Conservative Management of Iatrogenic Membranous Tracheal Wall Injury
A Discussion of 2 Successful Pediatric Cases
Lauren C. Cunningham, MD; Kris R. Jatana, MD; Jonathan M. Grischkan, MD, MS

Importance: Management of pediatric tracheal injuries is a controversial topic not well documented in the otolaryngology literature.

Objectives: To present our case outcomes in 2 pediatric patients with tracheal injury and to review the literature on surgical vs conservative management of tracheal injuries in the pediatric age group.

Design: Case series and literature review.

Setting: Tertiary referral pediatric hospital.

Main Outcome Measures: Morbidity and mortality outcomes.

Results: The 2 tracheal injuries in the case studies were successfully managed with intubation, antibiotics, and careful monitoring without morbidity related to the tracheal injury.

Conclusions and Relevance: A high level of clinical suspicion is necessary for the diagnosis of tracheal injuries. Both conservatively and surgically managed patients require serial chest and lateral neck plain radiographs to follow resolution of pneumomediastinum and pneumothorax. Both require surveillance of the airway with operative laryngoscopy and bronchoscopy, in addition to long-term follow-up. Surgical repair of trachea rupture, although resulting in shorter intubation, may require tracheotomy. Promising results have been reported in the literature for conservative management with a relatively small risk of airway stenosis without the complications associated with intrathoracic repair. Conservative management should be considered in the management of tracheal injuries in the pediatric population.


REPORT OF CASES

CASE 1
A newborn girl with Nager syndrome had been born at 37 weeks' gestation at a weight of 2500 g. Polyhydramnios and fetal anomalies, including severe micrognathia and phocomelia, had been diagnosed in utero by means of ultrasonography. An EXIT (ex utero intrapartum treatment) procedure was performed because of concern about an inadequate airway. The patient was found to have severe ankylosis of the mandible in addition to severe micrognathia, for which an intrapartum tracheotomy was urgently required. A small posterior tracheal wall laceration was inadvertently sustained during tracheotomy placement. During transport to the neonatal intensive care unit (ICU), the patient was difficult to ventilate, and vigor-
ous cardiopulmonary resuscitation was performed for more than an hour, including placement of chest tubes for bilateral pneumothoraces, umbilical catheter placement, and chest compressions. She was then transported to a tertiary care children’s hospital in stable condition, but later that afternoon increased ventilatory support was again required, including high-frequency oscillatory support with continued hypercapnia.

The patient underwent bedside tracheoscopy by means of a pediatric rigid telescope passed through the tracheotomy stoma. This demonstrated a large pars membranosa tear in the posterior tracheal wall, extending into the mediastinum (Figure 1). We suspect that during the prolonged resuscitative effort, the membranous tracheal laceration was propagated by direct pressure from vigorous bag-mask ventilation. A cuffless tracheotomy tube (3.0 PED; Shiley) was customized to be positioned adequately beyond the site of injury and above the carina to secure the airway. Its placement was confirmed with flexible tracheoscopy.

After a thorough discussion with the family about the patient’s uncertain course and her parents’ desire to consider hospice given her multiple severe congenital anomalies, a conservative management plan was chosen. The patient was paralyzed to decrease chance of accidental decannulation. The tracheotomy tube was positioned to place minimal pressure on the posterior tracheal wall. Gastric acid suppression and antibiotic therapy were administered. Nasogastric feeding was started after contrast esophagography ruled out an esophageal perforation.

The patient initially required high-frequency oscillating ventilation for pulmonary hypoplasia. Evaluations performed at bedside in the neonatal ICU on days 9 and 20 of life demonstrated healing of the tracheal wall. As her lung function improved, she underwent more thorough intraoperative evaluation, which demonstrated complete healing of the posterior tracheal wall without granulation, outpouching, or narrowing at the site of injury on day 22 of life (Figure 2). More than 9 months later, this patient continues to do well.

**CASE 2**

A 15-month-old boy with a history of respiratory syncytial virus infection, pneumonia, poorly managed asthma, and no previous surgery was brought to an outside facility in acute respiratory distress related to severe exacerbation of his asthma; he was subsequently intubated with a 3-0 cuffed endotracheal (ET) tube (at least 1 size larger than appropriate for his age). A postintubation radiograph demonstrated the ET tube to be in a good position, and the patient was transferred to a tertiary care pediatric facility. On arrival in the pediatric ICU, he was found to have oxygen saturation levels around 50% with subcutaneous emphysema, bilateral pneumothoraces, and severe atelectasis for which bilateral chest tubes were placed. A high-frequency oscillating ventilator was used to reduce airway pressure. There was no air leak from either chest tube within hours of placement. Treatment included prophylactic antibiotics and gastric acid suppression. The patient’s condition failed to improve, and he was again transferred to a higher level of pediatric ICU management within the hospital system for possible extracorporeal circulation membrane oxygenation therapy. After his condition improved during the next 24 hours, he was placed on conventional ventilation and deemed stable enough to undergo diagnostic bedside bronchoscopy; bronchoscopy demonstrated a distal tracheal rupture just above the right main stem bronchus, resulting in a posterior tracheal wall defect.

After several discussions, the ICU, otolaryngology, and cardiothoracic teams decided to use conservative management, given the resolved air leak and nonprogressive fever curve. The patient was kept on the conventional ventilator for 15 days while paralyzed. Several surveillance bedside bronchoscopic procedures were performed; these demonstrated gradual healing of the tracheal tear. On postinjury day 6, the tracheal tear was noted to be increasing in length to approximately 4 cm, with no air leak from the trachea. Under direct visualization, the ET tube was downsized to 4-0 (cuffed); at that time the trachea appeared to have a circumferential mucosal injury of the glottis from the previous 5-0 ET tube (Figure 3).

On postinjury day 22, the patient was transported to the operating room for direct laryngoscopy and bron-
choscopy, which demonstrated granulation tissue around the edges of the wound and filling the bed (Figure 4). There was some mild tracheal collapse that maintained patency with positive pressure. The patient was slowly weaned from narcotic and benzodiazepine sedation and slowly regained the ability to cough and clear his secretions, and a swallow study showed normal oral feeding with nectar-thick consistency.

In a follow-up on postinjury day 47, repeated bronchoscopy demonstrated complete healing of the tracheal defect and a normal larynx. The patient continues to do well more than 1 year after injury.

COMMENT

Higher rates of tracheal injury in the pediatric population are attributed to differences in fetal cricoid anatomy, specifically due to weaker intercartilaginous membranes, higher cartilage elasticity, and small airway lumina.2,6 The diagnosis should be suspected in the context of subcutaneous emphysema, respiratory insufficiency, hemoptysis, and pneumothorax. The patient’s condition may appear stable for a short period, with minimal respiratory insufficiency. However, if the diagnosis is delayed, subsequent sudden and rapid decline may result in death.4 Proper selection of ET tube size must be considered in every pediatric intubation.

Reported mortality rates for tracheal rupture after intubation in pediatric patients are as high as 75%.1 Mahieu et al1 reviewed the literature in 6 cases of intubation injury in neonates. In all of these cases, at least 1 of the aforementioned signs was noted, and in 3 cases (50%) the diagnosis was not made until autopsy. Although the specific diagnostic criteria are the same in infants and adults, the rates of subcutaneous emphysema, respiratory insufficiency, hemoptysis, and/or pneumothorax are not specifically reported for many pediatric patients.1

Radiologic evaluation can be helpful. Although the initial diagnostic test should involve chest radiography, plain radiography has a false-negative rate of 5% to 10% in patients with tracheal disruption. A negative chest radiograph does not rule out the diagnosis.6-8 Computed tomography may be more sensitive and may be performed if the patient’s condition permits travel to the radiology department, but its findings are still not definitive. Direct visualization of the site with rigid or flexible endoscopy is the criterion standard for determining the location and extent of the injury for all patients1 and should be performed as soon as the patient’s condition is stable enough for evaluation.

The standard treatment of choice has been urgent surgical repair, although more recent case reports in the adult literature show a trend toward conservative management.1,9,10 There seems to be limited discussion about conservative management in pediatric patients. Conservative management allows for spontaneous healing of the trachea; it involves placing an ET tube beyond the site of injury and using mechanical ventilation with paralysis or deep sedation to prevent further injury to the trachea or dislodgement of the tube. Intubation requires direct visualization with either rigid or flexible bronchoscopy to ensure appropriate placement. Methods of ventilation should also be considered because positive pressure ventilation carries the risk of exacerbating the injury or stenting the defect open, whereas spontaneous ventilation may allow the defect to collapse into a near-anatomic position and encourage wound healing.

If the patient’s condition is otherwise stable and the injury is contained, the possibility of avoiding intubation could be considered. Broad-spectrum antibiotic administration should be considered to reduce the likelihood of mediastinal infection and its sequelae, although some surgeons defer antibiotic therapy to avoid masking the signs of a serious mediastinal infection. Esophageal evaluation, typically performed with esophag-
Table. Literature Review: Cases of Tracheal Injury, Treatment, and Outcomes

<table>
<thead>
<tr>
<th>Source</th>
<th>Age/Sex</th>
<th>Source</th>
<th>Injury</th>
<th>Treatment</th>
<th>Outcome</th>
<th>Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present study, case 1</td>
<td>Newborn/F</td>
<td>Iatrogenic/tracheostomy</td>
<td>1.5 cm</td>
<td>Intubation</td>
<td>Healed in 22 d</td>
<td>HFOV secondary to immature lung function</td>
</tr>
<tr>
<td>Present study, case 2</td>
<td>15 mo/M</td>
<td>Iatrogenic</td>
<td>4 cm</td>
<td>Intubation</td>
<td>Healed with granulation in 22 d</td>
<td>Granulation tissue; postinjury dysphagia, resolved</td>
</tr>
<tr>
<td>Doherty et al., 2005</td>
<td>Newborn/M</td>
<td>CPR/intubation</td>
<td>0.5 cm</td>
<td>Intubation</td>
<td>Healed in 8 d; asymptomatic at 1 mo Healed in 14 d</td>
<td>Maternal-fetal transfusion reaction Unilateral vocal cord paresis</td>
</tr>
<tr>
<td>Hagåsén et al., 1992</td>
<td>Newborn?</td>
<td>Traumatic delivery</td>
<td>Anterior tracheal wall injury</td>
<td>Intubation</td>
<td></td>
<td></td>
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<tr>
<td>Kacmarynski et al., 2002</td>
<td>Newborn/M</td>
<td>Traumatic delivery</td>
<td>Anterior tracheal fracture with cricoid involvement</td>
<td>Failed intubation in the operating room</td>
<td>Death</td>
<td>Temporary improvement with chest tube placement</td>
</tr>
<tr>
<td>Newborn/M</td>
<td>Traumatic delivery vs intubation</td>
<td>Large subglottic tear involving cricoid</td>
<td>Failed intubation; tracheostomy placed urgently</td>
<td>Cotton grade II subglottic stenosis at age 34 d; normal patency after laryngotracheal reconstruction</td>
<td>Required single-stage anterior cricoid split laryngotracheal reconstruction</td>
<td></td>
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<tr>
<td>Newborn/F</td>
<td>Traumatic delivery</td>
<td>Circumferential</td>
<td>Intraoperative intubation</td>
<td>Death</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Newborn/M</td>
<td>Traumatic delivery</td>
<td>Anterior tear of cricothyroid membrane</td>
<td>Intubation</td>
<td>120° Exacerbation of tear; placement of neck drain; healing well on day 13 with granulation; no stenosis at 3 mo</td>
<td>Hypotension, anuria, hyperkalemia, coagulopathy None</td>
<td></td>
</tr>
<tr>
<td>McLeod and Sumner, 1986</td>
<td>Newborn/M</td>
<td>Intubation</td>
<td>Injury at TEF site</td>
<td>Right thoracotomy and repair</td>
<td>Mortality</td>
<td>Brain death and withdrawal of care at 8 d</td>
</tr>
<tr>
<td>Mahieu et al., 2004</td>
<td>Newborn/M</td>
<td>Delivery/intubation</td>
<td>1.5 cm</td>
<td>Near carina</td>
<td>Surgical repair</td>
<td>Recovery at 6 mo; subclinical tracheal stenosis at 2 y</td>
</tr>
<tr>
<td>Newborn/M</td>
<td>Delivery</td>
<td>50% Circumferential rupture of anterior subglottis</td>
<td>Surgical repair</td>
<td>Exhusted on postoperative day 5; no airway stenosis at 2 mo</td>
<td>Large for gestational age</td>
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<tr>
<td>Newborn/M</td>
<td>Intubation</td>
<td>33% Circumferential rupture of anterior subglottis</td>
<td>Surgical repair</td>
<td>Exhusted on postoperative day 5</td>
<td>Large for gestational age; thoracic-abdominal lymphangioma; death from pulmonary emboli</td>
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<tr>
<td>Newborn/M</td>
<td>Delivery</td>
<td>50% Circumferential rupture of anterior subglottis</td>
<td>Surgical repair</td>
<td>Exhusted on postoperative day 5; no airway stenosis at 2 mo</td>
<td>Large for gestational age; torticollis and brachial plexus injury</td>
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<tr>
<td>Newborn/M</td>
<td>Delivery</td>
<td>50% Circumferential rupture of anterior subglottis</td>
<td>Intubation</td>
<td>Exhusted at 12 d; subclinical tracheal stenosis at 6 mo bronchoscopy; no clinical symptoms at 1 y</td>
<td>Large for gestational age; phrenic nerve palsy; brachial plexus injury</td>
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<tr>
<td>Newborn/M</td>
<td>Delivery</td>
<td>Anterior subglottic rupture</td>
<td>Surgical repair</td>
<td>Exhusted on postoperative day 5; ventral glottic stenosis at 6 mo, doing well at 1 y</td>
<td>Large for gestational age; brachial plexus injury</td>
<td></td>
</tr>
<tr>
<td>Mendoza et al., 2002</td>
<td>8 wk/F</td>
<td>Intubation</td>
<td>Unknown</td>
<td>Intubation</td>
<td>Healed; no respiratory symptoms at 5 y</td>
<td>Required bilateral chest tubes</td>
</tr>
<tr>
<td>Roh and Lee, 2006</td>
<td>7 y/M</td>
<td>Cough/ Haemophilus influenzae</td>
<td>1-cm Rupture of the posterior lateral wall</td>
<td>Oxygen via nasal cannula</td>
<td>CT-confirmed healing with discharge at 7 d</td>
<td></td>
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</tbody>
</table>

Abbreviations: CPR, cardiopulmonary resuscitation; CT, computed tomography; HFOV, high-frequency oscillating ventilation; TEF, tracheo-esophageal fistula.

rphy, should be considered before feeding to rule out esophageal injury. This scenario allows the patient to heal without the added morbidity of intrathoracic surgery. In addition, conservative management allows for healing without the risks of tracheoplasty or bronchoplasty fistulae requiring increasing ventilator support and long-term chest tube placement.

In contrast, a review of 13 surgically treated adult patients who sustained large tracheal defects as a result of traumatic injury reported a survival rate of 38%. Although surgically treated patients probably represent a group with larger tracheal defects, they have been deemed stable enough for operative repair. This makes it difficult to attribute a poor mortality rate to a sicker patient population. Surgery may eliminate the need for prolonged intubation, which does seem to decrease the rate of stenosis. However, many patients undergoing surgical repair require tracheotomy, which has an intrinsic risk of stenosis. In addition, these patients are not always extubated in the immediate postoperative time frame.
Although surgical repair closes the defect most quickly, which theoretically decreases the risk of mediastinitis, this has not yet been proved true.12

Regardless of management strategy, the complications of a tracheal tear include tension pneumothorax, airway obstruction, stenosis, recurrent nerve injury, granuloma, fistula, dysphonia, atelectasis, pneumonia, and pulmonary or neck abscesses. With multiple options for treatment, we sought to determine which approach minimized risks and complications while attending to the cost-benefit ratio when results were equivocal.

We reviewed 5 publications specifically from the adult otolaryngology literature. These publications discussed iatrogenic injury, most commonly attributed to the intubation, and intrapartum injury resulting in tracheal tear. The publications discussed a total of 28 adult and pediatric patients,1,2,4,5,7 15 managed with surgical repair and 13 managed conservatively. One death was due to the inability to secure the airway in the operating room. Another death occurred in a patient who was managed conservatively and died of causes unrelated to the airway. A meta-analysis of postintubation tracheal rupture in the adult population found that surgical repair was performed in 61%, with conservative management in 39%; there was a 2-fold increase in mortality when surgical repair was performed after a delayed diagnosis of tracheal rupture.3

In 2004, Mahieu et al4 warned against conservative management. Because of excessive risk, they expressed concern about prolonged intubation and the risks of stenosis, infection, and extubation resulting in an unstable airway, which may not be easily rescued. Although these concerns are appropriate, each of the 13 conservatively managed patients whose cases we reviewed was paralyzed or deeply sedated to prevent extubation and further tracheal injury. There are no mentions of accidental extubation or prolonged intubation, which implies that the airway has been appropriately monitored to prevent such complications. We did not encounter these problems in either of our patients.

In 2002, Goudy et al7 retrospectively reviewed findings in 19 adult patients with traumatic airway injury. Fifty-five percent of the patients underwent surgical repair. Complications were found only in the surgical group and included aspiration injury in 10%, bilateral hypoglossal nerve injury in 5%, and vocal cord paralysis in 5%. No complications were noted in the conservatively managed group. In addition, 83% of the surgically managed group required tracheotomy placement, which adds to the risk of stenosis, scarring, dysphagia, pneumothorax, and damage to the surrounding structure during the procedure. This study highlights the increased risk associated with a more complex repair.

We then looked specifically at the pediatric literature (Table). In reviewing 7 articles,1,3,5,10-13 we looked at a total of 15 patients; 5 were managed surgically, 9 were managed conservatively, and 1 could not be intubated in the operating room and subsequently died. Of the 5 surviving surgical patients, 1 had persistent hoarseness and 3 had evidence of tracheal stenosis.4 Not all of these patients underwent follow-up endoscopy. Two surgical patients did not survive: 1 died on postoperative day 2 of a massive embolism,2 and 1 had care withdrawn because of brain death secondary to hypoxia.15 It is assumed that the more severe injuries necessitated surgical repair and were not the cause of death in these patients. If we eliminate the deaths, the rate of complications was relatively low compared with that in the conservatively managed group. This information is incomplete, however, because most of these patients did not have long-term airway surveillance.

Of the 9 conservatively managed patients, 2 were noted to have an asymptomatic subglottic stenosis at the injury site at follow-up,4,5,7 1 of whom later underwent successful repair with laryngotracheal reconstruction. Another patient had a reported vocal cord paresis that was improving at follow-up.14

Conservative therapy is typically advocated for patients with small ruptures (<2 cm), minimal nonprogressive symptoms with spontaneous breathing, or ventilatory needs requiring prolonged intubation.7 Critically ill patients, whose risk of mortality with a second procedure is expected to be as high as 71%, should also be conservatively managed.31

With a massive air leak making it difficult to maintain ventilation, surgical repair is mandatory. However, when the operative risk is high, conservative management may be chosen.

In conclusion, a high level of clinical suspicion is necessary for the diagnosis of tracheal injuries. Both conservatively and surgically managed patients require serial chest and lateral neck plain radiographs to monitor the resolution of pneumomediastinum and pneumothorax.5 Both groups require surveillance of the airway with operative laryngoscopy and bronchoscopy, in addition to long-term follow-up. Promising results have been reported for conservative management in the literature, with a relatively small risk of airway stenosis and without the complications associated with intrathoracic repair. Conservative management should therefore be considered in the treatment algorithm for tracheal injuries in the pediatric population.

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REFERENCES


