Tracheal stenosis in infants and children is typically characterized by the presence of complete cartilaginous tracheal rings and often involves significant lengths of the trachea. Although it may become symptomatic across a variety of ages, the most common presentation is in the first months of life. In infancy, the initial management of such patients can be very challenging due to the unstable nature of the stenotic airway with the need for paralysis to facilitate mechanical ventilatory support.

In our recent experience, quite a number of patients escaped recognition until they either were found to have difficulty with intubation for a nonairway operation or failed to wean from ventilatory support following another operation. That these children are often quite complex, with a number of associated anomalies, predominantly cardiovascular, is also emphasized in our experience.

Outcomes of surgical reconstruction of the stenotic trachea have been promising in recently reported series utilizing a number of techniques, yet this population still experiences significant postoperative morbidity and mortality, related not only to the reconstruction of the trachea, but also due to associated anomalies, the majority of which are cardiovascular. Since 2001, our program at Cincinnati Children’s Hospital has employed the technique of slide tracheoplasty, utilizing cardiopulmonary bypass support with simultaneous treatment of associated cardiac defects following disappointing experience with other surgical techniques.

Preoperative evaluation always includes bronchoscopy to document the degree and length of the tracheal stenosis. Echocardiograms are performed to assess for associated cardiac anomalies. Contrast chest computed tomography with 3D reconstruction is often performed to assist with documentation of vascular anomalies and to add information about the length of the tracheal stenosis, although this study has never substituted for careful, yet thorough, endoscopic airway examination.
Operative Technique

Figure 1 After induction of general anesthesia by mask, a careful rigid bronchoscopy is performed to confirm the proximal extent and length of the segment with complete tracheal rings. Airway secretions can be cleared and direction given to the anesthesiologist regarding ideal endotracheal tube size and placement, which is typically not advanced into the stenotic segment unless the entire length of trachea is made up of complete rings.

Median sternotomy is performed with the incision beginning superiorly at the level of the sternal notch. We have found that this will allow adequate exposure to allow tracheal dissection up to the level of the cricoid cartilage, if necessary. The ascending aorta is retracted to the left utilizing a stay suture and dissection of the anterior surface of the trachea and main-stem bronchi is performed before cannulation for bypass if the patient is stable.

The lower trachea is exposed by resecting the packet of lymphatics in the roughly rectangular space bounded laterally by the superior vena cava, inferiorly by the right pulmonary artery, medially by the ascending aorta, and superiorly by the innominate artery and vein. Above the level of the innominate vein, the anterior trachea is exposed by simple midline division of soft tissues, including the thyroid isthmus, up to the level of the cricoid cartilage. If a left pulmonary artery sling is present, limited dissection of the origin of the left pulmonary artery is performed at this time and dissection of the distal trachea is deferred. Ao = aorta; IA = innominate artery; Innom. v. = innominate vein; LCC = left common carotid artery; LPA = left pulmonary artery; MPA = main pulmonary artery; PA = pulmonary artery; RA = right atrium; RPA = right pulmonary artery; SVC = superior vena cava.
Cannulation for cardiopulmonary bypass (CPB) is performed utilizing a flexible aortic cannula, which can be draped inferiortly off the field, and a single right atrial appendage venous cannula, unless simultaneous repair of intracardiac defects is required. Repair of cardiac defects is performed first after initiation of CPB. In cases of left pulmonary artery sling, we prefer reimplantation onto the normal anatomic position on the main pulmonary artery, which can be done without aortic cross-clamping. If no intracardiac repair is to be performed, we maintain body temperature at normothermia. Ao = aorta; RPA = right pulmonary artery; SVC = superior vena cava.
Figure 3  The anterior surface of the main-stem bronchi are dissected as far as possible as is the inferior aspect of the carina, both deep to the right pulmonary artery, to facilitate later mobilization of the distal tracheal segment. The upper extent of the tracheal stenosis is reconfirmed utilizing a flexible bronchoscope to visualize from the tracheal lumen, while a fine needle is passed through the anterior wall of the trachea from the operative field. The total length of the stenosis is measured, typically extending to the bottom of the carina distally, and the midpoint of the stenotic segment is dissected circumferentially.
Figure 4 The trachea is divided at mid-stenosis, and this allows anterior traction on each segment to facilitate posterior dissection of each tracheal segment. The lateral soft-tissue attachments are left undisturbed as much as possible both to preserve blood supply and to avoid injury to the recurrent laryngeal nerves. Superiorly, posterior dissection must proceed carefully to avoid entry into the membranous trachea above the level of stenosis. Dissection is kept directly against the trachea to avoid esophageal injury. Thorough anterior and posterior dissection of the tracheal segments results in the ability to dramatically mobilize each segment, particularly in the younger patient. We have not had to employ hilar release techniques and only once utilized a hyoid release to achieve adequate mobilization.
Figure 5  Longitudinal incision is made in opposite surfaces (anterior and posterior midline) of each tracheal segment. Sliding the distal segment either anterior or posterior to the upper segment can be done with good results. We have found that opening the distal segment posteriorly and the upper segment anteriorly to be preferable. Beginning with the anastomosis on the posterior wall is simpler distally, and if the patient has had a prior tracheostomy tube, the anterior opening in the superior segment can be extended into the tracheostomy stoma, incorporating this into the repair. The corners are trimmed from each segment.
The anastomosis is performed in a running fashion using monofilament, absorbable suture, typically 6-0 in infants. Placement of two downward traction sutures superiorly and one upward traction suture inferiorly helps to relieve tension as does a suction instrument placed beneath the carina for upward pushing by an assistant. The anastomosis is begun from the interior of the trachea and then transitioned to being able to follow from outside, which discourages inversion of the tracheal edges, which is to some extent unavoidable.
Before completion of the anastomosis, the airway is cleared of blood and secretions using a flexible suction catheter and the endotracheal tube is advanced so that the tip lies at the midpoint of the repair. Metallic clips are placed on the peritracheal soft tissue to mark the superior and inferior extent of the repair to facilitate radiographic confirmation of proper endotracheal tube placement postoperatively. The patient is hand-ventilated with gradually increasing peak airway pressure up to 35 mm Hg, while the mediastinum is filled with saline to identify any air leaks, which are rarely seen but should be repaired with interrupted or mattress sutures.
The patient is weaned from CPB support and chest drainage and closure is performed as is typical for cardiac repairs. No drains are left adjacent to the airway and mediastinal drains are typically removed the following day if their output is low. Flexible, fiberoptic bronchoscopy is performed before transport to the intensive care unit to clear secretions and blood from the airway and to confirm proper endotracheal tube position. A mild “figure 8” deformity is typically seen at this stage but does not compromise airway function.
Conclusions

In the intensive care unit, the child is kept sedated and ventilated with the lowest peak pressures that deliver adequate tidal volumes. The head is positioned on a pillow to encourage neck flexion, but no other maneuvers are employed to avoid tension on the trachea. The inherent stability of a repair that uses only cartilage-supported tissue led us to an approach to strive for early extubation in this patient group. In our recent experience with 40 patients undergoing slide tracheoplasty at a median age of 6.2 months, over 50% of patients could be extubated within 48 hours of their reconstruction.

Analysis revealed only the need for preoperative mechanical ventilation and longer CPB duration were predictive of the need for prolonged postoperative ventilatory support. Follow-up bronchoscopy is performed weekly before discharge, which is commonly about 2 weeks following repair.

The appeal of the slide tracheoplasty technique lies mainly in its versatility: we have successfully employed it in both short-segment and full-length tracheal reconstructions, in patients who have undergone prior reconstructions using other techniques, and in cases where the orientation of the slide must be modified to deal with proximal bronchial stenosis or the presence of a tracheal origin of the right upper lobe bronchus. The use of only local, autologous, vascularized tissue in the reconstruction should result in the best prospect for tracheal growth in this young population, an observation we have made in longer follow-up of our youngest infants.

Successful early extubation in over half of the patients in our recent experience testifies to the quality of the slide tracheoplasty in management of congenital tracheal stenosis.