Management of Laryngeal Trauma

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KEYWORDS

• Laryngeal trauma • Laryngotracheal injury • Laryngofissure

KEY POINTS

- The key step in treatment of any laryngeal injury is the establishment of a secure airway.
- Early intervention (within 24–48 hours) is an important factor for improved patient outcomes (functional speech, swallowing, and airway patency).
- An awake tracheostomy is the airway of choice with grade II or higher laryngeal injuries.

INTRODUCTION

The larynx is a complex anatomic structure and a properly functioning larynx is essential for breathing, voice, and swallowing. Injuries to the larynx and trachea can result in significant and potentially fatal consequences. Laryngeal trauma is often associated with other injuries, including intracranial injuries (17%), penetrating neck injuries (18%), cervical spine fractures (13%), and facial fractures (9%).[1] Laryngeal injuries are rare, occurring in only 1 of 5000 to 137,000 emergency room visits[1–3] and among only 1 in 445 patients with severe injuries.[4] Because of this, even surgeons with a great deal of experience in managing maxillofacial trauma have limited exposure to management of laryngeal and tracheal injury. This article discusses the evaluation, diagnosis, and management of patients with laryngeal and tracheal injury.

CLASSIFICATION OF LARYNGEAL INJURIES

Several classification systems have been described to assist in developing an algorithmic approach to managing these difficult and rare injuries. These classification systems have been based on mode of injury, types of tissues involved in the injury, anatomic locations of injury, and severity of the injury. Modes of injury have been divided into blunt and penetrating injuries. Whereas blunt injuries have been described as being associated with greater length of hospitalization,[5] our experience has been that penetrating airway injuries, often associated with ballistic wounds, are much more likely to be associated with greater endolaryngeal disruption. The types of tissues involved have been divided into hard and soft tissue injuries. Locations of injuries have been classified as injuries that affect the supraglottic larynx, the glottis, and subglottic larynx.

Lynch[5] was the first to classify traumatic injuries based on location. In 1969, Nahum[6] described laryngeal injuries based on injury location and likelihood of recovery with and without intervention. In 1980, Schaefer and colleagues developed what has become the most popular classification system to assess the severity of such injuries.[7] This classification describes laryngeal injuries on a scale of I-IV. Schaefer's classification was later modified by Fuhrman and colleagues[8] to include laryngotracheal separation (**Table 1**) and again by Verschueren and colleagues[4] in 2006 to include the use of computed tomography (CT) imaging in staging (**Table 2**). In this article, the discussion of the initial evaluation and management of a patient with laryngeal trauma is within the framework of the Legacy Emanuel Classification, as outlined by the algorithm in **Fig. 1**. However, the principles are generalizable and can be applied to whichever system the reader finds most helpful in their practice.

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Table 1
Fuhrman-Schaefer classification of laryngeal injuries

Stage	Injury
I	Minor laryngeal hematoma, edema, laceration; no detectable fracture
II	Edema, hematoma, mucosal disruption with no exposed cartilage, nondisplaced fractures
III	Significant edema, noted mucosal disruption, exposed cartilage with or without cord immobility, displaced fractures
IV	Significant edema, noted mucosal disruption, exposed cartilage with or without cord immobility, displaced fractures with 2 or more fracture lines, skeletal instability/anterior commissure trauma
V	Complete laryngotracheal separation

INITIAL EVALUATION AND INITIAL MANAGEMENT

The initial evaluation of a patient suspected of having laryngeal or tracheal injury, as with any trauma, begins with the primary survey as outlined in Advanced Trauma Life Support algorithms. Because the larynx and trachea are critical components of the airway, prompt identification and management of these injuries are prioritized. This

Table 2
Legacy Emanuel Medical Center laryngeal injury classification

Stage	Diagnostic Findings	Management
I	Minor airway symptoms ± Voice changes No fractures Small lacerations	Observation Humidified air Head of bed elevation
II	Airway compromise Nondisplaced fractures No cartilage exposure Voice changes ± Subcutaneous emphysema	Immediate awake tracheostomy if airway not already secured in the field Humidified air Head of bed elevation ± ORIF
III	Airway compromise Edema Mucosal lacerations Palpable laryngeal fractures Exposed cartilage Subcutaneous emphysemas Voice changes	Immediate awake tracheostomy if airway not already secured in the field Direct laryngoscopy Exploration and ORIF
IV	Airway compromise Mucosal lacerations Exposed cartilage Palpable displaced laryngeal fractures with skeletal instability Subcutaneous emphysemas Voice changes	Immediate awake tracheostomy if airway not already secured in the field Direct laryngoscopy Exploration/ORIF Consider stenting

Abbreviation: ORIF, open reduction internal fixation.

Adapted from Verschueren DS, Bell RB, Bagheri SC, Dierks EJ, Potter BE. Management of laryngo-tracheal injuries associated with craniomaxillofacial trauma. J Oral Maxillofac Surg. 2006 Feb;64(2):203-14; with permission.

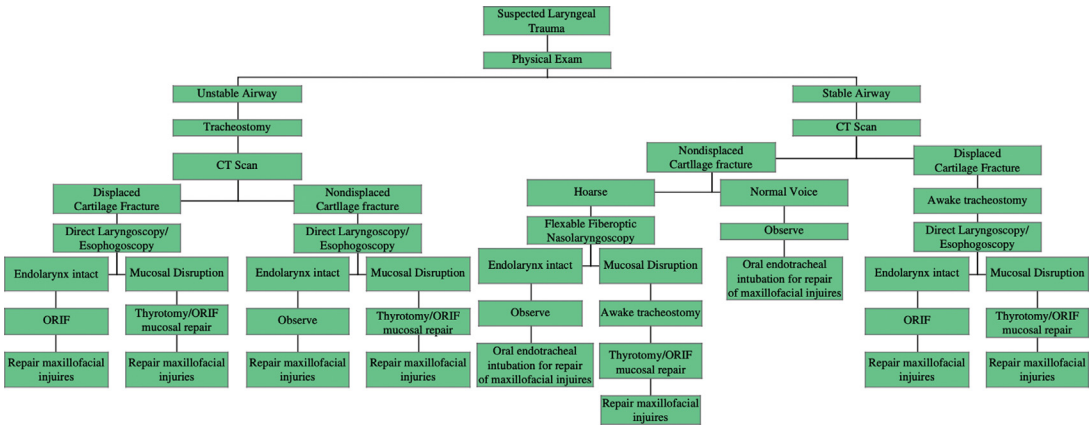

Fig. 1. Protocol for management of laryngotracheal injuries at Legacy Emanuel Hospital and Health Center in Portland, Oregon. ORIF, open reduction internal fixation. (*From* Verschueren DS, Bell RB, Bagheri SC, Dierks EJ, Potter BE. Management of laryngo-tracheal injuries associated with craniomaxillofacial trauma. J Oral Maxillofac Surg. 2006 Feb;64(2):203-14; with permission.)

begins with a quick survey of the injuries. Patients with either blunt or penetrating injury to the neck must be ruled out as having airway injury. The mechanism of the injury should also raise one's suspicion. In a review of laryngeal injuries from 1992 to 2004, high speed motor vehicle accidents were the most common mechanism (49%), followed by sports-related injuries (29%).[4] Certain mechanisms of injury, such as hanging, gunshot wounds, or work-related high-energy injuries to the neck, should obviously generate an elevated level of suspicion.

Stable Versus Unstable Airway

The first essential question is to establish whether the airway is secured and whether the patient is stable. If the patient is stable and protecting their airway, there is time for a more deliberate examination. This is important because occult tracheal-laryngeal disturbance can occur with minimal external signs of trauma.

The initial airway physical examination starts with visual inspection for swelling, soft tissue injury overlying the airway, loss of anatomic landmarks in the neck, and signs of troubled breathing. A cursory examination of the patient's voice is performed, noting the presence or absence of stridor and/or dysphonia. Next, use gentle palpation to assess for subcutaneous emphysema and palpable disruption of the hyoid bone, thyroid cartilage, cricoid, and trachea. The most common findings on physical examination include subcutaneous air, hoarseness, tenderness of the anterior neck to palpation, and stridor.[9]

A fiberoptic examination may also be performed if timing allows and other injuries do not take precedence. The fiberoptic examination may help to verify that the patient's airway is stable enough for transfer to the scanner. An awake fiberoptic examination also has the benefit of allowing visualization of the larynx in function. This examination is meant to be performed quickly and efficiently so as to not impede overall trauma management. The evaluating surgeon must keep in mind that traumatized airways that appear stable tend to deteriorate over time because of the onset of edema, expansion of hematomas, and other contributory factors.

The next step is a CT scan of the head and neck, which is done in addition to CT scans of chest, abdomen, and pelvis that are routinely performed as part of the trauma survey (**Fig. 2**). In stable patients with penetrating neck injury, a CT angiogram is also included to evaluate for vascular injury. CT imaging allows for rapid and accurate identification of hard tissue injuries to larynx and trachea and identification of soft tissue air emphysema.[10]

If the airway is not secure and/or is unstable, or the patient is unstable for other reasons, the patient is taken emergently to the operating room where securing the airway followed by stabilization of the patient is the immediate priority. Traditionally, this is via an oral endotracheal intubation. However, if the patient has a known laryngeal or tracheal injury, oral endotracheal intubation can fail, particularly because of false passage or further disruption of the injured airway. Although securing the airway trumps any other priority, in this situation the most ideal airway is a tracheostomy, performed awake with either mask or laryngeal mask airway support, as the situation allows. If endotracheal intubation is the route chosen, a fiberoptic intubation with a pediatric bronchoscope is one of several tools

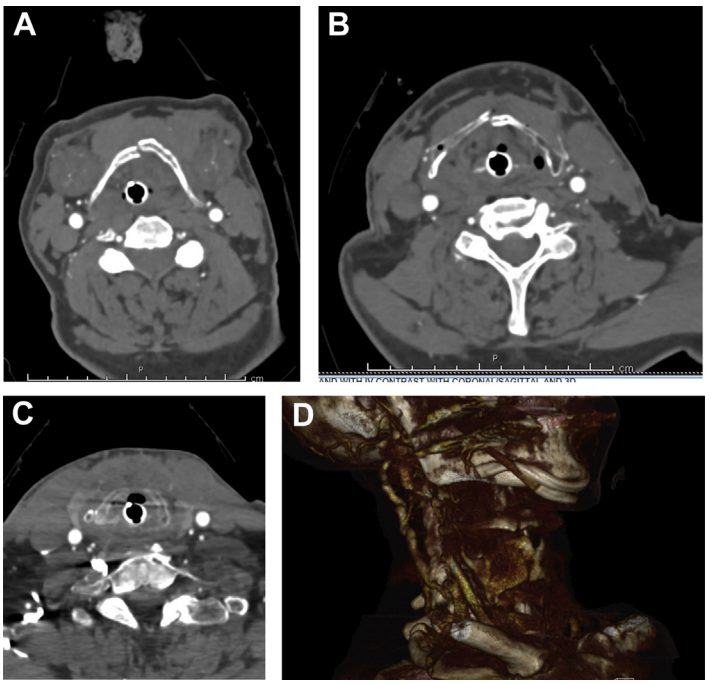

Fig. 2. Axial CT neck images of a 64-year-old male victim of a motorcycle accident with severe multisystem trauma. Injuries included (*A*) hyoid bone fracture, (*B*) a thyroid cartilage fracture, and (*C*) and cricoid cartilage fracture. (*D*) Three-dimensional reconstruction of the CT demonstrating the previously mentioned fractures.

to be considered by the anesthesiologist. In the presence of endolaryngeal lacerations, the primary risk is that of intubating a blind submucoperichondrial pouch that produces immediate and total airway obstruction. The stat surgical airway that follows not only risks the patient's life but can also worsen the existing laryngotracheal injuries.

Once the airway is secured and the patient is stable, the next step in the evaluation involves physical examination, CT imaging (if not already performed), and panendoscopy. Anatomically, the larynx is subdivided into the supraglottic larynx, glottic larynx, and subglottic larynx, and trachea. Injury can occur at any and all of these levels. Therefore, the examination is performed in such manner where each of these areas are carefully inspected. It is important to remember that, particularly with blunt trauma, disruption of the laryngeal framework can occur without obvious external findings. For example, disruption of the cricoarytenoid joint and shortening of the true vocal cord can occur with blunt trauma and manifest itself with vocal changes, without external signs of injury. If left untreated, the dislocated arytenoid may scar in that position resulting in permanent, more difficult to correct vocal disturbance. It is widely agreed on that early identification and treatment of laryngeal injuries yields superior results, ideally within the first 24 to 48 hours if circumstances allow.

Nondisplaced Versus Displaced Cartilage Fractures

The CT scan answers an essential branch point in our management algorithm, which is whether or not there are displaced fractures of the cartilaginous larynx. The CT scan is especially valuable because it can detect occult fractures missed on examination.[11]

Patients without cartilage fractures or with nondisplaced cartilage fractures are managed in a more conservative manner. Patients with nondisplaced cartilage fractures are carefully assessed for vocal disturbances. Signs of voice changes should prompt a fiberoptic nasopharyngoscopy to assess for endolaryngeal injury. If the patient has already been intubated or has a tracheostomy, a direct laryngoscopy under anesthesia is performed instead. While under anesthesia, a bronchoscopy and esophagoscopy are also performed to assess the full extent of injury.

If no signs of endolaryngeal injury are observed, the patient is observed and receives supportive care. If the laryngeal examination demonstrates mucosal injury, consideration should be given to surgical repair versus serial endoscopic examination. Mucosal lacerations are repaired primarily through a thyrotomy (laryngofissure) approach, or in some cases, endoscopically. Denuded laryngeal cartilage that is not amenable to primary closure is treated with a thyrotomy approach

coupled with use of a laryngeal stent or laryngeal keel.[12]

If the CT scan identifies displaced cartilage fractures, these are treated with open reduction and internal fixation. Before this, many such patients benefit from having the airway secured with an awake tracheostomy. This avoids the need for endotracheal intubation, which is challenging and further disrupts the displaced cartilage fractures. Once the airway is secured, direct laryngoscopy is performed to assess for endolaryngeal injury, as discussed previously. Consideration is given to including esophagoscopy and/or bronchoscopy. If there are no signs of endolaryngeal injury, the surgeon may proceed with open reduction and internal fixation of the displaced cartilage segments. If there are signs of significant endolaryngeal injury, repair them via laryngofissure approach followed by open reduction internal fixation of the cartilage fractures.

ANATOMIC CONSIDERATIONS

Epiglottis

The epiglottis, as the superior extent of the supraglottic larynx, connected by ligaments to the hyoid bone and thyroid cartilage, is significantly affected by laryngeal trauma. Hyoid fractures can result in an epiglottic hematoma (Fig. 3). An epiglottic hematoma quickly results in stridor, difficulty with speech, and eventually dyspnea and potential airway embarrassment. Partial or complete avulsion of the epiglottis can also occur with severe hyoid and thyroid fractures. This manifests as dysphagia and aspiration.

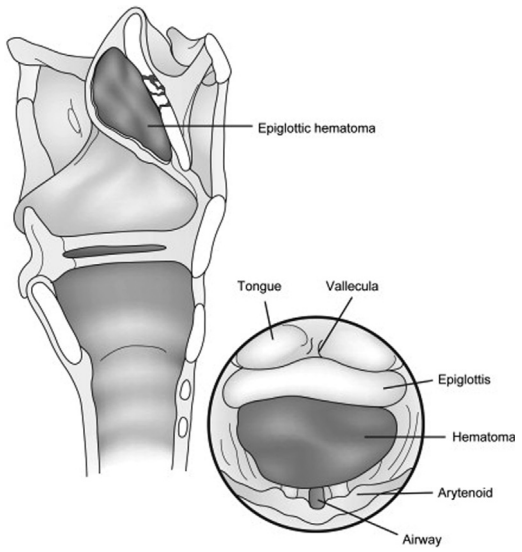

Fig. 3. Illustration of an epiglottic hematoma, which may result from hyoid or thyroid fracture. Note that as the hematoma expands, the airway is at risk for critical obstruction. (*From* Bell RB, Verschueren DS, Dierks EJ. Management of laryngeal trauma. Oral Maxillofac Surg Clin North Am. 2008 Aug;20(3):415-30; with permission.)

Hyoid Bone Fractures

Hyoid bone fractures are a result of high-energy impact and, in our Legacy Emanuel series, were often seen in sporting injuries, such as baseball, jet skiing, and martial arts.[4] Such injuries are also seen in suicidal hanging and in attempted manual strangulation. Most hyoid fractures do not require surgical intervention. However, they are usually accompanied by temporary odynophagia. Significantly displaced hyoid fractures are managed by either open reduction and internal fixation of the hyoid bone or partial hyoid resection.

Distortion of the Glottis

Injury to the larynx can result in changes in the anterior-posterior dimension of the vocal cords, the positioning of the vocal cords relative to each other, the mobility of the cords, and soft tissue injury of the cords. Any of these distortions can result in voice changes. Voice changes of volume loss and pitch lowering indicate shortening of the vocal cords. Voice changes of roughness indicate asymmetry of the vocal cords, such as a unilateral change in length or asymmetric swelling.

Displaced fractures of the thyroid cartilage involving the anterior commissure and/or arytenoid dislocation can result in foreshortening of the vocal cords. This is identified on endoscopic examination, confirmed on CT scan, and is a strong indication for open reduction internal fixation (Fig. 4).

Mucosal injury involving the vocal cords that remains unrepaired will heal by secondary intention, but such healing can result in synechiae between opposing vocal cords and at the anterior commissure. Careful inspection for such injuries is essential and their presence is an indication for repair.

Cricoid Injury and Cricotracheal/ Laryngotracheal Separation

Injury of the subglottic larynx can result in cricoid fractures and/or cricotracheal separation, both of which result in devastating airway obstruction that is difficult to rescue in the field because these generally require an emergent tracheostomy. Patients who are able to be stabilized are often found to have recurrent laryngeal nerve injury.

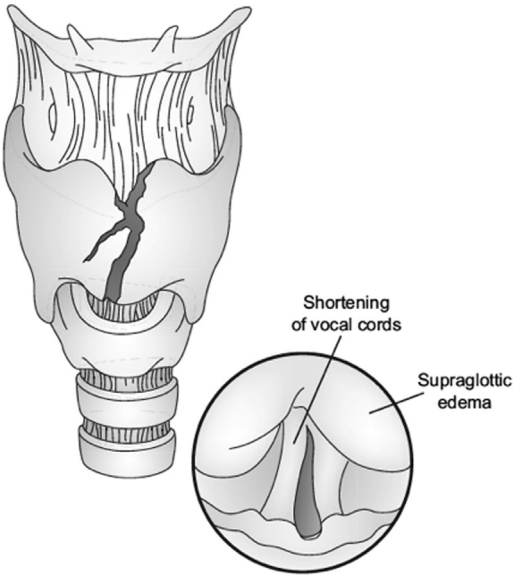

Fig. 4. Fracture of the thyroid cartilage may result in edema, shortening, and possible avulsion of the vocal cords resulting in significant voice changes. (*From* Bell RB, Verschueren DS, Dierks EJ. Management of laryngeal trauma. Oral Maxillofac Surg Clin North Am. 2008 Aug;20(3):415-30; with permission.)

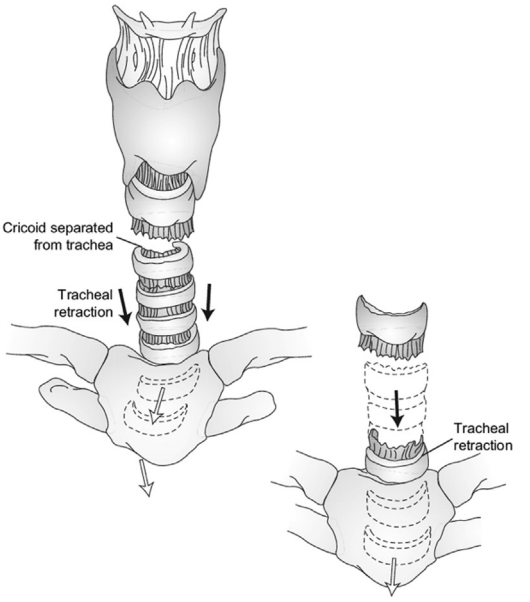

Fig. 5. Complete laryngotracheal separation with tracheal retraction may result in profound airway compromise and death if not treated with immediate airway stabilization in the form a tracheostomy. (*From* Bell RB, Verschueren DS, Dierks EJ. Management of laryngeal trauma. Oral Maxillofac Surg Clin North Am. 2008 Aug;20(3):415-30; with permission.)

If the larynx or cricoid becomes separated from the trachea, the trachea tends to retract inferiorly toward the mediastinum (Fig. 5). Reconstruction requires limited circumferential dissection of the trachea to allow placement of bolstering sutures for tension-free approximation of the divided airway.

OPERATIVE TECHNIQUE

Endoscopy

It is beyond the scope of this article to discuss the nuances of performing endoscopic examination of the upper aerodigestive tract. However, we will discuss some pearls related to these techniques.

Flexible nasopharyngoscopy is an efficient, widely available (found on most hospital airway carts), and effective way to examine the airway in an awake or sedated patient. Performing this on an awake patient affords the benefit of being able to visualize the larynx in function, specifically the presence of absence of vocal cord motion. The effective performance of this examination in an awake trauma patient is uniquely challenging. Blood and swelling in the airway or difficulty with topical anesthesia in an agitated patient can make good visualization impossible.

In these cases, performance of an endoscopic examination in an anesthetized patient after the airway has been secured is the other option. This is ideally performed directly using a laryngoscope, because this can address the collapse of the potential space that occurs when a patient is in a supine position. However, many trauma patients with airway injury are at risk of cervical spine injury and remain on cervical spine precautions that limit neck extension. This difficulty is compounded among patients with classic intubation challenges, such as anterior airways and mandibular hypoplasia. In such instances, we revert back to fiberoptic examination assisted by a videolaryngoscope. A videolaryngoscope is introduced in the traditional fashion, with the tip of the blade placed within the vallecula. This suspends the base of tongue and mandible anteriorly, opening the potential space in the oropharynx, which allows the fiberoptic scope to be more useful.

Examination of the trachea is performed with either a flexible or rigid bronchoscope. In the trauma setting, the flexible bronchoscope is the simplest to use, does not require neck extension, and allows creation of video documentation of the injuries.

Examination of the cervical and thoracic esophagus is performed either with a rigid or flexible esophagoscopy. Rigid esophagoscopy is thought to be more sensitive than flexible esophagoscopy in identifying injuries.[13] It also does not require

insufflation to create a potential space for visualization, which runs the risk of causing soft tissue air emphysema in the mediastinum and neck. However, as with laryngoscopy, it is difficult to perform on patients in a cervical collar and those with anatomic limitations. Also, a rigid esophagoscope also runs the risk of further disrupting an injured larynx.

Tracheostomy

The tracheostomy is a routine procedure that is a valuable part of the armamentarium of any surgeon active in trauma. There are also as many ways to perform the procedure as there are surgeons performing it. As such, we focus this discussion not on how to perform a tracheostomy, but modifications for performing a tracheostomy in a patient likely to have laryngeal injury.

Tracheostomy in this setting is often performed before the patient's cervical spine has been cleared. As such, maintaining neck immobilization is paramount. The head is typically stabilized with tape to the bed or operating table while the anterior portion of the cervical collar is removed for access. Additional support to the neck is provided by the anesthesiologist.

As previously mentioned, it is ideal to perform an awake tracheostomy. This requires a concerted effort between the anesthesiologist and surgeon. Although the procedure is described as "awake," it is most optimally performed with some degree of sedation. This is typically a combination of an amnestic with a general anesthetic at a dose that maintains spontaneous respiration. In addition to oxygenation, mask ventilatory support, typically by face mask, is essential. Good local anesthesia is of critical importance. We typically deliver field blocks to the cervical plexus along the anterior border of the sternocleidomastoid muscle on either side and infiltration from the skin down to the trachea.

In the absence of useful overlying lacerations, a horizontal incision is used for the tracheostomy at a level that can be incorporated into an apron incision later for neck exploration, if needed.

Once the trachea is visualized, the tracheotomy should ideally be placed distal to the injury, usually between the third and fourth tracheal rings. Although a cricothyroidotomy is the most expedient in an emergency situation, it does interfere with laryngeal reconstruction and risks limiting cricothyroid mobility in the future (limiting upper vocal range and maximal volume). If a cricothyroidotomy has been previously performed, the airway should be converted to a tracheostomy as soon as it is practical.

Surgical Exposure

If existing lacerations do not provide sufficient exposure, a limited neck exploration may be necessary. A horizontal incision is designed that is made to incorporate the incision of the tracheostomy. The incision is wide enough to explore the lateral neck if necessitated by the nature of the injury. The skin flaps are developed in a suprafascial plane over the strap musculature. The flaps are elevated superiorly to the level of the hyoid bone and inferiorly to the clavicles.

If broader exposure is necessary, the sternocleidomastoid muscles are skeletonized on the medial/deep sides for access to create an outer tunnel. Blunt and sharp dissection are used medial to the carotid sheath allowing lateral retraction to create the inner tunnel. This allows wide access to the larynx, pharynx, and esophagus on either side.

The median raphe is identified and dissection is carried in this plane through the infrahyoid strap muscles. The strap muscles are bluntly dissected and retracted laterally until the thyroid cartilage is visualized (**Fig. 6**).

Endolaryngeal repair and reconstruction is accessed by performing a laryngofissure using a midline thyrotomy, if the exposure has not already been created by the injury. A horizontal incision is made through the cricothyroid membrane. Using a 12 blade, and under the direct visualization, cut from an inferior to superior direction directly between the true vocal cords in the midline. This is important, because detachment or further disruption of the vocal cord at the anterior commissure is difficult to correct. An oscillating saw is used to complete the midline thyrotomy. The two sides of the thyroid cartilage can then be retracted laterally (**Fig. 7**).

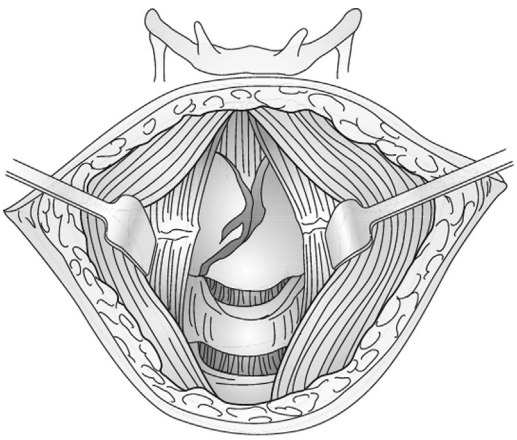

Fig. 6. Retraction of the strap musculature to allow for visualization of the cartilaginous injuries. (*From* Bell RB, Verschueren DS, Dierks EJ. Management of laryngeal trauma. Oral Maxillofac Surg Clin North Am. 2008 Aug;20(3):415-30; with permission.)

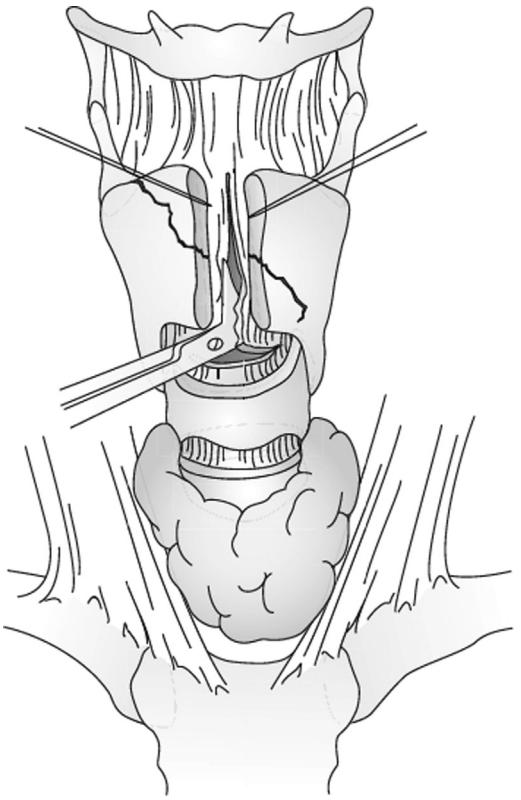

Fig. 7. Midline thyrotomy allows for lateral retraction of the thyroid and cricoid cartilages to allow for visualization of laryngeal and esophageal structures. (*From* Bell RB, Verschueren DS, Dierks EJ. Management of laryngeal trauma. Oral Maxillofac Surg Clin North Am. 2008 Aug;20(3):415-30; with permission.)

Alternatively, for surgeons with greater experience, a simpler method involves starting with a midline thyroidotomy. The oscillating saw is used to make a cut in the midline and the two halves of the thyroid cartilage are gently pulled to 3 to 4 mm apart. Generally, if performed with care this is executed without violating the mucosa and entering the airway. The vocal processes are visually identified as two white spots. They can be divided in the midline and remain attached to their respective thyroid ala. This obviates an incision in the cricothyroid area and allows improved airtight closure.

If the airway is inadvertently entered during thyroid cartilage division, it will nearly always be into the space between the true and false vocal cords, the thinnest area of mucosa. Using an 11 blade, the vocal ligaments are divided. Up-angled scissors can divide the false cords if needed for visualization. One can then leave the inferior mucosa intact for an airtight seal after closure.

If an esophageal injury has been identified, this should be repaired before the endolaryngeal repair.

Endolaryngeal Repair

After the laryngofissure is performed, the supraglottic, glottic, and subglottic larynx is directly visualized. Mucosal lacerations, particularly if there is exposed cartilage, are repaired primarily with resorbable sutures, such as 4–0 and 5–0 chromic gut. Do not debride lacerated mucosa, because this makes primary closure difficult. The arytenoids are inspected. If dislocated, they should be reduced. The vocal cord attachments to the thyroid cartilage are also inspected. If there is detachment, the vocal cords are resuspended using fine nonresorbable suture to the thyroid cartilage at Broyles ligament (Fig. 8).

Rarely, there may be avulsion injuries of the mucosa that are not amenable to primary closure. Special consideration is given to these, particularly if there are opposing injuries on the other side. This may result in adhesions that inhibit vocal cord mobility. This is managed using a laryngeal stent or a keel. A laryngeal stent is placed with or without a skin graft (with the underside of the graft facing outward) (Fig. 9). The stent is then secured with two nonresorbable sutures. The first suture is passed through skin, thyroid lamina, stent, opposite thyroid lamina, and back out through the skin. The second suture is passed through skin, subglottic trachea, stent, opposite wall of the trachea, and back out through skin. The two sutures are passed through an external silicone button and tied loosely, on either side. The primary advantage of the stent, beyond preventing synechiae and adhesions, is that it provides structural stabilization of the endolarynx circumferentially. By separating denuded areas from each other, it allows for epithelial migration and healing by secondary intention without adhesions. However, it comes at some risk. The stent itself may cause pressure on the endolaryngeal mucosa, creating raw areas that may heal as adhesions once the stent is removed. This may result in stenosis later on.

An alternative to a laryngeal stent is the use of a keel. Similar to a stent, it is a barrier that allows for healing by secondary to intention while preventing adhesions. In contrast to a stent, it does not provide circumferential support of the larynx. This avoids the risk of pressure or rubbing injury to the endolaryngeal mucosa.

The laryngofissure must be meticulously repaired. Fine nonresorbable sutures are used to reconstruct the anterior commissure. Special attention is given to lining up these two landmarks

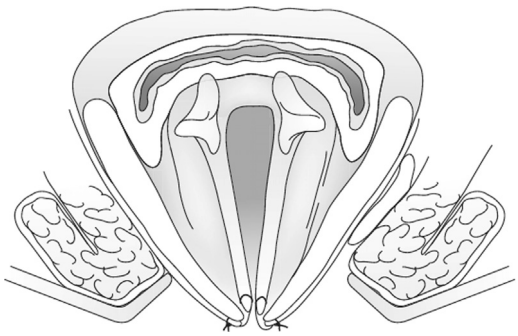

Fig. 8. Resuspension of Broyles ligament to the external perichondrium. (*From* Bell RB, Verschueren DS, Dierks EJ. Management of laryngeal trauma. Oral Maxillofac Surg Clin North Am. 2008 Aug;20(3):415-30; with permission.)

in the same horizontal plane, otherwise the vocal cords do not adduct evenly during function. A suture is passed through the thyroid cartilage and anterior commissure on one side, then through the anterior commissure and thyroid cartilage on the opposite side to line these points up correctly.

The thyroid (and cricoid, if necessary) is then repaired either with suture, wire, or miniplate fixation (Fig. 10). When using miniplates, be sure to choose screws that do not penetrate the endolaryngeal mucosa. Resorbable plates and screws have also been used for this indication.

Reconstruction of Cricotracheal Separation

For reconstruction of a complete separation of the trachea from the larynx, the trachea must be sufficiently mobilized. Blunt dissection is used anterior and posterior to the trachea. This can often be done carefully with a finger. Avoid excessive lateral dissection, because this may compromise the vascular supply to the skeletonized trachea. This dissection should be carried inferiorly into the superior mediastinum to allow for sufficient superior traction.

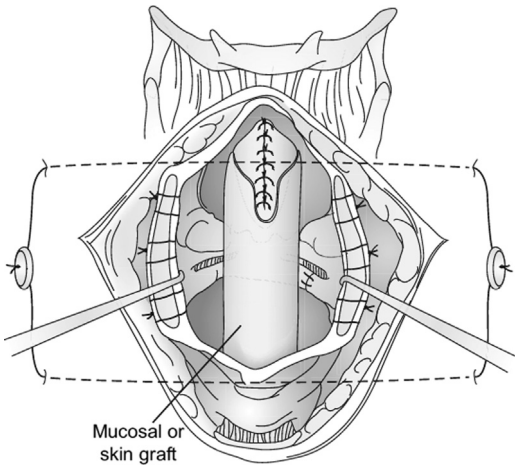

Fig. 9. A laryngeal stent can be secured with sutures that extend through the skin, thyroid lamina bilaterally before being tied loosely over skin buttons. (*From* Bell RB, Verschueren DS, Dierks EJ. Management of laryngeal trauma. Oral Maxillofac Surg Clin North Am. 2008 Aug;20(3):415-30; with permission.)

Nonresorbable sutures, such as 2–0 Prolene, are used to reconstruct. These sutures are passed through the cartilage of a tracheal ring at least one or more rings distal the injury. Superiorly, the suture needle is then passed through the cricoid. Be sure to avoid passing through the tracheal mucosa. These sutures are placed 270° around the trachea. Once all the sutures are passed, they are tied down one by one, working from lateral to anterior (Fig. 11). It is important to keep the patient's head out of extension, to minimize tension across the closure. As a reminder to the patient, a Grillo stitch, a heavy nonresorbable suture passed from menton to sternum, is placed. This discourages the patient from extending his or her neck and putting excess tension across the repaired trachea.

After the repair is complete, the patient can usually be extubated, assuming other indications for remaining intubated are not present. However, keeping the patient intubated may be prudent, depending on the surgeon's judgment and the patient's clinical status.

Wound Closure

The skin flaps are closed in layers. Special attention must be given to separation of the tracheostomy from the rest of the wound. Deep sutures are placed circumferentially around the tracheostomy to seal it off. Suction drains are placed under the skin flaps to prevent saliva or seroma accumulation or a subcutaneous aerocele. Although some authors advocate for passive drains for fear of promotion of fistula formation, we have not found this to be an issue in our experience.

POSTOPERATIVE CARE

Enteral Feeds

The patient is initially fed by a nasogastric feeding tube because temporary dysphagia is common. Enteral feeds are continued until the patient is able to protect their airway. If permitted by other injuries, a swallow evaluation is initiated by a speech language pathologist as early as the third to fourth postoperative day. If aspiration is present, enteral feeds are continued until this is resolved.

If there was an esophageal injury, we typically postpone initiation of oral feeding for 2 weeks. Before oral feeding, a modified barium swallow and esophogram are performed to assess for leaks.

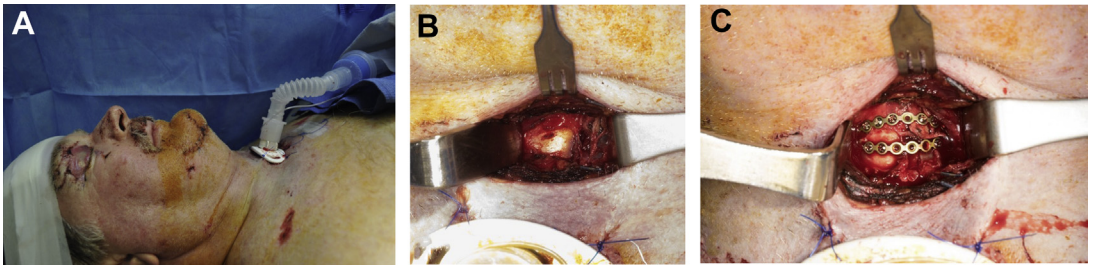

Fig. 10. A 64-year-old male victim whose CT images were presented in Fig. 4. Examination of the neck revealed and large submental laceration and edema and ecchymosis extending down to the sternal notch, which raised the suspicion for a laryngeal injury. (*A*) Clinical appearance after initial stabilization with a tracheostomy. (*B*) Intraoperative exposure for repair of the laryngeal injuries. (*C*) Open reduction internal fixation of thyroid and cricoid cartilages.

If leaks are present, enteral feeds are continued for an additional 2 weeks and the study is repeated.

COMPLICATIONS

Several perioperative complications can occur with laryngotracheal injuries including voice changes; bleeding; infection; fistula formation; and, most seriously, loss of airway. However, probably the most substantial and common long-term issue is stenosis of the airway. This can occur in the presence of mucosal injuries that results in adhesions or wound contracture. Circumferential injuries are at the greatest risk. Despite careful mucosal repair and use of stents, stenosis can still occur. This is a chronic and difficult to manage problem. Even with a patent airway, a stenotic airway can result in stridor, dyspnea on mild exertion, constant shortness of breath, and intractable fatigue. Such patients often undergo tracheostomy and subsequently seek tracheal "sleeve" resection.

Initial management of airway stenosis starts with a careful endoscopic examination to identify the

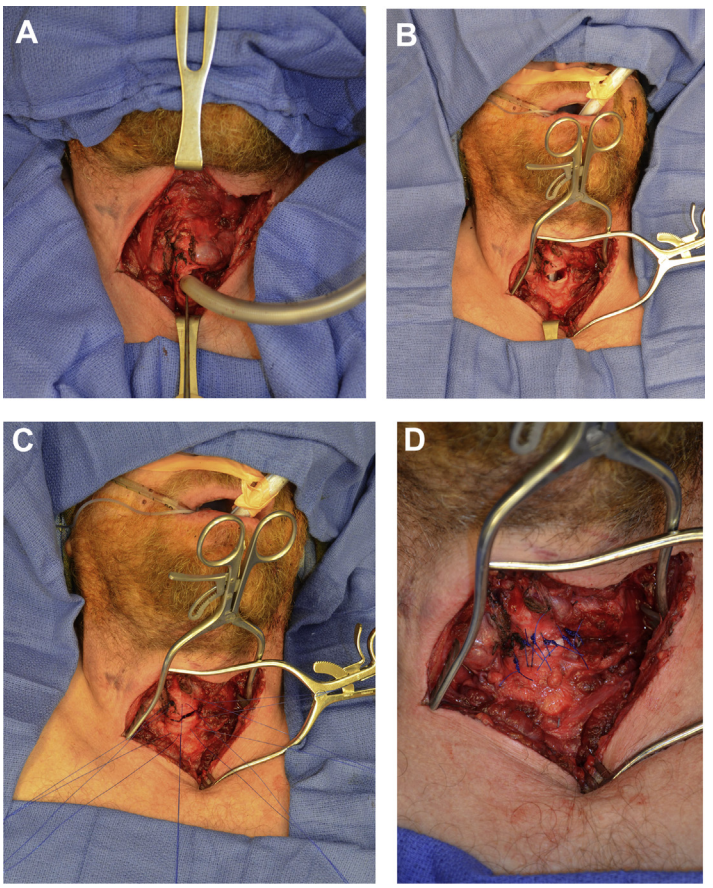

Fig. 11. Patient suffered a work-related injury where a chain saw rebounded off a metal pipe resulting in a penetrating anterior neck injury that led to near complete cricotracheal separation. An emergency medical technician in the field visualized bubbles from his neck wound and was able to intubate his trachea directly and secure his airway. He was immediately taken to Legacy Emanuel Medical Center, directly to the operating room. (*A*) After hemostasis was obtained and panendoscopy performed, the "trach" was converted to an oral endotracheal tube. (*B*) The trachea was mobilized with blunt dissection. (*C*) 2–0 Prolene sutures were used to repair the separation. Note the sutures are passed through a tracheal ring away from the site of injury. (*D*) The patient's neck was placed in slight flexion and the sutures tied down in a parachuting fashion.

location, length, and degree of stenosis. Tracheal stenosis isolated to a few rings is often amenable to serial bronchoscopic partial laser ablations combined with careful dilation. In severe, refractory tracheal stenosis below the second ring, tracheal resection of several rings and primary anastomosis is performed. Stenosis involving the cricoid is generally managed by cricoid split with interpositional grafting.

SUMMARY

Injuries to the larynx and trachea are rare. However, a high degree of suspicion is necessary for trauma patients with the right mechanism and examination findings, because early identification and treatment leads to better outcomes. Securing the airway is the first priority, with an awake tracheostomy being the ideal method in patients with displaced laryngeal fractures with or without substantial endolaryngeal injury. Early open reduction and internal fixation of displaced laryngeal cartilage fractures is recommended. Endolaryngeal injuries are managed through a laryngofissure or through existing cartilage fractures. The use of a laryngeal stent or keel can help prevent synechiae and laryngeal stenosis. Complete laryngotracheal separation is often quickly fatal because of loss of the airway in the field.

CLINICS CARE POINTS

- The key step in treatment of any laryngeal injury is the establishment of a secure airway.
- Early intervention (within 24–48 hours) is an important factor for improved patient outcomes (functional speech, swallowing, and airway patency).
- An awake tracheostomy is the airway of choice with grade II or higher laryngeal injuries.

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