Cervical Slide Tracheoplasty

Alessandro de Alarcon, MD, MPH; Michael J. Rutter, FRACS

Objective: To describe our experience with cervical slide tracheoplasty (CST) in managing complex laryngotracheal disorders.

Design: Retrospective analysis.

Setting: Quaternary care pediatric institution.

Patients: The study included 29 patients who underwent CST without cardiopulmonary bypass at our institution from January 2003 to January 2011.

Main Outcome Measure: Surgery-specific and overall operative success.

Results: The most common airway lesion in our cohort of 29 patients (mean age, 10.7 years) was tracheal stenosis (n=18); 10 of 18 patients had long-segment acquired tracheal stenosis. Operation-specific success was achieved in 23 of 29 patients (79%), including all 10 patients with long-segment acquired tracheal stenosis. Six patients failed initial CST and required additional surgical procedures. Overall success was achieved in 3 of these patients. Patients with subglottic stenosis (n=7), concomitant glottic stenosis (n=4), and multilevel airway lesions (n=10) had lower operation-specific and overall operative success than did patients with other airway lesions. Four patients (14%) experienced complications.

Conclusions: Cervical slide tracheoplasty is a valuable technique that should be added to the surgical armamentarium for patients requiring open airway reconstruction. This technique yields a high success rate in treating patients with a broad spectrum of complex laryngotracheal disorders.


Augmentation with grafting and resection techniques have historically been the 2 primary operative approaches for the management of tracheal stenosis. Although these techniques have withstood the test of time and have resulted in high rates of surgical success, they do not adequately address the entire spectrum of laryngotracheal disorders. We therefore propose adding another option to the surgical armamentarium for selected patients: the cervical slide tracheoplasty (CST). This procedure is an adaptation of the standard slide tracheoplasty, which is currently our preferred management approach for children with tracheal stenosis caused by complete tracheal rings, absent tracheal rings, sleeve trachea, and stenosis of the distal third of the trachea; to date, we have successfully used this established procedure in more than 100 patients.1

Whereas the standard slide tracheoplasty is generally performed in conjunction with cardiothoracic or thoracic surgery and usually requires cardiopulmonary bypass, CST offers the advantage of being performed without cardiopulmonary bypass. Moreover, this approach can be used to address a wide range of other complex laryngotracheal disorders, including long-segment stenosis, tracheal “A-frame” deformities, multilevel laryngotracheal stenosis, and tracheoesophageal fistula (TEF). The purpose of this study was to describe our experience with CST.

METHODS

We searched our clinical airway database to identify all patients who underwent cervical slide tracheoplasty without cardiopulmonary bypass at our institution from January 2003 to January 2011. We reviewed the medical records of these patients to obtain demographic data and information pertaining to indications for surgery, comorbidities, prior operative procedures, postoperative management, surgical success, and complications. We defined surgery-specific success as successful
treatment with CST. More specifically, in cases of laryngotracheal stenosis, success was defined as a symptom-free non-tracheotomy-dependent airway. In cases of TEF, success was defined as closure of the TEF. We defined overall operative success as successful treatment with CST and a second open airway operation. Endoscopic treatment after either CST or open airway surgery was not considered as operative failure. We defined failure as persistent symptoms or obstructive airway lesions despite surgery and/or failure to decannulate. We received approval for this study from our institutional review board.

Descriptive statistics were used to describe the series. Means and ranges are presented for continuous normalized data. Medians and interquartile ranges are presented for nonnormal data. Categorical variables are presented as percentages. The Fisher exact test was used to compare surgery-specific and overall surgical success in patients with single vs multiple airway lesions. *P*<.05 was considered statistically significant. We performed all analyses using SAS 9.2 software (SAS Institute).

All patients underwent initial microlaryngoscopy and rigid bronchoscopy at the time of surgery to assess the airway. Patients were then intubated transorally or transtracheally (through the tracheotomy site if present). Next, a standard midneck incision was made, and the airway was exposed and skeletonized. Endoscopic assessment was used to confirm the location of the airway lesion to be addressed by the cervical slide before the airway was transected. A 30-gauge needle was used to define the proximal and distal extent of the airway lesion. Incisions were planned using endoscopic findings. Slide tracheoplasty techniques have previously been described. For the CST, several modifications to these techniques were made. A bevelled resection, proximal anterior to distal posterior, was carried out. A posterior split of the distal segment and an anterior split of the proximal segment were then made. When the distal segment of the trachea is split posteriorly, if there is an excessive amount of trachealis present, then some of the redundant tracheal muscle may be resected rather than split. When the anastomosis is performed, sutures placed on the back wall of the distal segment are passed through soft tissue, not cartilage. Care should therefore be taken that sutures do not cut through the soft tissue when tensioning the running suture line.

In the presence of severe stenosis, partial resection of the stenosis was performed. A running continuous suture technique using a double-armed 4.0 polydioxanone suture was used; suturing was carried out posterosidally to anterosuperiorly. In patients with TEF, the esophageal mucosa was closed primarily with remnant tracheal mucosa, and a free peristomal interposition graft was placed over the esophageal repair. The tracheal wall of the TEF was completely resected, thus leaving no malacic wall at the TEF site. The overlying trachea was then anastomosed using a standard slide technique. If a stent was placed at the anastomotic site, it was secured with a transtracheal stitch and removed at a later date.

## RESULTS

Our cohort comprised 29 patients (11 females, 18 males) with a mean age of 10.7 years (range, 0.1-23.1 years). The demographic and clinical characteristics of the cohort are presented in Table 1. The most common airway disorder in our cohort was tracheal stenosis (n = 18). Ten of 18 patients had long-segment acquired tracheal stenosis. Other disorders included complete tracheal rings (n = 4), stenosis associated with early childhood intubation (n = 3), and stenosis associated with a traumatic laryngotracheal separation (n = 1). Ten patients had multilevel airway involvement. Representative preoperative and postoperative endoscopic images for a patient with long-segment stenosis and a patient with TEF are shown in Figure 1 and Figure 2.

Comorbidities were relatively infrequent. The most commonly encountered comorbid condition was gastroesophageal reflux disease (n = 9). One of the 9 patients with gastroesophageal reflux disease was also diagnosed as having eosinophilic esophagitis. Four of these 9 patients had undergone a Nissen fundoplication at an outside institution.

Fifteen patients had undergone prior open airway surgery. Ten patients had undergone procedures elsewhere before being treated at our institution. Eleven patients with stenosis underwent prior open airway reconstruction with techniques other than CST (ie, laryngotracheal reconstruction with grafts, tracheal resection, and homografts).

Four of 7 patients (57%) who underwent TEF repair had undergone prior attempts at repair (Table 2). Postoperative management with endoscopic interventions (dilation, removal of granulation, and temporary endoscopic stenting) was common. As shown in Table 3, endoscopic management frequently involved multiple interventions that occurred over a median of 1 month after the initial surgery (range, 0-18 months).

Surgical success in the cohort is described in Table 4. Patients with subglottic stenosis (SGS) (n = 7), concomitant glottic stenosis (n = 4), and multilevel airway involvement (n = 10) had lower operation-specific and overall operation success than did patients with other disorders. One patient with a large TEF after ingestion of a button battery was considered a success for analysis but required a tracheotomy for respiratory failure and remained tracheotomy dependent at the last follow-up visit. Operation-specific success was achieved in 23 of 29 patients (79%), including all 10 patients who had long-
segment acquired tracheal stenosis. A comparison of success rates in patients with a single airway lesion vs those with multilevel airway lesions is presented in Table 5. A comparison of revision surgery with CST (14 of 16 patients [88%]) and primary treatment with CST (10 of 13 patients [77%]) demonstrated no significant difference using the Fisher exact test ($P = .63$).

Six patients failed initial CST and required additional surgical procedures. Three of these patients underwent laryngotracheoplasty, 2 underwent revision slide tracheoplasty, and 1 underwent revision of a figure-of-8 deformity. Of these 6 patients, 3 had successful outcomes. Of those with unsuccessful outcomes, 2 remain tracheotomy dependent: a revision laryngotraheal reconstruction failed because of severe tracheomalacia in one patient, and a capping trial failed because of an inability to handle respiratory secretions in the other patient. A third patient was decannulated but has persistent symptoms of airway obstruction.

Four of our 29 patients (14%) experienced postoperative complications. One patient had a minor wound infection; 1 had a dehiscence that was managed with a revision slide tracheoplasty; 1 had an innominate artery injury that was successfully treated intraoperatively without sequelae; and 1 had a symptomatic severe figure-of-8 deformity (Figure 3) that required revision surgery.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of postendoscopic interventions, mean (SD) [range]</td>
<td>1.6 (1.9) [0-6]</td>
</tr>
<tr>
<td>Duration of postendoscopic intervention, median (range), mo [IQR]</td>
<td>1 (0-4) [0-18]</td>
</tr>
<tr>
<td>Stent at time of surgery, No. (%)</td>
<td>13 (44.8)</td>
</tr>
<tr>
<td>Duration of stenting, median (range), d [IQR]</td>
<td>14 (9-21) [0-90]</td>
</tr>
</tbody>
</table>

Abbreviation: IQR, interquartile range.
Although the use of the CST has previously been described,5 the present study is the first (to our knowledge) to illustrate the versatility of this operation, applying it to a wide variety of complex laryngotracheal anomalies. In the current series, we noted a high overall surgery-specific success rate of 79% and an overall success rate of 90%. These success rates are similar to previously reported rates for laryngotracheal reconstruction and resection techniques in the management of laryngotracheal stenosis.6-9

Patients with long-segment tracheal stenosis have historically been difficult to treat. Recent publications have shown the utility of the standard slide tracheoplasty operation for the management of long-segment congenital tracheal stenosis due to complete tracheal rings, and this procedure is currently the operation of choice for the management of this disorder. Nevertheless, long-segment acquired tracheal stenosis of the upper two-thirds of the trachea remains problematic. Of the 18 patients with tracheal stenosis in our series, 10 had long-segment acquired stenosis that was not easily amenable to standard grafting or resection techniques. We found that CST was effective in all 10 of these patients, yielding an operation-specific success rate of 100%; however, postoperative endoscopic interventions were crucial to a successful outcome. Many patients needed balloon dilatations, steroid injection, endoscopic lysis of scar tissue, and temporary endoscopic stenting.

Six of the 7 patients with TEF were successfully treated with CST, and most of these patients had undergone prior unsuccessful interventions to close the TEF. Only 1 patient needed a revision open procedure. This patient had a button battery injury and had a dehiscence early in his postoperative course, requiring a revision slide tracheoplasty. In view of our successes, we believe that CST is a valuable addition to the current surgical armamentarium for patients with challenging upper tracheal esophageal fistulas. The fistulas can be directly accessed and closed, and the tracheal anastomosis is offset from the esophageal closure.

We found that patients with SGS had lower success rates than patients with a single airway lesion, tracheal stenosis, or TEF (Table 4). In a recent study, Kim et al5 reported higher success rates for patients with SGS than we report in our series. We suspect that the lower rate of success among the patients in our series may be attributed to several factors. First, there were only 2 patients in our series with SGS as a single-level airway lesion; almost all patients also had other levels of airway obstruction that were addressed with CST. Second, given that our institution is a quaternary care facility, our referrals tend to include patients in whom prior open airway operations have failed.

In performing CST in patients with SGS, we observed that the manner in which the slide was performed had an impact on success. Early in our series, we performed a slide into the posterior cricoid plate and found that creating the anastomosis was difficult. This patient required a second procedure to achieve success. We therefore no longer perform a slide in this fashion. In cases

Table 4. Surgical Success

<table>
<thead>
<tr>
<th>Variable</th>
<th>Age,</th>
<th>Operation-Specific Success</th>
<th>Overall Success</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Median (Range), y</td>
<td>No./Total No. (%)</td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td>11.7 (0.1-23.1)</td>
<td>23/29 (79)</td>
<td>26/29 (90)</td>
</tr>
<tr>
<td>Airway lesion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tracheal stenosis</td>
<td>12.3 (3.9-21.4)</td>
<td>14/18 (78)</td>
<td>15/18 (83)</td>
</tr>
<tr>
<td>A-frame deformity</td>
<td>13.2 (9.5-23.1)</td>
<td>5/5 (100)</td>
<td>5/5 (100)</td>
</tr>
<tr>
<td>Subglottic stenosis</td>
<td>10.5 (4.6-16.7)</td>
<td>3/7 (43)</td>
<td>5/7 (71)</td>
</tr>
<tr>
<td>Glottic stenosis</td>
<td>13.4 (4.6-23.1)</td>
<td>2/4 (50)</td>
<td>3/4 (75)</td>
</tr>
<tr>
<td>Multilevel airway involvement</td>
<td>12.4 (4.6-23.1)</td>
<td>6/10 (60)</td>
<td>8/10 (80)</td>
</tr>
<tr>
<td>Tracheoesophageal fistula⁶</td>
<td>1.2 (0.1-17.3)</td>
<td>6/7 (86)</td>
<td>7/7 (100)</td>
</tr>
</tbody>
</table>

⁶One patient had resolution of the tracheoesophageal fistula but remains tracheotomy dependent.

Table 5. Multilevel vs Single-Level Airway Involvement

<table>
<thead>
<tr>
<th>Variable</th>
<th>Multilevel Airway Lesions (n = 10)</th>
<th>Single Airway Lesion (n = 19)</th>
<th>P Value⁶</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation-specific success</td>
<td>6 (60)</td>
<td>18 (95)</td>
<td>.04</td>
</tr>
<tr>
<td>Overall success</td>
<td>8 (80)</td>
<td>18 (95)</td>
<td>.27</td>
</tr>
</tbody>
</table>

⁶Fisher exact test.
that involve the cricoid, we preferentially slide into the anterior cricoid. Unlike Kim et al, we have not found it necessary to laterally distract the cricoid lamina onto the prevertebral fascia. In many cases, we have found that sliding a tongue of tracheal cartilage between the split anterior lamina of the cricoid provides adequate distraction. In the occasional case in which the “spring” of the cricoid cartilage threatens to crush the tracheal fascia, we have instead chosen to weaken the elasticity of the cartilage either by removing small extramucosal cartilage wedges laterally from the lamina or by performing a simultaneous posterior cricoid split.

In most cases of SGS, CST is not an appropriate option. Nonetheless, in cases in which laryngotracheal stenosis and the laryngeal portion of the stenosis would be improved by a simple small anterior graft (eg, an elliptical cricoid without significant scarring), CST not only may help address the tracheal component of disease but also may extend up through an anterior cricoid to expand a mild to moderate coexistent SGS. To provide some perspective, in 2011 our unit performed 100 open airway reconstructions for SGS, consisting of 90 cartilage expansion procedures (laryngotracheoplasty), 8 cricotracheal resections, and 2 CSTs.

Our experience indicates that although multilevel airway lesions can be addressed with CST, outcomes are less successful than those in patients with a single airway lesion (P = .04). This finding, however, may in part be attributable to the small number of patients with multilevel airway lesions (n = 10). Therefore, the surgical success of CST for multilevel airway lesions remains to be tested in a larger future series.

Four patients (14%) experienced complications, 2 of which warrant further discussion. The patient with the button battery ingestion had an early dehiscence. Such patients are difficult to treat and have high morbidity and mortality; the need to perform revision surgery in these patients is not uncommon. The patient with an innominate artery injury had a history of 2 sternotomies and tracheal repairs under cardiopulmonary bypass, and the innominate artery was adherent to the trachea. The injury was quickly recognized and was repaired by a cardiothoracic team. It is important to note that 3 other children in this cohort underwent prior sternotomies with the innominate scarred to the trachea; however, they had no complications with dissection of the innominate artery off the trachea. Nonetheless, we recommend that surgery be approached with caution in patients with prior chest approaches for tracheal reconstruction, as such patients may be at higher risk for potential complications. In our series, all of the complications were successfully managed, and we achieved overall surgical success in all of the patients with complications.

In conclusion, CST is a valuable technique that should be added to the surgical armamentarium for patients requiring open airway reconstruction. This technique is associated with a high degree of success in treating patients with a broad spectrum of complex laryngotracheal anomalies, including long-segment tracheal stenosis, TEF, and SGS.

Submitted for Publication: November 22, 2011; final revision received May 31, 2012; accepted July 10, 2012.

Correspondence: Alessandro de Alarcon, MD, MPH, Division of Pediatric Otolaryngology–Head and Neck Surgery, Cincinnati Children’s Hospital Medical Center, 3333 Burnet Ave, ML C-21018, Cincinnati, OH 45229 (alessandro.dealarcon@cchmc.org).

Author Contributions: Dr de Alarcon had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: de Alarcon and Rutter. Acquisition of data: de Alarcon. Analysis and interpretation of data: de Alarcon and Rutter. Drafting of the manuscript: de Alarcon and Rutter. Critical revision of the manuscript for important intellectual content: de Alarcon and Rutter. Statistical analysis: de Alarcon. Administrative, technical, and material support: de Alarcon. Study supervision: de Alarcon and Rutter.

Financial Disclosure: Dr Rutter serves on the Scientific Advisory Board of Acclarent and is a consultant for Gyrus/Olympus, Boston Medical Products, Hood Medical, and Karl Storz.

Previous Presentation: This study was presented in part at the American Society of Pediatric Otolaryngology Annual Meeting; April 29, 2011; Chicago, Illinois.

Additional Contributions: Aliza P. Cohen assisted with the editing and writing of the manuscript for this article.

REFERENCES