Short- versus Long-term Stenting in Children with Subglottic Stenosis Undergoing Laryngotracheal Reconstruction

David F. Smith, MD, PhD1,2, Alessandro de Alarcon, MD, MPH2,3, Niall D. Jefferson, MD2, Meredith E. Tabangin, MPH4, Michael J. Rutter, MD, FRACS2,3, Robin T. Cotton, MD2,3, and Catherine K. Hart, MD2,3

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Abstract

Objectives. Suprastomal stents are routinely used in laryngotraheal reconstruction (LTR) to stabilize grafts and provide framework to sites of repair. However, the duration of stenting varies according to patient history and physician preference. We examined outcomes of short- versus long-term stenting in children with subglottic stenosis (SGS) undergoing LTR.

Study Design. Case series with chart review.

Setting. Tertiary care pediatric hospital.

Subjects and Methods. Thirty-six children <18 years old who underwent double-stage LTR for SGS from January 2012 to January 2015 were included. Demographic data, stenosis grade, and decannulation rates were compared between children with short-term stenting (<21 days; n = 14) and those with long-term stenting (>21 days; n = 22).

Results. No significant difference between groups was seen for sex, age, race, or previous repair. Children in the short-term group were stented for 10.9 ± 4.9 days, compared with 44.0 ± 10.6 for those long-term (P < .0001). A similar number of children with short- versus long-term stents had grade 3/4 stenosis preoperatively (71.4% vs 77.2%). Although time to decannulation was not significantly different, 72.7% of children with long-term stents were decannulated, as opposed to 35.7% with short-term stents (P = .03). After adjusting for grade at surgery and age, children with long-term stents had 4.3 greater odds (95% CI, 1.0-18.3) of decannulation than children with short-term stents.

Conclusions. Children with long-term stenting were more likely to be successfully decannulated. Although long-term stenting improved outcomes for children with SGS, additional research is needed to better define ideal candidates for short- versus long-term stenting.

Keywords

laryngotraheal reconstruction, pediatric airway, stenting, pediatric airway reconstruction, subglottic stenosis

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The surgical management of subglottic stenosis (SGS) may be approached by an array of endoscopic procedures or via an open approach. Open airway reconstruction can be completed as a single-stage technique, double-stage technique, or hybrid technique depending on surgeon experience, associated comorbidities, severity of stenosis, history of airway surgery, synchronous airway lesions (eg, significant tracheomalacia), and level of available postoperative care.1 Double-stage reconstruction requires the presence of a tracheostomy tube while an indwelling stent is left in place. For these procedures, the stent serves to maintain graft position, stabilize the reconstructed portion of the airway, and provide a framework for healing.2

The use of stents in pediatric laryngotraheal reconstruction (LTR) is a common practice.3-5 However, much discussion by pediatric airway surgeons has focused on the role

1Division of Pulmonary Medicine, Cincinnati Children’s Hospital Medical Center, Cincinnati, Ohio, USA
2Division of Pediatric Otolaryngology–Head and Neck Surgery, Cincinnati Children’s Hospital Medical Center, Cincinnati, Ohio, USA
3Department of Otolaryngology–Head and Neck Surgery, University of Cincinnati, Cincinnati, Ohio, USA
4Division of Biostatistics and Epidemiology, Cincinnati Children’s Hospital Medical Center, Cincinnati, Ohio, USA

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Corresponding Author:
Catherine K. Hart, MD, Division of Pediatric Otolaryngology–Head and Neck Surgery, Cincinnati Children’s Hospital Medical Center, 3333 Burnet Avenue, MLC 2018, Cincinnati, OH 45229, USA.
Email: Catherine.Hart@cchmc.org
that characteristics may play in surgical outcomes for children, such as timing of stent placement, stent design, stent material, and length of stenting. In many cases, short-term stenting can be used to treat SGS. However, longer stenting is often required to repair SGS in children with poor stability of the larynx and subglottis, associated comorbidities or inflammatory processes, previously failed reconstruction attempts, severe SGS, or when concerns for adequate healing are present.2 Although stenting is routinely used at our institution, the duration of stent placement varies according to patient history and physician preference. To date, no study has examined the effects of short- versus long-term stenting in pediatric patients with SGS undergoing airway reconstruction.

The aim of our study was to compare postoperative changes in decannulation rates and grade of stenosis among children undergoing short- versus long-term stenting during double-stage LTR (dsLTR) for SGS. Here, we present data on these surgical outcomes in a select population of children with SGS treated at our tertiary children’s hospital.

Materials and Methods

Study Participants

This study was approved by the Cincinnati Children’s Hospital Medical Center institutional review board. A database query based on International Classification of Diseases, Ninth Revision codes for SGS, laryngotracheoplasty, and LTR was performed to identify children seen from January 1, 2012, through January 31, 2015, at a tertiary pediatric academic care center. Children <18 years old undergoing dsLTR (with anterior, posterior, or anterior and posterior graft) specifically for acquired SGS were included in the study. Children were excluded if they had any other open airway reconstructions besides a dsLTR, had stenosis at other sites within the larynx, were diagnosed with laryngeal atresia, had infections of the airway diagnosed either preoperatively or during the postoperative course, received any antibiotics other than those provided prophylactically, or if a diagnosis of eosinophilic esophagitis was made preoperatively.

Electronic medical records were reviewed for demographic data: sex, race, age at time of reconstruction, medical comorbidities (including gastroesophageal reflux disease and reactive larynx), grade of stenosis at time of reconstruction, duration of stenting, grade of stenosis at 6 and 12 months postoperatively, rate and time to decannulation, number of postreconstruction airway dilations performed in the operative suite, the number of times that children required removal of granulation tissue from the airway, the number of participants who received Ciprodex (ciprofloxacin/dexamethasone) perioperatively or during stent placement, and reasons for failure to decannulate. The Myer-Cotton Grading Scale was used to determine the degree of SGS for all participants per the following criteria: up to 50% obstruction is classified as grade 1 stenosis; 51% to 70%, grade 2; 71% to 99% obstruction, grade 3; and all children with complete obstruction of the subglottic lumen, grade 4.6

Preoperative Evaluation

Preoperative evaluation for all patients required microlaryngoscopy and bronchoscopy to evaluate the site of stenosis and size of the airway. Based on the Myer-Cotton Grading Scale,6 the stenosis grade was determined for each study participant.

Postoperative Outcomes

The date of surgery and date of stent removal were determined to calculate the duration of stent placement for each study participant. The dates of postoperative microlaryngoscopy and bronchoscopy were recorded. As part of the routine postoperative evaluations at our institution, airway sizing is routinely performed after the graft has mucosalized and there is no concern for displacement. Grade of stenosis at 6 and 12 months, as well as the size of the airway based on the endotracheal tube, was recorded. As in the preoperative evaluation, percentage stenosis was extrapolated by the age of the patient and the endotracheal tube used to size the airway. The time to decannulation was recorded. If the patient required a secondary airway reconstruction in the first 12 months, this was considered a failure of the initial procedure.

Statistical Analyses

Distributions of continuous variables were evaluated for normality via histograms and box plots. Descriptive statistics—such as means with standard deviations, medians with interquartile ranges, and frequencies or percentages for categorical variables—were used to describe demographics and clinical characteristics. To compare postoperative change in decannulation rates and stenosis grade, durations of short-term stents were defined as ≤21 days, and long-term stents were defined as >21 days. Differences in age at surgery by stent group were tested with a Wilcoxon rank sum test. Differences in average days of stenting were tested with an independent t test. Differences in categorical variables were tested with a chi-square test or Fisher exact test. Multivariable logistic regression models were used to examine stent duration as a predictor of decannulation, adjusting for preoperative stenosis grade and age. Significance was declared at α < 0.05. SAS 9.4 (SAS Institute, Cary, North Carolina) was used to conduct all analyses.

Results

Thirty-six children were included, 20 (55.6%) of whom were male (Table 1). Fourteen children were included in the short-term stent group and 22 in the long-term stent group, with median ages of 47.4 and 33.9 months, respectively (P = .39). No significant difference was seen in sex (P = .59), race (P = .21), children born prematurely (P = .71), children diagnosed with reflux preoperatively (P = .37), or those with active larynx (P = .59) between groups.
Although a higher percentage of children in the long-term stent group had a previous airway reconstruction (45%), this was not significantly different (\( P = .31 \)) from the number of children in the short-term group who also had a previous repair. The average stent duration was 10.9 ± 4.9 days in the short-term group, compared with 44.0 ± 10.6 days in the long-term group (\( P < .0001 \)). Within the short-term group, 2 patients had anterior-only grafts (14.3%), while 2 patients had posterior-only grafts (14.3%; Table 1). Three children in the long-term group (13.6%) had anterior-only grafts.

No significant difference was seen between the number of children with short- versus long-term stents who required postreconstruction airway dilations (\( P = .27 \)). Four patients in each group required 1 dilation postreconstruction; 4 in the short-term group and 5 in the long-term group required 2 or 3; and 1 patient in each group required ≥4 (Table 2).

Six (43%) children with short-term stents required removal of granulation tissue from the airway after the LTR, while 10 children (46%) with long-term stents required removal of granulation tissue (\( P = .87 \)). Significantly more children (n = 21, 96%) with long-term stents received intratracheal Ciprodex in the perioperative period or during stent placement, compared with 8 children (57%) with short-term stents (\( P = .008 \)). Preoperatively, most children in the short- (64.3%) and long-term (72.7%) stent groups had grade 3 stenosis per the Myer-Cotton Grading Scale (Table 3). At 12 months postoperatively, most children in the short- (57.1%) and long-term (81.8%) groups had grade 1 stenosis. There was no statistical difference in decrease of stenosis grade at 12 months between the groups (Figure 1).

Time to decannulation and the percentage decannulated were calculated for the 2 groups of children in our study. For those children who were decannulated within the 12-month postoperative follow-up period, the time to decannulation was no different between those in the short- (5.6 ± 3.4 months) and long-term (5.9 ± 3.2 months) stent groups (\( P = .84 \)). However, a significantly higher number of children in the long-term stent group (72.7%) were decannulated in the postoperative follow-up period versus those in the short-term group (35.7%, \( P = .03 \); Figure 2). After adjusting for grade at surgery and age, children with long-term stents had 4.3 greater odds (95% CI, 1.0-18.3) of decannulation than children with short-term stents (Table 4).

**Discussion**

We present the first study to compare the outcomes of short- versus long-term stenting after dsLTR in children...
with acquired SGS. With the goal of comparing postoperative change in stenosis grade and decannulation rates among children undergoing short- versus long-term stenting with dsLTR for SGS, we hypothesized that long-term stenting would result in better outcomes. Compared with children who received stents for ≤21 days, a larger percentage of children with long-term stenting were successfully decannulated. In this population, long-term stenting improved outcomes among children with SGS.

### Table 2. Postreconstruction Airway Dилations, Granulation Tissue Removal, and Ciprodex Administration between Patients with Short- and Long-term Stents.

<table>
<thead>
<tr>
<th></th>
<th>Short-term (n = 14)</th>
<th>Long-term (n = 22)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Postreconstruction airway dilations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>4 (28.6)</td>
<td>4 (18.2)</td>
<td>1.0^b</td>
</tr>
<tr>
<td>2 or 3</td>
<td>4 (28.6)</td>
<td>5 (22.7)</td>
<td></td>
</tr>
<tr>
<td>≥4</td>
<td>1 (7.1)</td>
<td>1 (4.5)</td>
<td></td>
</tr>
<tr>
<td>Granulation tissue removal</td>
<td>6 (42.9)</td>
<td>10 (45.5)</td>
<td>.87</td>
</tr>
<tr>
<td>Ciprodex administration</td>
<td>8 (57.1)</td>
<td>21 (95.5)</td>
<td>.008^b</td>
</tr>
</tbody>
</table>

^aValues are presented as n (%).
^bFisher exact test.
^cThe number of times that granulation tissue was removed from the airway postreconstruction.
^dIn the perioperative period or during stent placement.

### Table 3. Changes in Myer-Cotton Grading for Airway Stenosis Pre- and Postoperatively for Children with Short- and Long-term Stenting.

<table>
<thead>
<tr>
<th></th>
<th>Short-term (n = 14)</th>
<th>Long-term (n = 22)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative grade</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1 (7.1)</td>
<td>2 (9.1)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>3 (21.4)</td>
<td>3 (13.6)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>9 (64.3)</td>
<td>16 (72.7)</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1 (7.1)</td>
<td>1 (4.5)</td>
<td></td>
</tr>
<tr>
<td>Postoperative grade (12 mo)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>1 (4.5)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>8 (57.1)</td>
<td>18 (81.8)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>4 (28.6)</td>
<td>2 (9.1)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2 (14.3)</td>
<td>1 (4.5)</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Pre- to postoperative change in stenosis (12 mo)</td>
<td></td>
<td></td>
<td>.06</td>
</tr>
<tr>
<td>Decreased 2 grade levels</td>
<td>4 (28.6)</td>
<td>15 (68.2)</td>
<td></td>
</tr>
<tr>
<td>Decreased 1 grade level</td>
<td>8 (57.1)</td>
<td>5 (22.7)</td>
<td></td>
</tr>
<tr>
<td>No change</td>
<td>2 (14.3)</td>
<td>2 (9.1)</td>
<td></td>
</tr>
</tbody>
</table>

^aValues are presented as n (%).

Despite the many advances in airway reconstruction, approximately 10% to 20% of children undergoing reconstruction of the airway will require revision procedures.\(^7\)\(^-\)\(^15\) Failure can occur even with appropriate clinical judgement and good surgical execution.\(^16\) Regardless of the variable outcomes for children requiring these procedures, our understanding of the techniques that improve outcomes is incomplete. Causes of surgical failure can include poor patient selection, technical errors, and disease-specific causes, among others.\(^16\) Surgical outcomes comparing the type of stents used have been examined. For example, the use of closed Silastic stents, as compared with Teflon stents, can improve feeding postoperatively for children who undergo dsLTR, but they are also associated with increased granulation tissue development and longer periods before decannulation.\(^2\) Here, we demonstrate that long-term stenting can positively affect outcomes in our population of children undergoing dsLTR for high-grade SGS.

### Table 4. Multivariable Logistic Regression Results for Decannulation.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Beta Estimate (SE)</th>
<th>Odds Ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stent type (long- vs short-term)</td>
<td>1.4 (0.74)</td>
<td>4.3 (1.0-18.3)</td>
</tr>
<tr>
<td>Grade</td>
<td>0.21 (0.54)</td>
<td>1.2 (0.43-3.5)</td>
</tr>
<tr>
<td>Age at surgery, y</td>
<td>–0.11 (0.11)</td>
<td>0.89^ (0.72-1.1)</td>
</tr>
</tbody>
</table>

^aFor every 1-year increase.
excisions.\textsuperscript{17} This technique was designed to offer a more stable airway perioperatively after LTR while minimizing the complications of long-term stents.\textsuperscript{17} Fewer children undergoing the hybrid LTR required postreconstruction procedures as compared with the children in our short-term stent group, although some variability might exist based on the number of children who had primary reconstructions versus revision procedures and the length of stent duration with the hybrid technique. Of note, a significantly higher number of children in our study with long-term stents received intratracheal Ciprodex perioperatively or while the stent was in place. Although this could partially explain why the number of children with long-term stents did not develop granulation tissue at a higher rate versus those with short-term stents, these children are more likely to prophylactically receive intratracheal steroids according to the expected complications associated with long-term airway stenting. It remains unclear whether intratracheal Ciprodex contributed to the improved outcomes for the children who underwent long-term airway stenting.

Although we demonstrate differences in outcomes for children undergoing short- versus long-term stenting, it is important to note that short-term stenting is suitable in certain clinical scenarios. Our study is aimed at expanding our insight into factors that can affect outcomes of airway reconstruction. However, short-term stenting may be appropriate in children with milder forms of stenosis requiring open airway reconstruction, children with no history of reconstruction, children with immature scarring of the subglottis, and children with no other medical comorbidities known to contribute to failure in reconstruction. More important, although long-term stenting improved outcomes in our patient population, complications from long-term stenting—such as granulation tissue formation, feeding difficulties, risks of tracheostomy tube use, infection, and delayed speech\textsuperscript{4,18}—should be avoided when possible. Also, as the airway proximal to the tracheostomy tube is obstructed, there is a risk of loss of the airway while the stent is in place, highlighting the need to minimize the length of time that the stent is in place unless necessary for those previously established reasons.

Our study has several limitations. As a retrospective review, the number of included participants was limited by those charts with complete medical records. As mentioned, all children with acquired SGS undergoing dsLTR were included. Although we screened retrospectively to exclude children who had pre- or postoperative infections or those who had eosinophilic esophagitis, this was a heterogeneous population of children. Larger prospective studies should be performed to control for types of injury, prophylactic antibiotics used, and exclusion of children with other medical comorbidities (eg, gastroesophageal reflux disease or reactive larynx). Furthermore, to increase the number of participants, we included children who had only anterior and only posterior grafts. Even though only 3 participants among our 36 did not have anterior and posterior grafting, the location of grafting could certainly affect the outcome from surgery. All participants in our study did, however, have only costal cartilage grafting, and all received the same type of stent (Rutter stent). We also present stenosis grade at follow-up, a measure that does not necessarily reflect good or bad outcomes of reconstruction. Given the differences in primary outcome measures, this could be partially based on significant changes in anatomy of the airway. Without a larger number of study participants, we may not have had adequate power to detect statistical significance with change in stenosis grade, while adjusting for other covariates.

**Conclusions**

In our study, we demonstrate that a larger percentage of children with long-term stenting were successfully decannulated. In this population, long-term stenting improved outcomes for children with SGS undergoing LTR. Additional research is needed to better identify characteristics of ideal candidates for short- and long-term stenting following LTR.

**Author Contributions**

David F. Smith, conception and design, acquisition of data, drafting the work and revising, final approval, agreement to be accountable; Alessandro de Alarcon, conception and design, revising, final approval, agreement to be accountable; Niall D. Jefferson, conception and design, revising, final approval, agreement to be accountable.
accountable; **Meredith E. Tabangin**, analysis and interpretation, revising, final approval, agreement to be accountable; **Michael J. Rutter**, conception and design, revising, final approval, agreement to be accountable; **Robin T. Cotton**, conception and design, revising, final approval, agreement to be accountable. **Catherine K. Hart**, conception and design, drafting and revising, final approval, agreement to be accountable.

**Disclosures**

**Competing interests:** Michael J. Rutter was on the scientific advisory board for Acclarent Medical for the airway balloon dilator, is a consultant and patent holder for Bryan Medical for the Aeris balloon dilator, and is a consultant with no financial relationship for Boston Medical Products for the suprastomal stent. He is also an unpaid consultant for Tracoe.

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**References**