough. The denuded areas are covered with buccal mucosal grafts. After measuring the defect, a buccal mucosal free graft is then harvested and defatted. An airway stent is needed to stabilize the mucosal graft. A stent for the tracheal trough is made prior to placement of mucosal graft using solid conforming material (Coe-Soft, GC America) that is fitted to the specific defect. The mucosal graft is then placed overlying the denuded tracheal lumen and sutured in place using 4-0 or 5-0 chromic sutures. The Coe-Soft stent is then brought into the field and used to hold the buccal mucosa in place and keep the trough open (Figure 1B and Figure 2A). This is secured in place using a Xeroform bolster that is sutured in place (Figure 2B). Alternatively, if the defect is small, then a simple Xeroform bolster without a stent can be used. A cuffed tracheostomy tube is placed at the end of the case with the balloon gently inflated to prevent exposure of the grafted area by airway secretions. It should be noted that a traditional tracheostomy is not performed as part of this surgery; rather, the tracheostomy tube is used to cannu-

late the distal portion of the debrided stenotic segment. The patient is kept admitted in the hospital between the first and second stages.

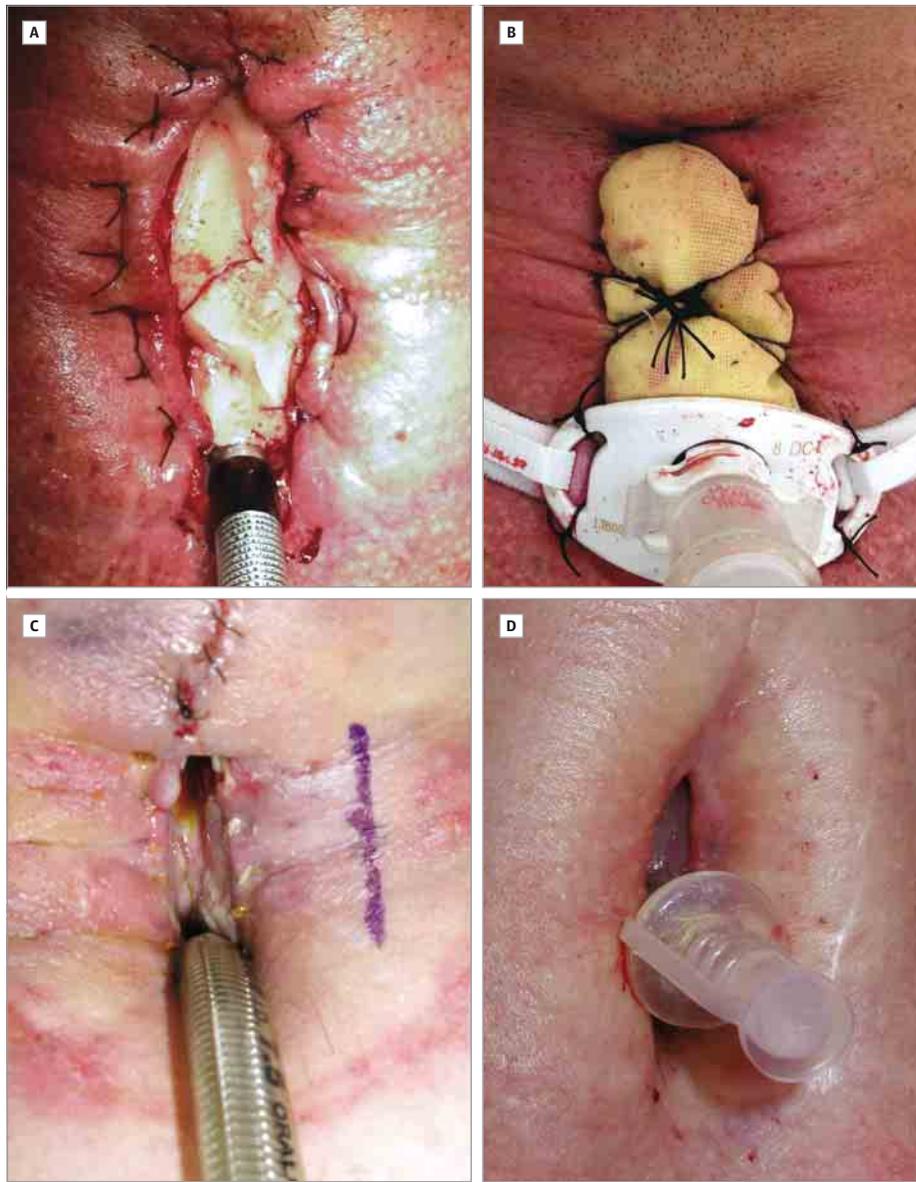
#### Stage 2

The second LTP stage is performed 5 to 7 days after stage 1. During the second stage, the mucosal graft is examined, and any formed granulation tissue is removed (Figure 2C). At this point, if anterior tracheal wall augmentation is necessary, then non-absorbable mesh (eg, Marlex or Prolene) is placed within a subcutaneous tissue pocket just lateral to the open trough in a non-hair-bearing area, which approximates the length and width of the absent anterior tracheal wall. Then, with the trough left open, this pocket containing the mesh is closed, and a Montgomery tympanostomy tube (T tube) is placed in the airway to stent the airway and provide voicing ability (Figure 1C). The patient is taught how to suction the T tube. The mesh is subsequently allowed to mature for several weeks.

#### Stage 3

At the third LTP stage (Figure 2D), the previously placed mesh, along with the overlying skin, is rotated medially in a subpla-

Figure 2. Photographs of Patients at Different Stages of Multistaged Laryngotracheoplasty (LTP)



A, During stage 1, a laryngotracheal trough has been created after excision of scar tissue. A free buccal mucosal graft has been used to line the trough, which is now filled with a custom Coe-Soft (GC America) stent. B, A Xeroform-lined bolster is used to secure the Coe-Soft stent in place, and a cuffed tracheostomy is left in place between the first and second stages. C, During stage 2, the trough lined with buccal mucosa is healing well, and an incision line for mesh placement has been marked. This patient had a relatively short trough, so the superior portion of the incision had been closed primarily during stage 1. D, At the beginning of stage 3, a tympanostomy tube is in place and the incision over the mesh placed during stage 2 has healed. During this stage the mesh and skin complex will be rotated over the trough to augment the anterior wall of the reconstructed airway.

tysmal plane and sutured to the contralateral tracheal wall, thereby recreating a new anterior wall of the airway. The mesh complex is secured to the airway with inversion of the skin edges on either side of the trough into the tracheal lumen. Typically, a T tube may be left to stent the airway and to allow for maturation of the reconstruction (Figure 1D). The neck incision is then closed in layers. The strap muscles are mobilized and sutured to the midline overlying the trachea, and the skin and subcutaneous tissues are then closed over the strap muscles. If the airway lumen appears healthy, with intact native mucosa, then the entire trough may be closed without a tracheostomy tube.

Patients were administered first-generation cephalosporin antibiotics for a week after each stage of the surgery. Clinical follow-up is 1 to 2 weeks after the third stage and every 3 months thereafter. Frequency of outpatient visits

may be dictated by the progress of each patient. It is important to note that the postoperative care and evaluation of patients who have undergone LTP toward the goal of decannulation is one that requires high levels of vigilance and flexibility. The reconstructed airway requires active monitoring, usually with outpatient bronchoscopy with general anesthesia to remove the T tube. The minimum amount of time that the T tube is left in place following stage 3 LTP is 3 months. However, the first postoperative airway staging can be scheduled at 6 months or longer in selected cases. The timing is dependent on the status of the airway during stage 3, the medical condition of the patient, and the appearance of the cutaneous wound healing. Most patients who will ultimately progress successfully to decannulation can expect to do so by the 9-month date following the stage 1 surgery.

Table. Subglottic Stenosis Demographic and Clinical Data

| Characteristic              | No. (%) <sup>a</sup> |                       |                               | P Value |
|-----------------------------|----------------------|-----------------------|-------------------------------|---------|
|                             | Overall (n = 61)     | Decannulated (n = 49) | Failed Decannulation (n = 12) |         |
| Age, mean (SD), y           | 47.1 (16.7)          | 48.1 (16.9)           | 43.0 (15.6)                   | .35     |
| Sex                         |                      |                       |                               |         |
| Female                      | 34 (56)              | 26 (53)               | 8 (67)                        | .52     |
| Male                        | 27 (44)              | 23 (47)               | 4 (33)                        |         |
| Etiology of stenosis        |                      |                       |                               |         |
| Prolonged intubation        | 27 (44)              | 20 (41)               | 7 (58)                        | .91     |
| Blunt laryngeal trauma      | 10 (16)              | 9 (18)                | 1 (8)                         |         |
| Autoimmune disease          | 9 (15)               | 8 (16)                | 1 (8)                         |         |
| Idiopathic                  | 11 (18)              | 9 (18)                | 2 (17)                        |         |
| Other etiology <sup>b</sup> | 4 (7)                | 3 (6)                 | 1 (8)                         |         |
| Surgeons, No.               |                      |                       |                               |         |
| 1                           | 36 (59)              | 31 (63)               | 5 (42)                        | .20     |
| 2                           | 25 (41)              | 18 (37)               | 7 (58)                        |         |
| History of intubation       |                      |                       |                               |         |
| Never                       | 14 (23)              | 13 (27)               | 1 (8)                         | .22     |
| Previously                  | 47 (77)              | 36 (74)               | 11 (92)                       |         |
| Clinical presentation       |                      |                       |                               |         |
| Tracheostomy                | 46 (75)              | 35 (71)               | 11 (92)                       | .14     |
| No tracheostomy             | 15 (25)              | 14 (29)               | 1 (8)                         |         |
| Length of stenosis          |                      |                       |                               |         |
| Short                       | 38 (62)              | 32 (65)               | 6 (50)                        | .31     |
| Long                        | 23 (38)              | 17 (35)               | 6 (50)                        |         |
| Grade of stenosis           |                      |                       |                               |         |
| I                           | 5 (8)                | 5 (10)                | 0                             | .03     |
| II                          | 19 (31)              | 17 (25)               | 2 (17)                        |         |
| III                         | 22 (36)              | 19 (39)               | 3 (25)                        |         |
| IV                          | 15 (25)              | 8 (16)                | 7 (58)                        |         |

<sup>a</sup> Percentages may not total 100% owing to rounding.

<sup>b</sup> Other etiologies include benign subglottic neoplasms in 3 patients and airway fire in 1 patient. Grade of stenosis is based on Myer-Cotton grading system for subglottic stenosis.<sup>15</sup> Fisher exact test was used to generate P values for categorical variables and t test was used to generate P values for continuous variables.

### Statistical Analysis

Statistical analysis was performed using Stata/SE statistical software (version 12.1; StataCorp). Univariate unadjusted comparisons between decannulated patients and tracheostomy-dependent patients were completed using the  $\chi^2$  test of proportions or Fisher exact test when appropriate. To determine predictors of decannulation, stepwise selection was used to create parsimonious regression models. We then examined the marginal effects of the regression model to obtain predictive probabilities of decannulation based on grade of stenosis. Independent covariates included age, sex, individual surgeon, grade of stenosis, length of stenosis, etiology of stenosis, and history of intubation. Clinically relevant variables and those with  $P < .10$  in univariate analysis were included.  $P < .05$  was considered to be statistically significant for our final model.

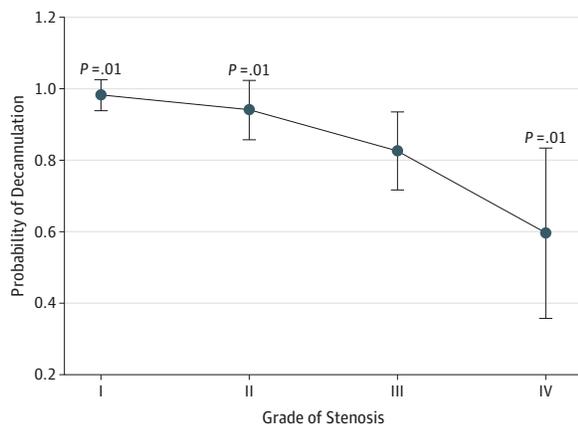
### Results

Between January 2000 and January 2012, 61 patients who met inclusion criteria were treated for LTS at our institution by staged LTP. Their mean age at the time of first-stage surgery was 47.1 years (range, 17-82 years). The mean duration of fol-

low-up from the time of first-stage surgery was 5.32 years (range, 0.5-17.3 years). The etiology of stenosis is detailed in the Table. The category of "other" included 3 patients with a history of resection of benign subglottic neoplasm and 1 patient with a history of airway fire. Of the 61 patients, 41 (67%) presented to the present institution with a tracheostomy already in place.

Among the 61 patients undergoing LTP, 49 (80%) were successfully decannulated, and in 12 (20%) decannulation attempts failed, and these patients are presently tracheostomy or T tube dependent as is seen in the Table. Unadjusted univariate comparisons between these 2 groups showed no significant difference based on age, sex, surgeon, etiology of stenosis, length of stenosis, and history of previous intubation (Table). In unadjusted analysis we found an association between grade of stenosis and rate of decannulation. Owing to these findings, calculations were carried out to measure this association after adjusting for patient and treatment characteristics. Multivariate logistic regression demonstrated a significant association ( $P = .01$ ) between grade of stenosis and rate of decannulation when controlling for age, sex, and previous intubation. Using this logistic regression, probabilities of decannulation were calculated based on grade of stenosis with 95% CIs and shown

Figure 3. Probability of Decannulation Based on Grade of Stenosis



The multivariate logistic probability of decannulation based on grade of stenosis as described by Myer-Cotton,<sup>15</sup> with adjustment for age, sex, and history of intubation. A significant improvement in rate of decannulation is demonstrated between grades I and II and grade IV ( $P = .01$ ). Error bars indicate 95% CIs.

in Figure 3. There was a significant difference in probability of decannulation between patients with grade I/II stenosis and those with grade IV stenosis. The rate of decannulation of patients with grade III stenosis fell between grade II and grade IV, and there was no statistical difference between grade III and either of those groups (Figure 3).

There were 38 patients with short-segment stenosis (62%) and 23 (38%) with long-segment stenosis. Essentially all patients had undergone prior endoscopic procedures, and 15 (25%) had undergone prior open airway surgical procedures, almost all of them being cricotracheal resection procedures. Most of the 61 patients presented to the current institution with a tracheostomy already in place (75%). Most patients' stenosis was limited to the subglottic larynx and trachea, but 11 patients (18%) had stenotic segments that extended up to and included the glottis. Two patients had a unilateral vocal fold paralysis. There were no cases of new vocal fold immobility after any stage of the surgery. There were no new findings of dysphonia or dysphagia that were not present preoperatively. Seventeen of the patients (35%) who were decannulated did require at least 1 endoscopic dilation procedure after the completion of LTP.

Of the 61 patients in this series, 9 (15%) experienced postoperative complications. One patient had a mild paratracheal cellulitis that was treated conservatively, and another had erosion of mesh after the second stage, requiring removal of the mesh. Two patients developed either subcutaneous emphysema or mild pneumothoraces. The other 5 patients had complications related to the use of T tubes. Three patients had dislodged T tubes, requiring replacement in the operating room. Another was readmitted for shortness of breath and found to have mucous plugging of the T tube, and the last patient had symptoms of choking and gagging from a high superior limb of the T tube, and the tube had to be revised. There were no mortalities in this series.

## Discussion

Laryngotracheal stenosis is a complex condition without a straightforward solution. Optimally, patients with stenosis can be treated conservatively with endoscopic dilations. Patients without benefit from endoscopic treatment or patients for whom endoscopic treatment is not a viable option are referred for open surgery, namely, either cricotracheal resection or staged LTP. While cricotracheal resection remains a mainstay for the open surgical approach of LTS, there are many clinical situations that limit this approach. Factors which have limited the universal application of cricotracheal resections include failed previous cricotracheal resection, glottal stenosis involvement, high posterior cricoid stenosis, recurring stenosis etiologies (eg, autoimmune disorders), and disorders of wound healing risking breakdown at anastomosis sites. Many variations in surgical technique have been suggested to address these challenging scenarios, including single-staged and multistaged laryngotracheal reconstruction, revision cricotracheal resection, tracheal reconstruction with a miniplates or other artificial implants, and even free-flap reconstruction.<sup>1,9,12,13,16-19</sup> To improve the reported experience with surgical treatment for LTS, we present the largest review of staged laryngotracheal reconstruction. Our institution's experience with segmental tracheal resection is also worthy of review and analysis. However, the outcome of tracheal resection vs staged LTP is the focus of a separate analysis and is a subject of a future report. It is our view that the inclusion of segmental resection data would distract from the clear importance of the largest single-site experience with adult staged LTP, and therefore we have chosen to report these data separately.

Within the present analysis, LTP demonstrated excellent decannulation rates. In our series of 61 adult patients with LTS, more than 80% were successfully decannulated. We demonstrated that the probability of decannulation was significantly and inversely associated with grade of stenosis. Interestingly, there was no significant predictive value for decannulation based on patient age or sex, etiology of stenosis, and length of stenosis. This suggests that most patients with stenosis who are not candidates for more conservative therapy may be candidates for this type of reconstruction, regardless of their age, sex, etiology of stenosis, or length of stenosis. The only caveat is that those with complete stenosis (grade IV) are less likely to achieve long-term decannulation (there was a 53% rate of successful decannulation vs 85% for less severe stenosis in the present study). These findings are in line with those of prior studies. In a study by Gallo et al<sup>20</sup> of 70 patients with LTS who underwent various surgical treatments not limited to LTP, the authors found a significant inverse correlation between decannulation rate and stenosis grade, with 94% of patients with grade II stenosis vs 50% of those with grade IV stenosis achieving decannulation. In a separate series by Wester et al<sup>21</sup> in which 53 patients underwent cricotracheal resection or LTP, the authors found a decannulation rate of only 40% in patients with grade IV stenosis compared with 78% overall for those with less severe stenosis. A small series by Cui

et al<sup>22</sup> reported cartilage graft LTP in 12 patients, with a total of 9 patients decannulated. The 3 patients whose decannulation failed included all of the patients with grade IV stenosis and 1 patient with grade III long-segment stenosis. These patients tend to have already undergone multiple surgical interventions and have intractable recurrent stenosis, or they have a severe relapsing underlying disease process. Owing to the universally low response rate to surgical intervention for this patient group, at the present time there may not be a good therapeutic option for these patients, and future work in tracheal replacements may be required for decannulation.<sup>23-26</sup> However, we continue to offer and recommend staged LTP to patients with grade IV LTS. This is from the overall improvement in airway function even in the situation of failed decannulation. Although with tracheostomy there is generally a desire to quickly proceed to decannulation, patients with tracheal T tubes maintain high quality of life, including unrestricted breathing, full voicing, unrestricted diet, showering, and minimal maintenance. It is this high quality of life that allows even nondecannulated patients to achieve high level of surgical satisfaction with long-term T tube dependence. However, it should be noted that T tube dependence requires frequent cleaning and maintenance along with annual tube change procedures.

In addition to treating patients with subglottic tracheal stenosis, LTP showed success in treating patients with stenosis involving the glottis and immediate subglottic area, particularly posterior cricoid involvement, which comprises segments traditionally considered unable to be resected. In fact, of the 38 patients in this series with relatively short segment stenosis, 13 had stenosis involving the glottis, and 9 had stenosis involving the posterior infraglottis just below the level of the cords. In 13 patients, treatment in previous open airway surgical procedures had failed, which shows that this technique can be applied with good results to patients who are not candidates for cricotracheal resection. In fact, several patients in this series consented to undergo both operations at the first surgery, and LTP was chosen when it was found that cricotracheal resection was not a possibility owing to findings on rigid bronchoscopy, including posterior cricoid stenosis, diffuse airway inflammation, or an interval lengthening of the stenotic segment beyond what was demonstrated on preoperative evaluation. The overall decision to perform cricotracheal resection or LTP is one that is made based on the entire clinical scenario. This study does not seek to prove superiority of LTP in patients who are also candidates for resection but

to present a method that can be used in many patients who are not candidates for resection.

One technical aspect of this surgery that may be superior to other open techniques is that all the dissection is carried out anterior to or within the larynx, thus keeping the recurrent laryngeal nerves relatively safe. This is demonstrated by the fact that none of our patients developed a new occurrence of vocal fold immobility after any stage of the surgery. After the last stage of the surgery, two-thirds of patients did not require any further surgical procedures of the airways, which is a considerable improvement because many of them had undergone a number of prior endoscopic procedures. However, about a third of the patients did require further procedures, highlighting the nature of this region and predilection to restenosis.

In the present study, to date 12 patients ultimately remain dependent on airway cannulation: 10 with T tube and 2 with tracheostomy secondary to inability to tolerate the T tube. Five of the 12 patients in whom decannulation failed had previously received cricotracheal resection, and 6 of the 12 continue to develop long-segment stenosis. Ultimately, only 1 of the nondecannulated patients was seen to be an acceptable candidate for cricotracheal resection following LTP. While that option was offered to this single patient, the patient declined this option.

There are several limitations to this study. A retrospective case series is not controlled, and thereby this technique cannot be directly compared with other techniques, such as endoscopic dilation. Patient selection was also not done systematically. A medical record review is also limited by the data that were gathered at the time of treatment; however, we were fortunate to have reliable medical record archiving and were able to ascertain relevant data points for all patients. In addition, follow-up assessments are less demanding compared with a standardized clinical trial.

## Conclusions

Laryngotracheal stenosis is a complex problem, especially in patients with more severe forms of the disease. We present long-term data suggesting that a staged laryngotracheal reconstruction approach has a reliable success rate. Prospective trials are necessary to compare different treatment modalities but may be challenging given the wide clinical variety inherent in this condition.

### ARTICLE INFORMATION

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**Author Contributions:** Drs Liu and Mendelsohn had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.  
*Study concept and design:* Liu, Mendelsohn, Berke.

*Acquisition, analysis, or interpretation of data:* Liu, Ching, Long, Chhetri.  
*Drafting of the manuscript:* Liu, Ching, Berke.  
*Critical revision of the manuscript for important intellectual content:* Liu, Mendelsohn, Long, Chhetri, Berke.  
*Statistical analysis:* Liu, Ching.  
*Administrative, technical, or material support:* Ching, Berke.  
*Study supervision:* Mendelsohn, Long, Chhetri, Berke.

**Conflict of Interest Disclosures:** None reported.

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**Additional Contributions:** David Khang Nguyen, MD, assisted with the statistical analysis of our data. Michael Ian Orestes, MD, provided some of the photographs presented herein. Both are from the Department of Head and Neck Surgery, David Geffen School of Medicine at UCLA, and were not compensated for their contributions.

**Correction:** This article was corrected online February 23, 2015, to add the Conflict of Interest Disclosures statement.

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