Abstract:
Pediatric laryngotracheal injuries as a result of blunt neck trauma are exceedingly rare, but they have the potential for fatal consequences if not identified and managed appropriately. Two cases on the spectrum of laryngotracheal trauma are presented followed by an overview of pediatric laryngotracheal trauma with a focus on acute airway management. Special considerations must be taken into account when evaluating and treating children with laryngotracheal injuries. Standard orotracheal intubation by direct laryngoscopy is risky, and awake tracheostomy is often not feasible. Flexible or rigid bronchoscopic airway management is the preferred method of tracheal intubation prior to tracheostomy. The airway surgeon must be prepared to perform an efficient, emergency tracheostomy. In stable patients, flexible fiberoptic laryngoscopy is an important diagnostic tool in the evaluation of laryngotracheal injuries. After ensuring a secure airway, further goals of management are aimed at preserving normal laryngeal function: airway patency, voice, and swallowing.

Keywords:
pediatric blunt neck trauma; laryngeal trauma; tracheal trauma; tracheostomy

Emergency Airway Management for Pediatric Blunt Neck Trauma

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Laryngotracheal injuries as a result of blunt neck trauma are exceedingly rare in children, but they have the potential for fatal consequences if not identified and managed appropriately. Two cases within the spectrum of laryngotracheal injuries are presented followed by an overview of pediatric laryngotracheal trauma with a focus on acute airway management.

CASE 1

A 17-year-old boy presented to the emergency department with chest and neck pain, dysphonia, and mild dyspnea after sustaining a fall from a 20-ft jump while snowboarding. The patient cracked his helmet during the fall, and he had a loss of consciousness. Upon arrival to the emergency department, advanced trauma life support (ATLS) protocol was followed, and he was in no acute distress, breathing comfortably on room air without any stridor; his voice, however, was hoarse. He had bilateral neck crepitus, and his laryngeal landmarks were normal to palpation without any step-offs. A bedside flexible fiberoptic laryngoscopy (FFL) was performed and identified mild supraglottic edema, mobile vocal cords, no visible lacerations or hematomas, and no exposed...
cartilage. A computed tomography (CT) scan was then obtained. The CT showed cervical and mediastinal subcutaneous air but no laryngeal fractures or other lesions (Figure 1).

The decision was made to closely observe the patient in the intensive care unit with serial examinations and plain film radiographs to assess for progression or resolution of his subcutaneous emphysema. Prior to initiating a diet, an esophagram was obtained, which showed a normal result. The patient continued to improve symptomatically, his cervical and mediastinal emphysema improved on examination and on chest x-ray, so he was discharged home. He was doing well at a 4-week follow-up appointment with a normal voice and no complaints.

CASE 2

A 6-year-old boy was riding a bicycle and fell, landing with his anterior neck onto the handlebars with significant force. He initially developed some difficulty breathing, and his neck and chest skin started to swell. His family took him to the nearest emergency department where ATLS protocol was followed, and he was sent by helicopter to a tertiary care children’s hospital with a cervical collar in place. He was evaluated immediately by the trauma service and was deemed to be clinically stable. Flexible fiberoptic laryngoscopy was performed by the pediatric otolaryngology service showing no laryngeal injury and normal vocal cord function. He had a normal voice, and crepitus of the neck and chest was present on physical examination. A CT scan of the neck and chest was obtained showing a traumatic tracheoesophageal fistula (Figure 2).

A rigid bronchoscopy was performed showing a 4-cm linear tear in the posterior membranous trachea. Rigid esophagoscopy confirmed that it extended through into the anterior wall of the esophagus. The patient was intubated in a controlled manner, and a tracheostomy was performed. The vertical tracheostomy incision was extended to allow for complete visualization of the traumatic posterior tracheoesophageal injury. A multilayered closure of both the esophageal and tracheal sides was performed with absorbable suture. The tracheostomy tube was placed at the inferior most portion of the anterior tracheal incision, and the superior portion of tracheal rings was closed in the midline with absorbable suture. Postoperative esophagram showed no evidence of esophageal leak, and oral feeding was begun on postoperative day (POD) 7. He was discharged home with a downsized tracheostomy tube on POD 9. Serial bronchoscopy was performed weekly to debride intraluminal granulation tissue, and decannulation was performed on

![Figure 1. Axial CT scan on the cervical spine without contrast at the level of the thyroid cartilage showing cervical emphysema in the deep soft tissues of the neck.](image1)

![Figure 2. Axial CT scan of neck with contrast, which was suspicious for a tear through the posterior wall of the trachea into the anterior wall of esophagus. This was confirmed intraoperatively by endoscopy, noted to be 4 cm in length. Diffuse cervical emphysema was also present.](image2)
POD 21 (Figure 3). The tracheal stoma closed spontaneously, and he is now 10 years old and doing well.

**Epidemiology**

Pediatric laryngotracheal trauma is rare but potentially fatal if not recognized and managed appropriately in the acute setting. In the 1980s, approximately 1:5000 emergency visits and 1:137 000 inpatient admissions involved patients with blunt or penetrating laryngeal trauma. In the 1990s, 1:30 000 emergency visits were for the evaluation and treatment of blunt or penetrating laryngeal trauma.\(^1\) The mortality rate for laryngeal trauma has been reported between 2 and 15%.\(^2\)

In a study published in 2011, the National Trauma Data Bank was used to identify laryngeal trauma encounters from more than 900 trauma centers across the United States.\(^3\) Of the 1.9 million patients identified from 2002 to 2006, 633 patients were diagnosed as having laryngeal trauma, and of those, 69 were pediatric patients. The median age for these pediatric patients was 12.8 years with a range of 2 to 17 years. The mortality rate in this population was 8.7%. Most of the patients had blunt vs penetrating laryngeal trauma (82.8% vs 17.2%). More than 75% of these patients also had multisystem trauma. Although the database does not identify all cases of laryngeal trauma, it is the largest database available and provides us with important information regarding pediatric patients with laryngeal injuries: (1) blunt trauma rather than penetrating trauma is more likely to be the etiologic mechanism of laryngeal trauma; (2) many patients with laryngeal trauma may present in the setting of multisystem trauma, which may lead to a delayed diagnosis of laryngeal injuries due to distracting injuries; and (3) although these are rare injuries, they are potentially deadly.

Although motor vehicle accidents are a common cause of laryngeal injuries in adults, typically when the anterior neck strikes the steering wheel, this is a much less common mechanism in the pediatric population. However, the incidence of motor vehicle accidents as a cause of pediatric laryngeal trauma is increasing.\(^4\) Other more common causes of pediatric laryngeal trauma include bicycle accidents, sports injuries,\(^5\) falls in which the anterior neck strikes an object,\(^6\) clothesline injuries,\(^2\) strangulation,\(^7\) and abuse.

There are major differences between the pediatric and adult larynx. These differences help explain the exceedingly low incidence of laryngeal trauma in children as well as the different types of injuries encountered. First of all, children have shorter necks. The larynx of a child is located higher in the neck, approximately at the level of C4, which allows for better protection by the mandible. Furthermore, the laryngeal cartilages in children are soft and pliable compared with the adult larynx, which makes them more resistant to fracturing when anterior blunt trauma causes compression of the cartilage posteriorly against the cervical vertebral bodies. The thyroid cartilage does not begin ossifying until approximately 20 years of age. However, the submucosal tissues of the pediatric larynx are loosely attached to the underlying perichondrium, which increases the risk for significant edema and even avulsion injuries in children.\(^8\)

Lastly, the caliber of a child's airway is much smaller than that of an adult, which makes them more susceptible to airway compromise secondary to edema because airflow resistance will increase by a power of 4 with any decrease in the radius of the airway lumen.

**Initial Assessment**

The tenets of ATLS protocol should always be followed when evaluating and treating a patient with possible laryngeal trauma. Under the ATLS guidelines, ensuring a safe and secure airway is the first priority. The acronym ABCDE (airway, breathing, circulation, disability, exposure/environment) is helpful in prioritizing the identification and treatment of life-threatening injuries. After assessing and possibly intervening to ensure adequate airway maintenance with cervical spine protection, the next steps involve assessing the patient's breathing and ventilation, circulation with appropriate hemorrhage control, disability (neurologic status) using...
the Glasgow Coma Scale, and then exposing the patient completely while maintaining control of the environment (ie, preventing hypothermia). In the next section, we will discuss in further detail the steps that may be taken to manage the airway of patients with suspected laryngotracheal injury.

After stabilizing the patient and identifying and treating any imminent life-threatening injuries, a history should be obtained from the patient, emergency medical services, and/or any possible witnesses present in the emergency department. The mechanism of injury must be taken into account to determine if there is a potential for blunt neck trauma. Any history suggestive of blunt neck trauma should be approached with a high index of suspicion for an airway injury regardless of any objective clinical findings, because a missed or delayed diagnosis may result in a serious morbidity or mortality.

**FURTHER AIRWAY AND LARYNGEAL ASSESSMENT**

Various signs and symptoms of laryngeal injury may be present, and such findings should be evaluated for a laryngeal injury. However, even patients with severe injuries may be minimally symptomatic and may or may not have any objective physical examination findings. The signs and symptoms of laryngeal injuries include hoarseness/dysphonia, aphonia, odynophagia, dysphagia, cervical tenderness, cervical crepitus, hemoptysis, stridor, and respiratory distress. In several case series, it has been found that patient signs and symptoms poorly correlate with the degree and severity of injury, with the exception of respiratory distress and impending airway compromise, which indicates a severe laryngeal injury. When examining a patient with a possible laryngeal injury, it is important to remember to palpate the laryngeal cartilages gently so as to avoid destabilizing the laryngeal framework further if a fracture is present, which may acutely precipitate compromise of the airway.

An important distinction to make when managing a patient with possible laryngeal trauma is whether they are stable or unstable, primarily with regard to their airway status. This dichotomous status of acuity (stable vs unstable) guides further management, which will be discussed in the subsequent section and is the first major branching point of the management algorithm of these patients (Figure 4). The question that should be addressed when deciding whether a patient is stable vs unstable is whether the patient requires an emergent airway intervention. During the 2004 Fallujah Offensive, head and neck surgeons would triage patients by going from bed to bed asking the patients how they are doing. If the patient was able to respond intelligibly and appropriately, the surgeon was
assured that the airway was patent, there was enough respiratory effort to generate voice, and there was adequate cerebral perfusion with at least a Glasgow Coma Scale score of 8. All stable patients with laryngeal trauma or suspected laryngeal trauma should be evaluated by an otolaryngologist with FFL. This assessment should be made prior to sending the patient to a CT scanner, which was illustrated in both cases presented above. If this is not possible and the patient needs imaging to identify another possibly life-threatening injury (ie, intracranial hemorrhage), a surgeon capable of performing an emergent surgical airway should remain with the patient in the event that the patient's injury progresses to airway compromise. The FFL should be used to identify and assess the patency of the airway, presence of edema or hematoma, mucosal laceration, exposed cartilage, vocal fold immobility, displaced fracture, Group III with 2 fracture lines or massive trauma to laryngeal mucosa, and hypopharyngeal perforation. Lacerations should be further characterized as minor or major, single or multiple, and with or without involvement of the free edge of the vocal fold. Vocal fold mobility may be impaired because of cricoarytenoid joint dislocation or injury, recurrent laryngeal nerve injury, or local vocal fold injury (edema or hematoma). Based on the FFL, at least a preliminary grade (I-V) may be assigned to the laryngeal injury based on the endolaryngeal findings (Table 1).13

**AIRWAY MANAGEMENT**

In unstable patients in acute respiratory distress, some basic airway management techniques may be used while preparing to place a definitive airway. These initial steps include providing supplemental oxygen, performing a jaw thrust or chin lift to open up the upper airway, and gentle mask ventilation. If possible, it is important to avoid aggressive positive pressure with mask ventilation to prevent the development or worsening of cervical emphysema, which may compromise adequate ventilation.

Intubation is inherently risky in patients with laryngeal trauma because of the potential for (1) losing the airway, (2) completing a partial cricotracheal or laryngotracheal disruption with the endotracheal tube (ETT), or (3) placing the ETT in a false lumen when significant endolaryngeal lacerations exist.1 In patients with acute airway compromise, the safest environment to manage the airway is in the operating room (OR) where a full armament of bronchoscopes, both rigid and flexible, as well as the instruments necessary for a tracheostomy, is readily available. However, on the rare occasion when the airway must be emergently managed in the emergency department, intubation by direct laryngoscopy may be attempted by the most experienced physician present with a tracheostomy set up at the bedside. Bronchoscopic guided intubation is the preferred method of orotracheal intubation14 because of the visualization of the carina prior to advancing the ETT over the scope using the Seldinger technique, which reduces the risk of false passage placement of the tube. A smaller size ETT than would normally be used should be selected. Some authors recommend against the use of a laryngeal mask airway in patients with laryngeal trauma because of the potential for completing the airway obstruction and ventilation of a mucosal defect forcing air into the soft tissue of the neck. A surgeon must always be ready to proceed with an emergency tracheostomy whenever an intubation is being attempted.

It is important to note that many patients with laryngeal trauma may be intubated in the field prior to arriving to the emergency department13; correct placement must be confirmed upon arrival. Although it may be reassuring to the receiving trauma and emergency teams that these patients have a secure airway, it is important to not overlook and work up the patient for a possible laryngeal injury whenever the mechanism is suggestive or if specific objective signs of laryngeal trauma exist. Failure to do so may result in a delayed diagnosis, which often results in untoward complications, such as respiratory distress upon extubation and/or laryngotracheal stenosis in the long term.

A tracheostomy is the criterion standard for securing the airway when a severe laryngotracheal injury exists; however, this requires an experienced surgeon, particularly when the patient is very
young. Cricothyroidotomy is less technically challenging and may be converted to a formal tracheostomy at a later time in the OR; however, one must be absolutely certain of the continuity of the cricoid cartilage with the cervical trachea for a cricothyroidotomy to be safe in the setting of laryngotracheal trauma. If continuity of the cricoid cartilage with tracheal rings cannot be palpated on physical examination, a cricothyroidotomy should not be performed. There is a very limited role for percutaneous jet insufflation via a needle cricothyroidotomy. It may be performed with a large caliber needle only as a temporizing measure as a means to provide oxygenation, but adequate ventilation cannot be performed via a needle cricothyroidotomy.

In patients that are stable but are found to have significant laryngeal injuries on FFL or subsequent CT scan requiring intervention or a secure airway, a tracheostomy is often performed. In adults, this may be achieved under local anesthesia with the patient awake in the OR. However, in a frightened, injured child, this is often not feasible. In these instances, anesthesia may be achieved via an inhalational anesthetic with the patient breathing spontaneously. Once the patient is adequately anesthetized but still breathing spontaneously, a rigid bronchoscope is used to inspect the larynx, subglottis, and trachea. Once the trachea is intubated with the bronchoscope, the child may be ventilated through the bronchoscope. At this point, the otolaryngologist may decide to perform a tracheostomy, as occurred in Case 2. However, this is not always the intervention, and the decision often depends on the severity of the injury, surgical plan for repair, and experience of the surgeon.

**ROLE OF IMAGING**

The imaging modality of choice for laryngeal injuries remains CT scan of the neck and larynx. However, this should not be relied on for the diagnosis of laryngotracheal injuries. Furthermore, as previously emphasized, CT scan should never be performed in an unstable patient without a secure airway. In stable patients, an FFL should be performed first if possible. Often based on the FFL findings, the severity of laryngeal injury may necessitate operative intervention with open neck exploration. If this is the case, CT may not be indicated because it is unlikely to change management. However, if obtaining a CT scan has the potential for changing or altering management, it should be considered. An occult, nondisplaced laryngeal fracture is one type of injury that may require open exploration for stabilization of a fracture that may not have been identified without a CT scan. Although there exists some controversy over whether single, nondisplaced fractures need to be repaired, Shafer advocates fixation of all laryngeal fractures.

**INDICATIONS FOR SURGICAL MANAGEMENT OF LARYNGEAL TRAUMA**

For grade I and select grade II laryngeal injuries, conservative management may be used. Patients are monitored closely in the hospital with elevation of the head of bed, voice rest, humidified air, acid suppression medication, antibiotics, and corticosteroids. A tracheostomy tray is kept at the bedside, and serial FFL examinations are performed for 24 to 48 hours as needed. This allows for monitoring for worsening airway edema. Significant progression of symptoms toward airway compromise may warrant operative endoscopy and possible tracheostomy. Oftentimes, airway edema will worsen prior to resolution, which is particularly significant for children with their small-caliber airways. When subcutaneous emphysema is present, serial examinations and x-rays may be obtained to assess for progression or resolution of the soft tissue air, which was depicted in Case 1. Refer to the pediatric blunt neck trauma algorithm (Figure 4) for an overview of the evaluation and management of these patients.

Severe laryngeal injuries (some grade II and grades III-V) require surgical management, and any laryngeal repair always comes secondary to ensuring the patient has a secure airway. As mentioned previously, tracheostomy is the preferred method for securing the airway in laryngeal trauma because of the risk and further damage that an ETT may cause to an already injured endolarynx. A thorough operative endoscopic evaluation of the airway and upper aerodigestive tract should be performed in the OR. Esophageal injuries should not be overlooked and are best diagnosed by rigid esophagoscopy in this setting. A contrast esophagram should be obtained prior to initiation of oral intake as occurred in both cases presented.

The indications for open surgical repair of laryngeal injuries include laryngeal cartilage fractures, exposed cartilage, significant mucosal lacerations, lacerations involving the free edge of the vocal folds or anterior commissure, vocal fold avulsion, ericoarytenoid dislocation, vocal fold paralysis, and ericoetracheal or laryngotracheal disruption. Endoscopic repairs of some injuries have been reported in the literature, but open repair is still considered the standard approach for severe cases. The goals of
surgery are preservation of normal anatomy and function of the larynx, namely, phonation, airway patency, and lower respiratory tract protection during swallowing. The endolarynx may be exposed via an existing thyroid fracture. If there is no fracture, a midline or paramedian thyrotomy or laryngofissure is created and the anterior commissure of the larynx is carefully divided to access the mucosal surfaces of the endolarynx. Lacerations are repaired with absorbable suture. Cartilage is reduced to its normal position. There are a number of different methods in which fractures are repaired, including use of nonabsorbable sutures, wires, or miniplates. Although miniplates provide excellent rigid fixation, the nonossified thyroid cartilage of the pediatric larynx makes the use of miniplates in children more technically challenging.

Stents are also rarely required but may be necessary when the nature of the laryngeal mucosal injury places the patient at risk for the development of synechiae and subsequent stenosis. Indications include anterior commissure injuries or significant lacerations of opposing mucosal surfaces. Stents are sewn in place to prevent migration. The superior end is often sewn closed to prevent gross aspiration, and the superior-most portion of the stent is ideally placed at the level of the false vocal folds. Stents are typically kept in place for 7 to 14 days postoperatively.

TRACHEAL INJURY

A wide variety of tracheal injuries may result from blunt trauma to the neck. These may range from minor tracheal lacerations to complete transection of the trachea. The treating physicians should have a high index of suspicion for such injuries, especially when cervical emphysema and respiratory distress are present. Intubation without bronchoscopic visualization is exceedingly risky if a tracheal injury exists due to the potential to extend the tracheal injury or even complete a tracheal transection. For severe injuries, the airway is best managed by an airway surgeon, and a tracheostomy is often required. Minor injuries may be managed without surgical intervention, although the patient may require intubation to bypass the area of injury. When the cervical emphysema improves, the patient may be extubated and closely monitored for any worsening symptoms. Larger or more severe injuries often require open repair with or without a tracheostomy while the area of injury heals.

For cricotracheal or laryngotracheal disruption, the distal tracheal segment may be brought up to the skin to create a tracheal stoma at the time of surgical airway management in order to prevent airway loss until the surgical team is prepared to undertake a cricotracheal or laryngotracheal anastomosis. Laryngectomy or laryngotracheal separation with a permanent end tracheostoma is reserved as an option for patients with severe laryngeal injuries, such as complete laryngeal crush injury.

Patients that undergo laryngotracheal repairs almost always have a tracheostomy, which is kept in place until the patient may be safely decannulated. With the addition of tracheostomy care, postoperative management is otherwise very similar to conservative management with respect to head of bed elevation, voice rest, humidified air, gastric acid suppression medications, corticosteroids, and antibiotics. A drain in the neck may be placed at the time of surgery and removed when the drainage is sufficiently low and the risk of subcutaneous air reaccumulation is low. Often swallowing function is assessed by a video fluoroscopic swallow study prior to initiation of an oral diet, in addition to an esophagram. The patient’s larynx is examined with serial FFLs as an outpatient, and an airway endoscopy is typically performed prior to decannulation.

SUMMARY

Blunt trauma to laryngotracheal structures is rare but potentially fatal if injuries are overlooked or mishandled. Emergency medicine and trauma care responders should have a low threshold for suspecting laryngotracheal trauma guided by knowledge of the mechanism of blunt cervical injury and patient signs and symptoms; the priority is ensuring a safe airway. If the patient is stable, a flexible laryngoscopy will guide further management. If the patient is unstable and needs an emergency airway, a tracheostomy is the ideal method of securing the airway. However, securing the airway in the OR by direct laryngoscopy and bronchoscopy, and intubation under direct visualization in a controlled setting is preferred. An experienced airway surgeon, capable of performing an efficient, emergent tracheostomy should be directly involved. Standard intubation by direct laryngoscopy carries significant risks of failure and/or worsening the injury even if performed by an experienced physician. Once the airway is managed safely, further management goals revolve around preserving the normal function of the larynx, namely, airway patency, voice, and swallowing.

REFERENCES


