Objective: To determine the causes of laryngotracheal reconstruction (LTR) failures.

Design: Retrospective chart review.

Setting: Tertiary care children’s hospital.

Patients: Seventeen pediatric patients who underwent revision LTR from October 1, 1986, to December 31, 1998.

Intervention: Laryngotracheal reconstruction.

Main Outcome Measure: Decannulation.

Results: Seventeen patients required a total of 42 LTRs for decannulation. There were 27 unsuccessful LTRs, 17 of which were primary and 10 that were revision LTR failures. The rate of decannulation after primary LTRs and after revision LTRs ranges from 40% to 83% and 72% to 97%, respectively, and appears to depend on the severity of stenosis. A previous report has stressed the importance of preoperative recognition and treatment of gastroesophageal reflux disease (GERD) as well as other ancillary measures to ensure a successful outcome of LTR, although the role of gastroesophageal reflux has been disputed. Unfortunately, there is a paucity of these reports and for the most part they have been anecdotal. To our knowledge, no report has evaluated factors that may contribute to LTR failures. This review attempts to delineate specific factors that may contribute to LTR failures by analyzing a series of cases managed at a single institution over an 11-year period.

Conclusions: Although some LTRs may fail secondary to factors that are not under the surgeon’s control, many LTR failures can be avoided by accurate preoperative and intraoperative assessment of the stenosis, correct choice of surgical procedure, and close postoperative monitoring.


The management of severe laryngotracheal stenosis (LTS) is a challenging problem. For many years, laryngotracheal reconstruction (LTR) has been very successful in relieving LTS. Cotton and O’Connor reported a success rate of 90% for all lesions and all techniques. Similarly, a 90% success rate was reported by Zalzal. The rate of decannulation after primary LTRs ranges from 40% to 83% and 72% to 97%, respectively, and appears to depend on the severity of stenosis. A previous report has stressed the importance of preoperative recognition and treatment of gastroesophageal reflux disease (GERD) as well as other ancillary measures to ensure a successful outcome of LTR, although the role of gastroesophageal reflux has been disputed. Unfortunately, there is a paucity of these reports and for the most part they have been anecdotal. To our knowledge, no report has evaluated factors that may contribute to LTR failures. This review attempts to delineate specific factors that may contribute to LTR failures by analyzing a series of cases managed at a single institution over an 11-year period.

Results: Seventeen patients required a total of 42 LTRs, of which 25 were revision LTRs. There were 27 unsuccessful LTRs, 17 of which were primary and 10 that were revision LTR failures. The patient population included 13 males and 4 females. The cause of LTS was prolonged intubation in 13 procedures, external trauma with fracture of laryngeal, cricoid, and/or tracheal cartilages in 3, and subglottic stenosis (SGS) associated with Down syndrome in 1. The primary LTRs were done at our institution in 14 patients and elsewhere in 3. However, in many of the patients who were operated on at our institution, multiple closed procedures including dilatation, laser excision, or cautery were performed prior to the referral of the patients for an open LTR. The majority of the LTRs were performed by one of us (G.H.Z.). The age at the initial open LTRs ranged from 10 months...
PATIENTS AND METHODS

The medical charts of all patients who had undergone LTR at the Children’s National Medical Center, Washington, DC, from October 1, 1986, to December 31, 1998, were retrieved and reviewed. Only patients who had failed decannulation after the initial LTR procedure were selected for this study. Data gathered for each LTR procedure included institution where the LTR was performed; patient’s age at each LTR procedure; the cause of LTS; presence of GERD; findings at each rigid endoscopic evaluation, including site, degree, and length of stenosis; types of cricoid split (anterior, lateral, and posterior) performed; location and type of graft used; type, length, and duration of stent; endoscopic findings of the airway at stent removal; adequacy of follow-up; need for revision procedure; and decannulation status.

Factors contributing to LTR failures were grouped into preoperative, intraoperative, and postoperative categories (Table). In 3 procedures, no factors that may have adversely affected LTR outcome could be found. In the remaining 24 procedures, there was at least 1 and often multiple reasons that may have contributed to LTR failure.

Poor preoperative evaluation of the airway lesion at rigid endoscopy with subsequent inadequate correction of the posterior component of LTS was seen in 6 procedures. The most common intraoperative decision that may have contributed to LTR failure was inappropriate duration of stent in the airway in 8 procedures, with 7 being too short and 1 too long. Other factors included inappropriate choice of type of stent (n = 7), type of graft (n = 2), and stent length (n = 1). In 6 cases, although correct assessment of the airway stenosis was made preoperatively, an incorrect procedure was selected to address the LTS. Postoperative factors contributing to LTR failures included keloid formation in 5, anterior suprastomal collapse in 2, slipped or broken stent in 2, poor postoperative follow-up in 2, and intractable GERD in 1. We have previously reported that the evaluation, presence, and treatment of GERD do not have statistically significant impact on the LTR outcome except in rare cases. No other coexisting medical illnesses were present in any patients.

### COMMENT

Laryngotracheal reconstruction is a well-accepted procedure with a high rate of success. It is not a single uniform procedure and includes many different variations to address specific aspects of the narrowed airway. Accurate assessment of LTS is a prerequisite to a successful LTR outcome. The severity, sites, length, and maturity of LTS determine the types of cricoid split and the use of graft and stent. Therefore, correct preoperative rigid endoscopic evaluation of the LTS and accurate functional evaluation of the supraglottis and glottis is crucial. In our series, all 6 cases of inadequate preoperative assessment of the airway were due to failure to adequately assess the severity of the posterior component of LTS. As a result, the posterior stenosis was not addressed and the LTR resulted in failure to decannulate.

For an isolated anterior SGS, an anterior cricoid split is sufficient. If there is a circumferential or posterior SGS, both anterior and posterior splits are necessary to allow for an adequate distraction of the cartilaginous framework. The usual posterior split includes the division of the posterior cricoid lamina to the median raphe of the cricopharyngeal and upper esophageal constrictors. In cases where the posterior stenosis extends and involves the glottis, the scarred interarytenoid muscle must be divided as well. Lateral cricoid splits are used in conjunction with anterior and posterior splits when maximal expansion of the laryngeal framework is needed, as in cases of complete SGS. In 6 of our cases, although correct assessment of LTS was made preoperatively, the posterior stenosis was not treated (n = 4) or inadequately treated (n = 2). In the latter 2 cases, the posterior split and placement of the posterior graft did not extend high enough.

Costal cartilage graft is used for treating anterior SGS to maintain distractions of the cricoid split and also to decrease the duration of stenting. With a posterior split, an elliptical posterior graft is placed. If there is an absence of a rigid posterior cricoid lamina, posterior grafting is not possible. The graft is placed at a more superior position when there is a concomitant glottic stenosis, although this may result in a breathy voice. The insertion of a posterior graft allows for a shorter duration of stenting (from 6 months or longer to a 4- to 8-week period). Cartilage grafts are not used in lateral splits.

Many graft materials have been used for LTRs. Cartilage is superior to bone (including hyoid bone) for several reasons. Cartilage grafts have a lower rate of resorp-

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**Factors Contributing to Laryngotracheal Reconstruction Failures**

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Factors</th>
<th>No. of Procedures</th>
</tr>
</thead>
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<tr>
<td>Preoperative</td>
<td>Inadequate assessment of the posterior laryngotracheal stenosis</td>
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<tr>
<td>Intraoperative</td>
<td>Duration of stent</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Type of stent</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Correct assessment with failure to address posterior laryngotracheal stenosis</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Type of graft</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Length of stent</td>
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</tr>
<tr>
<td>Postoperative</td>
<td>Keloid formation</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Anterior suprastomal collapse</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Poor follow-up</td>
<td>2</td>
</tr>
<tr>
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</tr>
<tr>
<td></td>
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</tr>
<tr>
<td></td>
<td>Gastroesophageal reflux disease</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>No discernible factors</td>
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</tr>
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</table>

*There were 27 procedures in 17 patients.*
tion, are easy to carve, are viable without a vascular pedicle, and can retain bulk without functional use. Irradiated homologous cartilage graft also has been used successfully in human and animal studies.\(^9\) Today the most commonly used graft materials in pediatric LTR are costal and auricular cartilages. Of our procedures that used grafts, only 2 were not costal cartilage grafts. In 1 procedure hyoid bone was used and in the other irradiated homologous cartilage graft. A hyoid bone graft requires a vascular pedicle, can resorb, and is difficult to carve. The reason that the irradiated cartilage may have been a poor choice is that it may be less able to withstand infection. In this particular patient, there was postoperative infection of the operative field and subsequent unexpected resorption of the cartilage. This may have not occurred with the use of autogenous cartilage.

Stents used for LTR should be hard enough to keep the reconstructed area and grafts in place, allow voice production, allow easy intake of food without aspiration, and be easy to examine and remove. Although the Aboulker stent is far from ideal, it is a very useful stent in pediatric LTR.\(^{10-11}\) Cotton\(^1\) found the Silastic Swiss-roll stent to cause more tissue reaction and granulation formation than the Aboulker stent. The Swiss-roll stent works by providing gentle pressure rather than rigid support. When a posterior cricoid split is performed, an Aboulker rather than Swiss-roll stent is preferable because the instability of the airway requires more rigid support.\(^1\) In older children, where adequate distance between the true cords and the subglottis is present, the Montgomery stent can also be useful.\(^1\) In younger children, the Montgomery T-tube can cause granulation tissue formation at its upper end and may become easily blocked because of its small lumen size.\(^13\) Crysdale\(^14\) found the Aboulker stent to be superior to the Montgomery T-tube because of less irritation and granulation formation. Gray et al\(^1\) found that infraglottic stents frequently irritate and cause granulation tissue at the glottic level and therefore they recommended a long stent that is placed high enough through both the false and true cords to prevent glottic and supraglottic granulation tissue. Other stents such as the Portex endotracheal tube and finger cot stents are only of historical interest. In our series, inappropriate stent choices were made in 7 procedures: with endotracheal tubes in 2, Swiss-roll stents in 2, Montgomery T-tube in 1, Portex endotracheal tube in 1, and in 1 case a stent was required but not used.

The only type of airway narrowing that can be treated without the use of a stent is anterior SGS. Oftentimes even with isolated SGS, short-term stenting with an endotracheal tube is used.\(^1\) Other types of LTS require a stent to keep grafts in place, to lend support to the reconstructed area, and to provide a rigid support around which scar contracture can occur. Short-length stents are used when LTS does not involve the trachea and when short duration of stenting (4 to 6 weeks or less) is needed. Short-length stents should not be used for a longer duration of stenting because of the risk of developing suprastomal granulation tissue and stenosis.\(^5,11\) Long-length stents are indicated for LTS involving the trachea (including suprastomal or infrastomal collapse) and when long-term stenting is required. The incidence of suprastomal collapse preventing decannulation is lower with the use of long-length stents.\(^1\) In one of our procedures, a long-length stent was required because long-term stenting was needed; however, a short-length stent was used, thus resulting in suprastomal stenosis and LTR failure.

The duration of stenting is usually determined by the experience of the surgeon with certain guidelines in mind. The duration of stenting may be short (4-6 weeks) or long (\(>2\) months). Long-term stenting is usually required (1) for absence of rigidity in the area of stenosis; (2) in cases where the anatomy is severely distorted; (3) in patients with keloid formation; (4) when there is poor stability of grafts; and (5) when stenting is used to prevent scar contracture.\(^1\) When the posterior cricoid lamina is absent and the placement of a posterior graft is not possible and the distracted area is anticipated to fill with epithelialized scar tissue, even a longer period of stenting (\(>6\) months) is required. Short-term stenting is sufficient for other types of LTS. In 8 of our procedures, inappropriate duration of stenting was used. In 7 procedures, the nature of LTS required long-term stenting, but short duration was chosen. In 1 case, a short-length stent was left in place for 7 months (too long), and thus resulted in suprastomal anterior collapse with resulting stenosis that required a revision procedure.

After the appropriate LTR for a particular LTS is performed and before the patient is awakened, the proper superior position of the stent is confirmed by endoscopy. The patient is discharged from the hospital with oral antibiotics. Patients are also examined in the office with flexible laryngoscopy every 3 to 4 weeks to check for proper positioning of the stent and to monitor for granulation tissue formation. In 1 patient, the stent slipped below the glottis with subsequent complete glottic stenosis. In another case, which involved a teenager, the stent broke at the site of tracheotomy tube following trauma to the neck. This type of complication has been previously reported.\(^1,16\) Steps that should be taken to minimize this risk have been outlined.\(^16\) In both of these cases, premature removal of the stent was necessary and thus resulted in LTR failure.

The stents are removed at a predetermined time. Patients undergo repeated endoscopy at 2- to 3-week intervals as necessary until decannulation. At each endoscopy, pedunculated granulation tissue is removed and the airway size is evaluated to determine the possibility of decannulation. During this period, the patients are maintained with use of inhaled topical steroids. In 2 of the procedures, there was poor follow-up both for the clinic and operating room visits and thus there was inadequate control of granulation tissue formation and subsequent failures.

Postoperatively, anterior suprastomal collapse was seen in 2 procedures. The reason that this occurred is not clear since both patients had long-length stents. Both patients were decannulated after single-stage LTR with use of anterior cartilage graft and short-term stenting with an endotracheal tube.

In only 1 patient was reflux believed to have any significant role in LTR failure. This patient had massive reflux documented on pH probe study, was treated with medication, but still had significant GERD. Finally, in 5 procedures that involved 1 patient, the formation of keloid was believed to have contributed significantly to LTR failure. This patient is described below.
CASE REPORT AND ANALYSIS

The patient was involved in an automobile crash at age 5 years. Because of head and multiple other injuries, he required prolonged intubation that subsequently led to the development of SGS. He underwent placement of a tracheotomy tube initially, which was followed by LTR at age 5 years 4 months. For his circumferential SGS, an anterior cricoid split with placement of a Montgomery T-tube for 6 months was performed. Granulation tissue was removed several times from the glottic area. Shortly after the stent removal, massive scar formation was seen in the subglottis. Although successful use of the Montgomery T-tube has been reported in the pediatric population, it was probably not a good choice in this case because of the child’s age and the short distance between the subglottis and true cords, which predisposes the glottis to injury from the stent. A second factor contributing to LTR failure was the formation of keloids in this patient.

A second LTR was done at age 8 years 3 months. There was almost complete obstruction of the subglottis. An anterior and posterior split with a Swiss-roll stent above the site of the tracheotomy was performed. The stent was removed 4 weeks later. Massive granulation tissue formation was seen. Both the choice of the stent and duration of stenting were inadequate. The Swiss-roll stent was a poor choice because posterior cricoid split results in greater instability and usually requires a more rigid stent. Anterior and posterior cricoid splits without a graft requires long-term stenting and therefore a stent above the tracheotomy site is not an ideal choice since it can lead to suprastomal collapse and stenosis.

A third procedure was attempted at age 8 years 6 months and the same mistakes regarding choice and duration of stent were repeated. An anterior and posterior split with placement of a trimmed Portex endotracheal tube above the site of tracheotomy tube was performed. The stent was removed 6 weeks later. The subglottis was filled with granulation tissue and subsequently narrowed down rapidly, resulting in total stenosis of the glottis, subglottis, and upper trachea. Because of the reactive nature of Portex, it was a poor stent choice. In addition, to stabilize anterior and posterior cricoid splits without the use of a graft, a long-term stent was necessary and therefore a long-length stent would have been a better choice.

A fourth procedure was done at age 13 years 1 month. Anterior and posterior splits with an anterior costal cartilage graft and a long Aboulker stent was performed. The stent was removed 8 months later. The patient was decannulated for 6 months when the LTR failed. Significant keloid formation was seen. No other reason than formation of keloid could be found for this LTR failure.

The patient required a fifth procedure at age 14 years 9 months. An anterior cricoid split without a graft and a long Aboulker stent was performed to address almost complete stenosis of the glottis, subglottis, and upper trachea. The stent was removed 2 months later because of stent breakage during a football game. The stent broke at the site where the tracheotomy tube entered the stent. This may have been due to the child’s level of physical activity, which placed excessive motion on the tracheotomy tube and subsequent breakage. This procedure failed not only because of stent breakage, but also because of failure to address the posterior component of the stenosis that was recognized preoperatively, but not addressed.

The final procedure consisted of a 4-quadrant split using a Striker saw and placement of a Montgomery T-tube that was left in place for more than 5 years. The stent was intermittently replaced endoscopically with new stents. The patient was decannulated at age 23 years 8 months. Because of the multiple procedures, the glottis and the anterior commissure are permanently scarred.

CONCLUSIONS

A certain number of LTRs fail for unknown reasons; however, many LTR failures can be avoided if accurate preoperative assessment, especially of the posterior LTS is done. Intraoperative reassessment when the airway is open and selection of the appropriate type of LTR for a particular patient is crucial. The decision on the type, length, and duration of stent must be individualized. Close postoperative monitoring to ensure proper positioning and timely removal of the stent and subsequent evaluations for removal of granulation tissue and the need for continued use of inhaled steroids are the other important factor in ensuring successful LTR outcome. Other factors such as GERD and keloid formation seem to play only an occasional role in LTR failure.

Accepted for publication October 2, 1998.
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REFERENCES