Introduction

Laryngeal injury is rare. It has an estimated incidence of 1 in every 14,583 to 42,528 emergency room visits. Four of ten blunt laryngeal trauma victims are estimated to die at the scene of the accident. Rapid recognition is key. Securing the airway is crucial. The effectiveness of the initial management will determine the final airway and voice. Thus, the otolaryngologist must be conversant with the diagnosis and treatment of this rare injury.

Anatomy and Physiology of the Larynx

The larynx provides an airway for breathing, protects the lower respiratory tract and induces vibration in the air column for voice. Three structures lend support to the larynx: the hyoid bone, thyroid cartilage, and the cricoid cartilage. The cartilaginous framework relies on the perichondrium for its blood supply. Intrinsic muscles that are innervated mainly by the recurrent laryngeal nerves act upon the larynx. The sensory innervation of the supraglottic larynx is from the superior laryngeal nerves. The larynx is lined mostly by respiratory epithelium. The larynx is divided into three anatomic areas: the supraglottis, the glottis, and the subglottis. The supraglottis has much soft tissue and is less dependent on external support. Glottic function makes use of cartilaginous support, cricoarytenoid joint mobility, and neuromuscular coordination. The adult airway is narrowest at the glottis. The cricoid cartilage, the only circular cartilage of the larynx or trachea, supports the subglottis (the narrowest part of the infant airway).

Mechanism of Injury

Laryngeal injury is classified as blunt or penetrating. The larynx is protected by the mandible, the sternum, and neck flexion. Blunt injury occurs when the larynx is crushed
between an object and the cervical spine. High speed motor vehicle accidents are the most common cause of blunt injury usually causing cartilage and soft tissue injury secondary to shearing forces. Strangulation type injuries typically cause cartilage fracture without mucosal lacerations. Associated arytenoid cartilage dislocation and recurrent laryngeal nerve injury can occur. Cervical spine injury must be excluded. The clothesline injury is one of the most severe forms of blunt trauma to the larynx. This occurs when the individual is riding a motorcycle or snowmobile and his neck hits a stationary object such as a fence or tree limb. This can result in crico-tracheal separation.

Gunshot or knife wounds are the primary causes of penetrating injuries. Gunshot wounds result in tissue loss in the path of the bullet and in peripheral injury that is related to the velocity of the bullet. Knife wounds cause damage in the path of the blade but depth of the injury is often underestimated. Associated injuries to blood vessels and the esophagus must be considered.

History and Physical Exam

Any patient with a history of trauma to the anterior neck should be evaluated for laryngeal injury. Symptoms include hoarseness or change in the patient’s voice, dysphagia, odynophagia, difficulty breathing and/or anterior neck pain. Those patients with difficult breathing were found to have more severe injuries.

Physical exam findings include stridor, subcutaneous emphysema, hemoptysis, laryngeal tenderness, loss of thyroid cartilage prominence and ecchymosis or edema in the overlying skin. Inspiratory stridor is usually associated with supraglottic obstruction and expiratory stridor usually indicates obstruction subglottically while combined inspiratory and expiratory stridor indicates the site of injury to be the level of the vocal cords. Determination of airway stability dictates the next step (see Figure I). Patient’s with a stable airway undergo flexible fiberoptic laryngoscopy. True vocal cord mobility, soft tissue injuries including edema, lacerations and hematomas as well as the status of the airway are evaluated. Associated injuries including cervical spine, esophageal and vascular injuries must be considered and evaluated. Active bleeding, expanding hematoma, bruits, and the loss of pulses are signs of vascular injury.

Diagnostic Imaging

The entire cervical spine should be evaluated radiographically. Computer tomography with fine cuts (1 mm) is used to evaluate the larynx. The integrity of the laryngeal skeleton and cricoarytenoid joints is assessed. CT is useful in cases where the flexible fiberoptic exam is limited by edema. Some authors utilize CT scanning in almost all cases, others recommended it only when the results will change the treatment plan. These authors do not scan patients with obvious severe injuries that will require open exploration and tracheotomy or cases of minor trauma and no physical findings. Most intermediate cases warrant a CT scan. Angiography and barium esophagrams may be indicated in select cases.
Airway Management

As with any trauma patient, airway evaluation and management is the first concern. If stable, the history, physical exam and radiological workup may proceed. If unstable, the airway must be secured immediately. Although controversial, most authors recommend tracheotomy under local anesthesia as the safest, least traumatic method of securing the airway in an adult. An emergency cricothyrotomy is performed if time does not allow a formal tracheotomy. If oral endotracheal intubation is attempted, an experienced physician with direct visualization of the larynx should perform it with a small diameter endotracheal tube. This is difficult to do in cases of laryngeal trauma. Problems with endotracheal intubation in the laryngeal trauma patient include risk of further iatrogenic injury and possible loss of a marginal airway. Pediatric patients with laryngeal injuries and an unstable airway should be managed in a manner similar to epiglottitis using inhalation anesthesia with spontaneous respirations followed by rigid endoscopic intubation. Once the airway has been evaluated and secured, tracheotomy can be performed if needed.

Medical management

Management can be primarily medical or surgical and is based on the type of injury as determined by the physical examination and CT scan. A patient is managed medically if the injury will resolve without surgical intervention and the patient has a stable airway. Usually these injuries include:

1. Edema
2. Small hematoma with intact mucosa
3. Small glottic or supraglottic lacerations not involving free margin of the vocal cords or the anterior commisure; no exposed cartilage
4. Single nondisplaced stable thyroid cartilage fracture. Note: even single nondisplaced angulated fractures can produce subtle vocal changes

Medical management includes a minimum of twenty-four hours of airway observation, voice rest, elevation of the head, and inspiration of humidified air. Antibiotics are recommended with disruption of the laryngeal mucosa. H2 blockers reduce further injury from reflux of gastric acid. Although not proven, early initiation of systemic steroids are often given to reduce laryngeal edema.

Surgical management

Penetrating trauma is more likely to require open exploration than is blunt trauma. Patients with significant injuries should be taken to the operating room expeditiously for direct laryngoscopy, bronchoscopy and esophagoscopy. Tracheotomy is performed if indicated. If the patient is found to have only laryngeal edema, small hematomas with intact mucosal coverage, or minimal lacerations as described above, no further surgical intervention is indicated. Adjuvant medical management is employed and the airway is
maintained via the tracheotomy until the patient tolerates prolonged plugging. Injuries likely to require open laryngeal exploration and repair include:

1. Lacerations involving the free margin of the vocal cord or anterior commissure
2. Large mucosal lacerations, exposed cartilage
3. Multiple displaced cartilage fractures
4. Avulsed or dislocated arytenoids
5. Vocal cord immobility

When laryngeal exploration is indicated, it should be performed within 24 hours of the injury. A horizontal skin incision is made at the level of the cricothyroid membrane and subplatysmal flaps are elevated. The strap muscles are separated and the larynx exposed. To explore the mucosal surfaces, a thyrotomy is performed using an oscillating saw in the midline if no nearby fracture (within 2-3 mm of the midline) is available. Effort should be made to place the laryngofissure directly through the midline. This is accomplished by first horizontally incising the cricothyroid membrane. Then a vertical incision is carried superiorly through the anterior commissure to the thyrohyoid membrane under direct visualization. The thyroid laminae can be retracted laterally exposing the endolarynx. Afrin soaked pledgetts are placed to achieve hemostasis and the endolarynx is carefully evaluated. The goals are to return all remaining tissue to its appropriate location and to cover all cartilage. Exposed cartilage is a factor responsible for the formation of granulation tissue and subsequent fibrosis. Primary closure is usually possible because most injuries do not involve significant tissue loss and debridement should be minimized. When necessary minimal undermining of adjacent mucosa can be performed to achieve closure. Mucosal flaps can be rotated from the epiglottis or pyriform sinus. Skin or mucosal grafts are rarely needed. All lacerations are carefully and meticulously closed using 5.0 or 6.0 absorbable suture. The arytenoids are palpated to evaluate their position and mobility. If dislocated, the arytenoid cartilage should be reduced. The normal scaphoid shape of the anterior commissure is then reconstituted by using 4.0 suture to suspend the anterior true vocal cords to the outer perichondrium or thyroid cartilage. The thyrotomy is then closed with nonabsorbable suture, wire or wire-tube techniques.

When the initial work up and endoscopy indicate an intact endolarynx with a displaced thyroid cartilage fracture, open reduction and internal fixation is indicated. If the fracture is comminuted, small fragments of cartilage with no intact perichondrium are removed to prevent chondritis. Many forms of fixation have been described including nonabsorbable suture, wire, and miniplates. Wires have the tendency to break. Austin et al. have described a wire-tube technique that involves passing a stainless steel wire around the fracture and submucosally on the medial surface of the cartilage. On the lateral aspect of the cartilage, the wire is passed through a blunted 18-gauge needle. This helps prevent wire pull-through and maintains fixation of the cartilage position with less angulation or blunting. For vertical fractures, a wire-tube device is placed both above and below the true vocal cord. Miniplates have the theoretical advantages of immediate stability,
preservation of the anterior/posterior diameter of the glottis, and the ability to bridge missing cartilage.

Endolaryngeal stenting is required with disruption of the anterior commissure, multiple displaced cartilage fractures, and multiple and severe endolaryngeal lacerations. Stenting prevents the loss of the normal scaphoid shape of the anterior commissure, stabilizes severely comminuted fractures or lacerations, and prevents endolaryngeal stenosis. Stent use requires a compromise between the above benefits and the inherent injury caused by the stent. Stents must be removed as soon as possible, usually after about two weeks. Many types of stents are available including home-made finger cots, modified endotracheal tubes (Portex), and commercial silastic stents. The stent should extend from the false vocal folds to the first tracheal ring, should be soft and able to be secured inside the larynx such that it allow movement with the larynx during swallowing. The shape of the stent should resemble the shape of the larynx and be able to be recovered easily by endoscopy. A heavy, nonabsorbable suture can be passed through the stent and the larynx at the level of the laryngeal ventricle and another suture at the cricothyroid membrane. These are tied over buttons outside the skin. Additional superior and inferior sutures may be brought out the nose and the tracheotomy site, respectively. This four-point fixation allows easy recovery of the stent if the fixation sutures break.

If the anterior commissure lacks epithelium, a keel can be placed to prevent web formation. A keel differs from a stent in that it just keeps the opposing mucosal surfaced from touching whereas a stent provides 360 degrees of support. The thyrotomy site is then closed with wire, nonabsorbable suture, or miniplates. If a portion of the anterior cricoid ring is missing, the infrahyoid strap muscles can be sutured into the defect to help airway and voice function.

In order to assess the adequacy of current laryngeal trauma management techniques, Schaefer published a study of 139 consecutive laryngeal trauma patients treated at one major medical center over 27 years (follow-up ranged from 1 month to 20 years). Based on the physical, endoscopic, and radiographic findings, laryngeal injuries can be classified into one of four groups according to Schaefer’s classification system. Patients with Group I injuries have minor endolaryngeal hematomas or lacerations, no fractures, and minimal airway compromise. Flexible laryngoscopy is the preferred method to evaluate these patients. CT was used to evaluate questionable cases. Patients were managed medically with occasional use of steroids.

Group II injuries include moderate edema, lacerations, mucosal disruption without exposed cartilage, nondisplaced fractures, and varying degrees of airway compromise. Tracheotomy under local anesthesia is the preferred method to manage the airway. Again, CT was used to evaluate questionable cases. No further surgical intervention was needed for no fractures or single nondisplaced fractures.

Group III patient’s have massive edema, mucosal disruption, displaced fractures, cord immobility, and varying degrees of airway compromise. Group IV was the same as group
III with two or more fracture lines and/or skeletal instability or significant anterior commissure trauma. Tracheotomy and endoscopy was performed in these patients followed by exploration of the larynx with repair of mucosal lacerations with absorbable suture and reconstitution of the anterior commissure. Patients with Group IV injuries usually required a stent which left in place for two weeks. Cartilage fractures underwent ORIF. CT was omitted in these patients because the injuries were so great that it was known restorative surgery was indicated.

Out of the 139 studied, only two patients were left with a poor airway (defined by the inability to decannulate). Time to decannulation ranged from 14 to 35 days; except in those patients with stents who needed 35 to 100 days to decannulation. 112 of the 115 evaluated patients achieved a good voice.

Special Considerations

Laryngotraheal separation is an injury that requires special consideration. Often this injury results in immediate death but a mucosal attachment may remain. Tracheotomy is the preferred method of airway management. If not possible, bronchoscopic intubation may be attempted. The mucosa is repaired using absorbable suture with permanent sutures between the cricoid and the second tracheal ring to provide support if the cricoid is intact. If the cricoid is fractured, the repair is limited by the stability of the cricoid cartilage after internal fixation. ORIF of the cricoid cartilage and stenting, is preferable to significant resection of the cricoid with thyrotracheal anastomosis. Bilateral recurrent nerve injury and subglottic stenosis are common complications with this injury.

Repair of recurrent laryngeal nerve injuries is controversial. Although direct repair provides little chance of functional return due to of the mixture of abductor and adductor fibers in the nerve, it may help maintain true vocal cord bulk and should be considered. Anastomosis of the phrenic nerve to the distal stump of the recurrent laryngeal nerve and direct implantation of the phrenic nerve into the posterior cricoarytenoid muscle has not been shown to be more effective than simple anastomosis of the severed nerve.

As mentioned above, most laryngeal injuries do not involve significant tissue loss. In those cases where portions of the larynx are lost or completely destroyed, techniques similar to those used in various partial laryngectomy procedures can sometimes be used to restore function.

Pediatric laryngeal injuries deserve special consideration because of several important differences when compared to adult injuries. First the proportionally smaller pediatric larynx tolerates much less edema before airway obstruction occurs. Second, the pediatric larynx is more flexible with more loose connective tissue. This results in a lower incidence of cartilage fracture but more soft tissue injury including edema, arytenoid dislocation, recurrent laryngeal nerve injury, and telescoping injuries where the cricoid becomes displaced under the thyroid cartilage. The third and only protective difference is the relatively high position of the pediatric larynx under the mandible. Except for the
differences in airway management mentioned above, the medical and surgical treatment is similar to adult injuries

Complications
Granulation tissue formation is the most common immediate complication. Prevention using the techniques of meticulous primary closure and cartilage coverage is the best treatment of this problem. Additionally, limiting the use of stents to selective cases and their early removal also lessens its occurrence. Once granulation tissue develops, careful laser excision offers the best chance of effective treatment. This problem is often leads to fibrosis and subsequent stenosis.

Laryngeal and tracheal stenosis may also complicate the final result. This is often related to maturation of areas of granulation tissue. The management is site specific. Thin anterior glottic webs may be lysed with a laser or cold knife and a keel placed to prevent recurrence. Posterior glottic webs or interarytenoid scarring may be excised along with an arytenoidectomy and covered with advance mucosa. Extensive stenosis often requires a laryngofissure with direct excision of the stenotic area, followed by placement of a tissue graft with a stent to promote reepithelialization.

Subglottic stenosis is difficult to treat. Small lesions can be treated with repeated dilatation or noncircumferential laser excision of the scar tissue. Significant stenosis may require anterior or posterior cricoid splits with cartilage. Resecting the stenotic area with end-to-end tracheal anastomosis treats significant tracheal stenosis. Lesions up to 4 cm may be resected with laryngeal release techniques.

After blunt trauma, a persistently immobile vocal fold may be due to either recurrent laryngeal nerve injury or to cricoarytenoid joint fixation. Differentiating these causes is essential in selecting the proper form of therapy. This is best accomplished by observing the vocal fold for any sign of movement with fiberoptic laryngoscopy or with direct laryngoscopy under light anesthesia followed by direct palpation of the arytenoid to assess its mobility. If the arytenoid is mobile, the vocal cord should be observed for a year to await the return of recurrent laryngeal nerve function. If aspiration or dysphonia is severe, the vocal fold can be injected with Gelfoam paste. Persistent paralysis resulting in an inadequate voice may be treated with Teflon injection of the vocal fold or thyroplasty-type vocal fold medialization procedures.

If the arytenoid is fixed unilaterally with an adequate voice and airway, no treatment is needed. Bilateral arytenoid fixation or recurrent laryngeal paralysis with a compromised airway can be treated with arytenoidectomy and vocal fold lateralization, but this results in a weak voice.

Conclusion
Recognition of laryngeal injury related to either blunt or penetrating trauma is important for both initial preservation of life as well as long term airway and vocal function. A
history a cervical trauma coupled with signs and symptoms of hoarseness, pain, stridor, hemoptysis, or subcutaneous emphysema should prompt appropriate airway management and evaluation of laryngeal injury. This work up includes flexible fiberoptic laryngoscopy and computer tomograms and may include direct laryngoscopy, bronchoscopy and esophagoscopy. Associated cervical spine and vascular injuries must also be evaluated. Treatment is based on the site and extent of injury. Treatment options include medical management with observation and open surgical treatment with or without stenting.

BIBLIOGRAPHY


