Pediatric Tracheal Surgery

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Background. Pediatric tracheal procedures are uncommon. We reviewed our experience to clarify management and results.


Results. One hundred sixteen children were evaluated, mean age 10.4 years (10 days to 18 years). Tracheal pathology was postintubation stenosis (n = 72; 62%), congenital stenosis (n = 23; 20%), neoplasm (n = 8; 7%), tracheomalacia (n = 7; 6%), and trauma (n = 6; 5%). Twenty-nine patients had previous tracheal operations. Thirty-six patients received only a minor procedure. Eighty patients had major operations: tracheal resection (n = 46; 58%), laryngotracheal resection (n = 22; 28%), slide tracheoplasty (n = 7; 9%), and carinal resection (n = 5; 6%). The mean length of airway resected was 3.3 cm (1.5 to 6 cm), which represented 30% of the entire trachea. Twenty-eight patients (35%) had complications. These included tracheomalacia (n = 3), recurrent nerve injury (n = 3), laryngeal edema requiring intubation (n = 2), stroke (n = 1), esophageal leak (n = 1), and lobar collapse (n = 1). Nineteen patients had anastomotic failure: severe restenosis (n = 6), mild restenosis (n = 9), dehiscence (n = 2), dehiscence with tracheoesophageal fistula (n = 1), and tracheoinnominate fistula (n = 1). Two children died (2.5%). Complications were more frequent in children less than 7 years of age (p = 0.05) and after previous operations (p = 0.02). Longer fractions of tracheal resection (>30%) were more likely to result in anastomotic failure (p = 0.0005). Sixty-four (80%) patients achieved a stable airway free of any airway appliance. All patients with neoplasms are alive.

Conclusions. The principles of adult tracheal operations are directly applicable to children and usually lead to a stable, satisfactory airway. Children tolerate anastomatic tension less well than adults; resections more than 30% have a substantial failure rate.

Patients and Methods

From 1978 to 2001, 116 children (aged <19 years when first evaluated) were evaluated for tracheal pathology by the general thoracic surgical unit. Hospital and office records were retrospectively reviewed and pertinent information recorded in a database. Follow-up was obtained from office records, referring physicians’ records, and by direct patient contact. The average follow-up was 4.3 years (range, 6 days to 20 years).

Patient Evaluation

The diagnosis and selection of patients for operative repair have been outlined and are quite similar between adults and children. In general, very young children are less well evaluated with radiographic techniques than with endoscopic evaluation due to differences in body habitus, motion artifact, and failure to obtain sufficient detail of the status of the tracheal wall (congenital O rings or malacia). Cross-sectional imaging (computed tomographic scans or magnetic resonance imaging) is very important in congenital stenosis (to detect other associated anomalies such as a pulmonary artery sling), malacia (to detect vascular or cardiac causes of extrinsic compression), and in tumors (to define extraluminal extent of disease). Cases involving congenital tracheal stenosis also require a thorough search for extratracheal malformations, especially of commonly associated car-
Table 1. Tracheal Pathology and Surgical Treatment

<table>
<thead>
<tr>
<th>Pathology</th>
<th>Number (%)</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Postintubation stenosis</td>
<td>72 (62%)</td>
<td>TR = 31, LTR = 17, CR = ...</td>
</tr>
<tr>
<td>Congenital stenosis</td>
<td>23 (20%)</td>
<td>...</td>
</tr>
<tr>
<td>Neoplasms</td>
<td>8 (7%)</td>
<td>4, 1, 3</td>
</tr>
<tr>
<td>Tracheomalacia</td>
<td>7 (6%)</td>
<td>2</td>
</tr>
<tr>
<td>Trauma</td>
<td>6 (5%)</td>
<td>3, 1</td>
</tr>
<tr>
<td>Total</td>
<td>116</td>
<td>ST = ...</td>
</tr>
</tbody>
</table>

CR = carinal resection; LTR = laryngotracheal resection; ST = slide tracheoplasty; TR = tracheal resection.

Diaphragm anomalies so that appropriate plans for repair are made. A pediatric otolaryngologist should evaluate the larynx, as obstructive lesions of the larynx, such as laryngomalacia, may also be present and alter planning. The larynx should also undergo a detailed examination in cases of postintubation stenosis to identify commonly associated supraglottic (arytenoid scarring and fixation), glottic (vocal cord paralysis or granulomas), or proximal subglottic pathology. These problems, if severe enough, may require repair before the tracheal stenosis is repaired.

Bronchoscopic evaluation of the airway is very similar to that of adults and is the most critical component in evaluation. The extent of the lesions must be evaluated and measured, the quality and extent of remaining trachea must be ascertained, and the character of the tracheal mucosa (normal, scar, granulation, or tumor) assessed. If a stoma is present, the site should be inspected for peristomal granulations, which are frequently present. If a stoma is present in the normal portion of the trachea, its management must be planned. The stoma may be resected or closed at the time of resection. Rarely, if the stoma is present in relatively good trachea it may be relocated to the most severely damaged trachea to allow recovery of additional tracheal length. Malaria is often present adjacent to the stoma. It must be determined whether it is severe enough to alter the proposed length of tracheal resection or the result of tracheal resection if left in place. Malaria is best evaluated during spontaneous breathing, requiring close cooperation with the anesthesiologist.

Older children are evaluated with small-sized (4, 5, and 6) ventilating rigid bronchoscopes with the aid of a magnifying 0-degree telescope. Infants and small children are evaluated with a very small (infant size) ventilating rigid bronchoscope (Karl Storz, Culver City, CA) with ultra-thin 0-degree telescopes. Ultrathin flexible bronchoscopes with an outside diameter of only 3 mm are useful for examining infants’ airways and larger standard pediatric bronchoscopes are used for older children. The operating surgeon is the optimal person to assess the airway preoperatively and to decide whether operation is indicated and plan the repair. It is surprising how commonly previous bronchoscopic findings have been incomplete or misleading. Intraoperative bronchoscopy (by pulling back the endotracheal tube over a tracheoplasty; TR = tracheal resection. flexible bronchoscope) is frequently helpful to decide where to make a tracheal incision and also to examine the completed repair.

Operative Technique
The principles and techniques of tracheal [9], laryngotracheal [10], and carinal resection [11] have been standardized and outlined by our group in adults. These techniques are directly applicable to children, except that we use finer absorbable sutures (Vicryl-Ethicon, Somerville, NJ). We typically use 6-0 sutures for infants, 5-0 for young children, and 4-0 for adolescents. Cross-field ventilation with appropriately sized sterile endotracheal tubes is used in essentially all patients, even infants, obviating the need for cardiopulmonary bypass. We have used cardiopulmonary bypass in 5 children with congenital tracheal stenosis when concomitant pulmonary vascular or cardiac procedures were necessary (3 patients with pulmonary artery reimplantations, 1 atrial septectomy, and 1 for poor ventricular function associated with cyanotic heart disease) [5]. The operative technique and outcome of slide tracheoplasty have been recently reported on by our group [4, 5].

Statistical Methods
Continuous variables were analyzed with the t test and categorical variables with the x² test. Multivariable logistic regression was used to identify risk factors for dichotomous outcomes. All p values were two-tailed and p less than or equal to 0.05 was chosen as significant.

Results
Demographics
The mean age of the children was 10.4 years, with a range of 10 days to 18 years. Seventy-nine (68%) children were male and 37 (32%) were female.

Etiology
The pathology of the tracheal condition is listed in Table 1. The majority of patients had postintubation tracheal stenosis reflecting our unit’s interest in this condition and the common occurrence of this condition. Of the 78 patients with acquired pathology, motor vehicle accidents were the initiating cause in 36. Four patients had
burns and 6 patients suffered other accidents. Perinatal ventilation caused stenosis in 14 patients. Six children suffered tracheal stenosis from prolonged ventilation after an operation. Five children had stenosis as a result of intubation for croup or epiglottitis. Three patients were intubated for medical conditions (drug overdose, asthma, seizure) and 3 patients, for unknown reasons. One patient had a previous tracheal resection for neoplasm and developed postoperative stenosis. The average duration of intubation was 29 days (range, 2 to 165 days). The etiology of the tracheomalacia was idiopathic (n = 4), associated with congenital tracheoesophageal fistula (n = 2), and from extrinsic vascular compression (n = 1). The types of tracheal tumors were mucoepidermoid (n = 2), granular cell tumor (n = 2), malignant fibrous histiocytoma (n = 1), adenoidcystic carcinoma (n = 1), Schwannoma (n = 1), and thyroid cancer (n = 1).

Previous Procedures
Twenty-nine patients had major tracheal operations before referral to our unit. Fourteen had tracheal resections, 10 had a tracheoplasty (6 anterior cartilage tracheoplasty, 2 anterior rib tracheoplasty, 1 anterior tracheoplasty for tracheomalacia, and 1 anterior tracheoplasty for postintubation stenosis), and 5 patients underwent repair of a tracheoesophageal fistula. Sixty-one patients had an artificial airway created: 56 had a tracheostomy and 5 had a tracheal T tube.

Delay of Operation
For 22 of the 116 patients (19%) there was a delay between initial presentation to the thoracic unit and a subsequent major operation. The mean delay was 2.4 years (range, 1 month to 23 years). Nine patients (8%) were initially judged not to have severe enough symptoms to warrant operation. Subsequent follow-up changed that opinion as symptoms worsened, which then led to operation. Seven patients (6%) with only moderate symptoms were electively followed to allow growth to minimize risk of operation. Five patients (4%) needed more time to recover from a previous tracheal operation. One patient (1%) was delayed to allow recovery from a closed head injury.

Minor Operations
Thirty-six patients (31%) had only minor procedures. A majority of these patients, 24 (67%), had bronchoscopy only to evaluate the suspected tracheal pathology. Five patients (14%) had a tracheal T tube placed, 3 (8%) had removal of stomal granulation tissue, 2 (6%) had a tracheostomy placed, 1 (3%) had a carinal Y stent placed, and 1 (3%) had a tracheal dilation. The reason for not proceeding with a major operative procedure was as follows: stenosis not severe enough, 18 patients (50%); severe laryngeal damage, 10 (28%); and irreparable damage (excess length of damaged trachea), 8 patients (22%).

Major Operations
Eighty patients (69%) had major operations, which are listed in Table 2. The average length of tracheal resection alone was 3.4 cm (range, 1.5 to 6 cm). The average length of laryngotracheal resection was 3.1 cm (range, 1.5 to 6 cm). The percent trachea resected was calculated for each patient by dividing the amount resected by the estimated tracheal length based on tracheal length nomograms specific for age and gender [12]. The average percent of trachea resected was 30%. Figure 1 demonstrates the length of resection normalized to the patient’s overall tracheal length. Six patients had an adjunctive laryngeal release [13]. The average length of resection for tracheal resection with congenital stenosis was 28%, whereas the average extent of stenosis for slide tracheoplasty was 56% [5]. The mean length of hospital stay was 13.5 days (range, 4 to 170 days). The number of patients younger than 4 years who underwent tracheal resection was 4 (9%) and laryngotracheal resection was 1 (5%). The number of patients who had an artificial airway appliance before operation was 24 (52%) in the tracheal

Table 2. Types of Major Tracheal Operations and Indication for Operation (n = 80)

<table>
<thead>
<tr>
<th>Operation</th>
<th>Number (%)</th>
<th>Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tracheal resection</td>
<td>46 (58%)</td>
<td>PITS</td>
</tr>
<tr>
<td>Laryngotracheal resection</td>
<td>22 (28%)</td>
<td></td>
</tr>
<tr>
<td>Slide tracheoplasty</td>
<td>7 (9%)</td>
<td></td>
</tr>
<tr>
<td>Carinal resection</td>
<td>5 (6%)</td>
<td></td>
</tr>
</tbody>
</table>

PITS = postintubation tracheal stenosis.

Fig 1. Distribution of fraction of trachea resected with tracheal resection and reconstruction (open bars) and laryngotracheal resection and reconstruction (solid bars).
resection group and 16 (73%) in the laryngotraheal group.

Complications

Complications after major tracheal operations are listed in Table 3. Overall, 28 patients (35%) had complications, with some patients having more than one complication. Any airway narrowing postoperatively that led to symptoms or another procedure was judged to be a complication. Six patients had severe restenosis and were treated as follows: tracheostomy (n = 3), re-resection (n = 2), and no treatment (n = 1). Nine patients had minor restenosis and were treated as follows: temporary stenting (n = 4), removal of granulation tissue (n = 3), and tracheal dilation (n = 2). All three patients with anastomotic dehiscence were treated with a permanent tracheal T tube. Three patients with symptomatic postoperative tracheomalacia were treated as follows: tracheal T tube (n = 1), tracheostomy (n = 1), and tracheoplasty with external plastic stents (n = 1). The patient who developed an esophageal leak (tumor that invaded the esophagus required a partial esophagectomy) healed spontaneously. Two patients died (2.5%). One patient with postintubation stenosis who had undergone two previous tracheal resections expired from a tracheoinnominate fistula after the third resection. One patient with congenital stenosis who previously had an anomalous left pulmonary artery reimplanted had an intraoperative arrest and subsequent stroke after tracheal resection. Postoperatively, the left pulmonary artery anastomosis was found to be severely stenotic. The patient was comatose after the operation and a severe restenosis developed 1 month later; the family withdrew support and the child died.

The complication rate in patients less than 7 years old (56%) was higher than in older patients (30%) (p = 0.05). Patients who had previous tracheal operations had a higher complication rate (52%) than those who did not (26%) (p = 0.02). The incidence of complications, major and minor, was 37% for tracheal resections, 41% for laryngotraheal resections, 23% for carinal resections, and 14% for slide tracheoplasty. Of the 6 patients who had adjunctive laryngeal release only one had an anastomotic problem. The incidence of airway complications was highly correlated to the fraction of trachea resected (Fig 2). Longer fractions of trachea resected are associated with higher rates of airway complication (p = 0.0005). Anastomotic dehiscence, a most severe complication, was also correlated with longer fractions of tracheal resection (p = 0.03). Multivariable logistic regression was used to define risk factors for airway complications after tracheal or laryngotraheal resection. Length of resection (p = 0.001) and reoperative tracheal procedures (p = 0.05), but not age (p = 0.19) were independent risk factors for postoperative airway complications.

Outcome

Operative outcomes for major operations are listed in Table 4. A stable airway was defined as one that allows normal function without an airway appliance. The outcome was judged to be good if the patient was asymptomatic and follow-up studies demonstrated that the trachea was essentially normal. The result was satisfactory if the patient had minor airway symptoms or if follow-up studies showed the trachea to be narrowed. Failure was defined by requirement for a permanent airway appliance (tracheostomy or tracheal T tube).

All patients who had a slide tracheoplasty had a good outcome. All patients who had a carinal resection had a stable outcome. Both patient deaths and all 4 reoperations were included in the reoperation group and all 4 deaths were in the reoperation group.

Table 4. Operative Outcome for Major Operations (n = 80)

<table>
<thead>
<tr>
<th>Operation</th>
<th>Good</th>
<th>Satisfactory</th>
<th>Reoperation</th>
<th>Failure</th>
<th>Died</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial</td>
<td>49</td>
<td>12</td>
<td>4</td>
<td>13</td>
<td>2</td>
</tr>
<tr>
<td>Reoperation</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Overall</td>
<td>52 (65%)</td>
<td>12 (15%)</td>
<td>14 (18%)</td>
<td>2 (3%)</td>
<td></td>
</tr>
</tbody>
</table>
tions occurred after tracheal resections. A stable outcome was also achieved in more than 70% of patients who underwent tracheal or laryngotracheal resection (Table 5). All 8 patients resected for neoplasms are alive, have a stable airway, and 7 are free of disease, with a mean follow-up of 6.9 years (range, 4 months to 15 years).

Comment

The distribution of our patients' pathology is unusual with a preponderance of postintubation stenosis rather than congenital stenosis. This is likely due to our unit being an airway surgery referral center with a long history of interest in postintubation stenosis. This distribution skews the series and the results of treatment. Comparison to other pediatric tracheal surgery series is thus problematic. In addition, many of our patients had failed operative treatment elsewhere and thus were high-risk patients. Last, the majority of our patients had an indwelling airway appliance before airway resection, which complicates treatment.

All 7 patients who underwent slide tracheoplasty had a stable airway and only 2 had minor complications; a temporary recurrent nerve palsy in 1 patient and a granuloma requiring bronchoscopy in the other. We [5] and other researchers [6] are pleased with the results of slide tracheoplasty and believe that it represents improvement over results achieved with augmentation tracheoplasty [6, 14-16]. Advantages of slide tracheoplasty include: (1) immediate tracheal reconstruction with rigid, vascularized tissue with a normal mucosa; (2) ability to extubate the patient immediately in most cases; (3) rare postoperative granuloma formation; and (4) normal growth of the reconstructed trachea [5]. Replacement of the tracheal wall by scar tissue and mucosa by granulation tissue in postintubation stenosis precludes the use of slide tracheoplasty in these patients. Children with short congenital stenosis are still best treated with standard tracheal resection, as the resultant airway diameter is normal. Data from this report clarifies what is "short" and what is "long" so that the proper operation can be selected for a child with congenital stenosis. From information in Figure 2 on anastomotic complication rates as a function of percent of trachea resected, 29% or less can be considered short and should offer a high probability of a good result after tracheal resection. Alternatively, when stenosis involves 30% or more of the trachea, slide tracheoplasty should be performed. Slide tracheoplasty may also offer an advantage in small infants with a short stenosis, as any postoperative anastomotic edema is distributed obliquely rather than circumferentially.

Tracheomalacia in most children gradually improves with time [17, 18]. Children with severe symptoms require treatment, which is often problematic due to the extent of malacic airway. Short, focal malacic segments should be resected in standard fashion as was done in 2 of our 7 patients. Unfortunately, these patients with short malacic segments constitute only a small minority of malacic patients. It is important to search for vascular causes with contrast computed tomographic scans, because vascular compression should always be treated first as this usually resolves the problem. Children who have had a tracheoesophageal fistula repaired can present later with an associated malacic tracheal segment that can be very difficult to correct [2, 19]. Two of our children had this association. Airway stenting with silicone and metallic expandable stents has been reported but remains problematic due to the small size of the pediatric airway and the need for growth [18]. Expandable metallic stents are of limited use because they frequently cause granulation tissue and, by being permanent, produce stenosis again with growth. Silicone stents can be changed as the child grows but have less luminal diameter (compared to metallic stents), which limits their use to older children. Two of our children have been well palliated with silicone stents, which have been replaced with progressively larger ones as the children have grown.

Tracheal neoplasms are quite rare in children and most reports are of single cases. In the most recent review spanning the past 30 years, only 36 patients were reported [20]. Two-third of tumors were benign with hemangioma the most common benign tumor and malignant fibrous histiocytoma the most common malignant tumor. About 50% present with wheezing, which is almost invariably initially misdiagnosed as asthma. Only 8% have hemoptysis. Treatment is excision, usually by tracheal resection. Our patients were unusual because the majority were malignant. This is probably the result of selective referral of more complex cases. All of our patients were treated with segmental airway resection and reconstruction: tracheal resections (n = 4), carinal resections (n = 3), and laryngotracheal resection (n = 1). All patients had a stable airway after resection and all are long-term survivors.

The majority of our patients had postintubation stenosis and most of the major operations were done for this indication. Most patients had a tracheostomy when operated on, which complicated treatment. Tracheostomy is always best avoided, if possible, as it endangers a small length of an already all too short trachea. If tracheostomy is necessary, it should be performed in the damaged trachea that is to be resected to minimize the length of resection. The larynx is more commonly involved in children with postintubation stenosis, probably due to the underappreciated small relative size of the cricoid aperture. In our primarily adult series of postintubation stenosis, 12% of the patients required laryngotracheal resection, whereas in the present series 36% did. Most
children achieved a stable airway but the success rate was not as high as in our adult series (94% good or satisfactory results) [9]. The main problem was anastomotic. As in adults, the success rate was higher in a first operation. Complications were also more frequent in younger children, not surprising given their smaller and more fragile tracheas. There is no absolute age in which a resection cannot be done; tracheal resection has been successfully performed in the neonate [21]. The treatment of acquired subglottic stenosis is currently in flux with increasing enthusiasm for laryngotracheal resection. Decannulation rates close to 100% have been reported [7, 8]. Normal growth of the cricotraheal anastomosis has been reported in an experimental rabbit model [22] and in children [7]. Subglottic stenosis is usually treated by ears, nose, and throat surgeons who may have little experience in tracheal operations. Hence, for many years anterior (± posterior) cricoid split with a free cartilage graft was performed [23]. This required prolonged stenting, tracheostomy, multiple revisions, and numerous bronchoscopic removals of granulations. With awareness of the experience with laryngotracheal resection in adults, the technique was applied in children with very favorable results [7, 8]. We and other investigators [7] believe that this is the preferred treatment for subglottic stenosis, as the airway is reconstructed with vascularized, rigid trachea with normal mucosa.

This series includes our earliest experiences with pediatric tracheal reconstruction. The complication rate was high and primarily involved anastomotic failure (stenosis or dehiscence), the result of excessive tension. The airway-related complication rate is a function of the fraction of trachea resected (Fig 2). The complication rate approaches 50% when one-third of the airway is resected and was 100% in the 2 patients who had one-half resected. Reoperative tracheal procedure is also a risk factor for anastomotic problems, emphasizing the need to carefully plan and execute the first operation. Fortunately, essentially all patients could be salvaged. Ten of the 19 patients with airway complications achieved a stable, appliance-free airway. In our adult series of patients who had an airway resection for postintubation stenosis the anastomotic failure rate was 6% (29 of 503 patients) [9]. In children, the failure rate was 23% (11 of 48 patients), four times higher. This is a sobering number and is in accord with experimental work done by Grillo and Maeda [3] in puppies, which demonstrated an increasing rate of stenosis as anastomotic tension increased in resections beyond 25%. Given this information, it is prudent to select very carefully children who need to have 30% or more of the trachea resected. Parents should be cautioned about the possibility of postoperative anastomotic stenosis. Tracheal release maneuvers [13] should be strongly considered in these patients to reduce tension on the anastomosis even if the tension does not seem excessive. Postoperative surveillance bronchoscopy should be considered in high-risk patients to identify and treat anastomotic problems early before they become life-threatening. Because more than half of these patients with more than 30% resections end up with a stable airway with a very low mortality, it is still appropriate to resect these patients with the precautions noted.

References
DISCUSSION

DR CARL L. BACKER (Chicago, IL): First I want to congratulate Dr Wright on an excellent presentation and for sending me the manuscript well in advance of this meeting. This review represents the largest number of pediatric patients undergoing tracheal surgery ever reported from a single institution. The survival rate of over 97% is truly remarkable given the severe pathology involved, the complexity of these procedures, and the number of patients with a prior, often failed, procedure. This review would propose a surgical standard of 30% of the total tracheal length as being a safe resection length for infants and children. Our own experience with 55 tracheal stenosis patients would support that conclusion. This is a change from the classic teaching that a 50% resection is a safe surgical standard.

This review has a large number of patients with post intubation tracheal stenosis, which leads me to my first question. In our series, we have had very few patients with post intubation tracheal stenosis. Do you think there are regional differences in intubation techniques and, specifically, the use of cuffed tubes in smaller children, that might account for this difference in the incidence of post intubation stenosis?

The other question I had was: has there been any change during the 23-year time period of this study in the incidence of post intubation stenosis over time? Are we getting better at preventing this complication?

There are some significant differences between the techniques that we have used at Children’s Memorial Hospital and those outlined here by Dr. Wright. The mean age in our series was only six months, significantly lower than the MGH series, and the mean number of complete tracheal rings in our series was 14. We have used a full median sternotomy and cardiopulmonary bypass in all of our patients, and I believe this greatly facilitates exposure, safety, and a better dissection. The question I have here is: do you think that your single intraoperative death from a cardiac arrest during tracheal resection could have been prevented by the use of cardiopulmonary bypass?

Another significant difference is that we have adopted the tracheal autograft technique instead of the slide tracheoplasty for infants with long-segment tracheal stenosis. Under cardiopulmonary bypass, the trachea is incised anteriorly and the mid-portion of the trachea is resected. A posterior end-to-end anastomosis is performed and the tracheal autograft is inserted anteriorly. Pericardial augmentation is used superiorly if the length of the tracheal autograft is insufficient.

We have used this technique now in 16 infants with one early death. I find this procedure to be more flexible and technically easier than the slide tracheoplasty, and actually began using it after a failed slide tracheoplasty. The question I have here is, do you think the slide tracheoplasty technique can be applied to patients with complete tracheal rings involving the entire length of the trachea, which is frequently what I see?

I congratulate you again on your superb results and your outstanding contribution to the practice of pediatric tracheal surgery. I thank the Society for the privilege of discussing this excellent manuscript. Thank you.

DR WRIGHT: Thank you for those insightful comments. I think we have four questions to address. One is the issue of regional referral patterns. We have a nationwide referral practice, and, in fact, if you look at the distribution of where these patients came from, only a small minority came from Massachusetts. We end up providing care for patients from across the country, which skews both our practice and the practices from which these patients came.

The second question is time-related events. We did look at our data as a function of time and there was no change in our complication rate or in the etiology of the tracheal pathology with time. We are still seeing intubation injuries, and, if anything, I think we are seeing more because more children are surviving their precipitating illnesses.

The third related to one of our patients’ death. This patient had a PA sling repaired in infancy, and unbeknownst to us, there was a stenosis involving the origin of that reimplanted LPA. Our preoperative evaluation with our echocardiographer and cardiologist thought that this anastomosis was patent and normal. This was a complex resection through the right chest, and we needed to deflate the right lung; and that, of course, was the only lung receiving blood flow, and that led to an intraoperative arrest. Had we known that, we would have done that operation on cardiopulmonary bypass and re-repaired the PA stenosis. I do not think that represents a faulty technique in terms of the need for cardiopulmonary bypass. Essentially, all patients can be done without cardiopulmonary bypass as long as you are not operating on either the heart or the pulmonary artery.

Last, we would respectfully disagree as to what the correct operation is for long-segment tracheal stenosis. We have recently reported our detailed results with slide tracheoplasty and I believe the longest patient we had was 83% of the airway involved. That patient and 7 others with lesser involvement had a successful outcome with slide tracheoplasty. Indeed, there are several successful reports from across the world, including Japan, Italy, the United Kingdom, and other centers in America. The advantage of slide tracheoplasty is that it is an immediate reconstruction with rigid vascularized trachea with a normal mucosa. Your operation devascularizes a portion of the trachea, and we do not understand the reason for doing that. It violates the surgical principle of repairing a damaged structure with vascularized tissue if possible. Our patients were all able to be immediately extubated; there is rare granuloma formation; and subsequent follow-up has demonstrated excellent growth of the completely vascularized tissue.