14 Diagnosing Injuries of the Larynx and Trachea

Flowchart and Checklist Injuries of the Neck, Chapter 3, p. 25.


**Surgical Anatomy**

Anteflexion of the head positions the mandible so that it affords effective protection against trauma to the larynx and cervical trachea. Injury to this region occurs if this protective reflex function is inhibited and the head is prevented from bending forward on impact.

The rigid framework of the larynx is formed by four cartilages:
- thyroid cartilage;
- epiglottic cartilage;
- arytenoid cartilage;
- the cricoid cartilage.

The thyroid cartilage is made up of two laminae, which meet at approximately a right angle in men and at ca. 120° in women. The epiglottis petiole attaches to the inner side of the thyroid cartilage. The dorsal cricoid lamina extends into the interior of the thyroid cartilage frame, articulating with it and with the arytenoids. The vocal ligament and vocalis muscle are secured at the vocal process of the arytenoids.

The laryngeal muscles are divided into those that open the glottis and those that close it. The only muscle that acts to open the glottis is the posterior cricoarytenoid (posticus) muscle. Spanning the ventral aspect of the cartilage framework, the cricothyroid muscle is the only laryngeal muscle innervated by the superior laryngeal nerve. All other muscles are supplied by the inferior (recurrent) laryngeal nerve, which originates from the vagus nerve and, after it loops in the thorax, travels cranially between the trachea and esophagus (Fig. 14.1).

The trachea extends from the cricoid cartilage to its bifurcation, a distance of 10–13 cm, or in topographic terms of the vertebral column, from the sixth cervical vertebra to the fourth thoracic vertebra. The tracheal framework is made up of 15–18 horseshoe-shaped cartilage rings which are closed off dorsally by the membranous portion of the trachea (Fig. 14.2).

Fig. 14.1 Anatomy of the outer and inner larynx (modified from Richter 1992). 1 epiglottis, 2 hyoid bone, 3 superior laryngeal nerve, 4 superior thyroid notch, 5 superior horn of thyroid cartilage, 6 thyrohyoid membrane, 7 cricothyroid muscle, 8 annular ligament, 9 pyriform sinus, 10 plica vestibularis (ventricularis, vestibular ligament), 11 laryngeal ventricle (sinus of Morgagni), 12 vocal fold (vocal ligament), 13 supraglottic space (this level is described as the transglottic space, which comprises the vestibular ligament, Morgagni’s ventricle, and vocal fold).
Injuries of the larynx (Figs. 14.3, 14.4) and trachea can be grouped according to pathomechanism as follows:

- **Direct trauma:**
  - *blunt extraluminal causes of trauma*: impact, blow, strangulation, entrapment, sudden longitudinal pull from dorsal reflection of the head;
  - *blunt intraluminal causes of trauma*: long-term intubation, endoscopy, violent coughing, blunt foreign bodies;
  - *sharp extraluminal causes of trauma*: penetrating injury, cut, missile wound, rotating objects;
  - *sharp intraluminal causes of trauma*: sharp, aspirated foreign bodies;
  - *sharp perforating trauma*: missile wound, puncture, cut;
  - *endolaryngeal mucosal lesions*: caustic injury, scalding, thermal burn.

- **Indirect trauma.**

Classification by degree of severity has proven itself clinically, as it also provides information useful for deriving necessary therapeutic measures (Table 14.1).

Table 14.1  Clinical classification of severity of trauma to the larynx

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Visible hematoma, hemorrhage, no fracture</td>
</tr>
<tr>
<td>2</td>
<td>Hematoma, swelling, nondisplaced stable fracture</td>
</tr>
<tr>
<td>3</td>
<td>Free cartilage, vocal cord dysfunction, unstable moveable fracture</td>
</tr>
<tr>
<td>4</td>
<td>Open laryngeal injury, laryngotracheal separation</td>
</tr>
</tbody>
</table>
Fig. 14.3  Schematic illustration of injuries of the larynx (modified from Richter 1992).

a  **Linear vertical laryngeal fracture.** A common form of fracture in noncalcified cartilage skeleton; associated with injuries of internal structures, which are destroyed as a result of elastic deformity of the inward and outward movement of the cartilage laminae. 1 Destruction of the soft tissues on one side.

b  **Linear oblique fracture of the larynx.** The fracture line is above the level of the glottis (supraglottic fracture). The cranial thyroid cartilage fragment can be considerably displaced toward the hyoid, so that there is marked diastasis, which can be observed in the intrinsic structures as separation and mucosal tears in the Morgagni’s ventricle. The region around the arytenoids is edematous and hemorrhagic. Dislocation of the arytenoid cartilage is possible. 1 Edematous arytenoid.

c  **Multiple fracture or comminuted fracture of the larynx.** This fracture form is most suited to calcified cartilage. The harder cartilage better protects the soft tissues of the transglottic space. However, the epiglottis is often separated at the petiole and covers the entrance to the larynx. Visualization of the interior of the larynx is then only possible with transnasal pharyngolaryngoscopy. 1 Supraglottic constriction.

d  **Cricoid fracture.** Proximity of the recurrent nerves causes palsy of the vocal cords with unilateral or bilateral medialization of the vocal folds. The mucosa of the subglottic space is injured and heals with formation of granulation tissue, which may develop into subglottic stenosis. 1 Cricoid fracture and fracture of the first tracheal ring; 2 view of the vocal fold level with complete vocal fold closure (medialization); severe respiratory distress, voice good; 3 subglottic granulation.
Fractures

The dynamics of laryngeal fractures vary. Fracture dynamics are determined by the direction and force of the blow, and by the maximum bending or fracture behavior of the cartilage. Compression testing has shown that the laryngeal lumen closes with a compression force of 15–20 kg from anterior.

Anteroposteriorly Directed Trauma

Anteroposteriorly directed trauma compresses the thyroid cartilage against the cervical spine, dislocating the arytenoid cartilages to dorsal. The “elastic strength” of the cartilage skeleton causes the thyroid cartilage to rebound to ventral, resulting in internal injury:

- Avulsion of the thyroarytenoid muscle (vocal ligament) at the vocal process of the arytenoid cartilage, which fold into the lumen.
- Avulsion of the thyroarytenoid muscle (vocal ligament) at the anterior commissure near the macula flava.
- Wide separation of the inner perichondrium of the thyroid cartilage.
- Dislocation and overlapping of thyroid cartilage laminae with impaction of the cartilage in the inner musculature. The vocal ligament on the side of impact cannot move.

In addition, disarticulation of the cricothyroid joints may occur with cranial displacement of the thyroid cartilage laminae into the base of the tongue. The thyroepiglottic ligament avulses and there is prolapse of fatty tissue from the pre-epiglottic space into the laryngeal lumen.

The most common thyroid cartilage fracture is the vertical midline fracture.

Lateral Trauma

Laterally directed force causes the cartilage to break at two points. Segmental fractures of the thyroid cartilage laminae occur in the ventral portions. Usually the arytenoid cartilage is dislocated or also fractured. Delayed sequelae include unilateral or bilateral ankylosis of the cri-coarytenoid joints.

Supraglottic Injuries

Supraglottic structures include the hyoid bone, thyrohyoid membrane, and supraglottic larynx. In supraglottic injuries the thyroid cartilage is disrupted horizontally.

The epiglottis and vestibular ligament are avulsed from the anterior commissure. The posterior wall of the pharynx is often also injured.

Transglottic Injuries

The transglottic space at the level of vocal fold insertion on the thyroid cartilage may be injured.

Transglottic injuries are usually caused by impact from a blunt or flat object at a right angle to the thyroid cartilage.
Subglottic Injuries

This region includes the cricothyroid membrane, the cricoid cartilage itself, and the first tracheal ring. The cricoid cartilage is the only complete laryngeal cartilage ring. Isolated fracture is uncommon as is isolated fracture of the arytenoid cartilage.

Tracheal Injuries

Tracheal injuries include fractures of the cartilage rings from the first tracheal ring to the bifurcation.

- A direct frontal blow usually causes fractures in the area located between the impacting object and the cervical spine (hammer-and-anvil effect).

Lateral impact causing hyperextension of the soft tissues of the neck leads to tissue rupture.

Ruptures

A different mechanism of injury underlies rupture. Direct frontal impact forces the vertebral column to move excessively to dorsal, causing tissue rupture.

- The glottis closes reflexively, and the increased pressure in the larynx and trachea causes rupture.

Supraglottic Rupture

In this case the rupture is located on the inferior side of the vestibular folds in the Morgagni’s ventricles. The thyrohyoid membrane is torn.

The hyoid bone, root of the tongue, and epiglottis, with the vestibular folds, form the cranial portion, and the larynx and trachea the caudal portion.

Subglottic Rupture

Subglottic rupture is highly uncommon. The tear runs through the cricothyroid ligament and the cricothyroid membrane of the vocal folds.

Laryngotracheal Separation

Laryngotracheal separation is the most common form of rupture and can occur either as partial or complete rupture.

Partial Laryngotracheal Separation

The tracheal stumps remain connected to each other at the membranous portion of the trachea. The two airways separate 1–1.5 cm from each other to ventral. Temporarily sufficient breathing is usually possible. Figure 14.5 shows a partial tracheal separation.

- Intubation attempts may tear the membranous bridge apart and dramatically worsen the patient’s respiratory status.

Isolated rupture of the membranous portion of the trachea is an uncommon finding. In experiments the membranous portion ruptures at levels of 0.3–0.68 Pa.

Complete Laryngotracheal Separation

Complete disruption is followed by retraction of the trachea due to pulling forces into the thorax, resulting in diastasis. Soft tissues prolapse into the space in between, obstructing the airway.

- Unlike the cervical trachea, the thoracic segment is a very uncommon site of rupture because of its deep, protected position behind the sternum. Injury of main stem bronchi is more likely. If rupture directly involves the cricoid cartilage, there may be additional strain or tearing of the recurrent laryngeal nerves.

Esophageal Rupture

A sudden increase in intrathoracic pressure can rupture the esophagus. There is usually concomitant tracheal rupture. Causes related to penetrating trauma—puncture or missile wounds—are uncommon. The chief symptoms are retrosternal pain, mediastinal emphysema, and shock.

In the early stage, bradycardia suggests vagal irritation. With development of mediastinitis, the patient experiences fever, tachycardia, and tachypnea.

Radiographic views of the esophagus with gastrografin administration reveal extravasation of the water-soluble contrast agent. If injury is nonperforating, gastrografin is absorbed and excreted via the kidneys, and thus not detected with this technique.

- Rigid esophagoscopy is contraindicated!
Clinical Signs and Symptoms

Clinical symptoms of laryngeal and tracheal injury are:
- respiratory distress;
- emphysema;
- coughing up light-red blood;
- dysphagia;
- dysphonia.

Respiratory Distress

The cause is usually submucosal or peritracheal hematoma. Obstruction runs the gamut of severity. Dyspnea can be worsened by aspiration.

Emphysema

Subcutaneous emphysema: Subcutaneous emphysema can be palpated bimanually as air crepitation (“snowball crepitus”) beneath the skin and also causes the contour of the neck to bulge outward.

Emphysema of the neck and mediastinum: This is deep emphysema that occurs in injury of the pharynx, cervical esophagus, and cervical trachea (see Fig. 14.5). Initially it develops in the pretracheal layer of the cervical fascia, later reaching the surface, and spreading over the head, arms, and thorax.

Complications

Salivary fistula: Injury to the pharynx and esophagus can cause a salivary fistula. Saliva leaks into the cervical space, leading to phlegmon and, with further development, mediastinitis.

External salivary fistulae can develop with open wounds of the neck. They can be initially palpated by instilling air through a gastric tube placed through the wound or they may be visualized using methylene blue dye.

Esophagotracheal fistula: Esophagotracheal fistulae are formed by compression of the trachea and esophagus against the vertebral column. A necrotic area forms on the esophagus following tracheal rupture, and can be followed by fistula formation. Symptoms include coughing attacks when eating.

Infections: Infection (perichondritis, prevertebral neck abscess, and/or mediastinitis, aspiration pneumonia) can occur as a delayed complication.
Evaluation Procedures and Functional Testing

Endoscopy

Magnifying Laryngoscopy and Flexible Nasopharyngolaryngoscopy

Endoscopic examination should be performed for any suspected injury of the larynx. The most suitable method is transnasal flexible pharyngolaryngoscopy.

Examination with magnifying laryngoscopy requires patient cooperation, which is not always to be expected.

Examination allows assessment of injuries involving mucosa, cartilage, and muscle, as well as functional testing of the vocal folds and structures involved in swallowing.

Microlaryngoscopy, Tracheobronchoscopy

Microlaryngoscopy should be used for further evaluation and for initiating necessary treatment measures for injury of the larynx. Routine bronchoscopy is performed using a rigid ventilating bronchoscope, as the aspiration channel in a fiberoptic bronchoscope may be too small if there is heavy bleeding. However, it should be noted that fiberoptic bronchoscopy allows more exact peripheral observation and is less invasive.

In tracheal ruptures, the threading of the instrument through the trachea in a bronchoscopy can secure the airway. Rigid bronchoscopes containing a battery-pack in the handle are available for emergency use.

Evaluation of Phonation

Testing of phonation allows a more precise differentiation of vocal fold function and impairment. Testing is an essential part of monitoring injury course and long-term follow-up therapy after laryngeal injury.

Stroboscopy

Stroboscopy allows examination of vocal fold vibration, helping to assess whether glottic function is intact. Pliability, structure, and surface characteristics of the glottis are evaluated. In vocal fold palsy, the tension difference between muscle and mucosa is absent, eliminating the mucosal wave. In ankylosis of the arytenoid joint, on the contrary, mucosal wave function remains intact.

Vocal Output and Characteristics

Tone sustainability: After maximum inspiration, the patient hums at about his or her middle speaking voice range, for at least 15–25 seconds. Values under 10 seconds are considered pathologic.

Vocal range testing: Range (highest and lowest pitch) is determined using instruments to play notes for comparison. Testing usually comprises two octaves, seldom three octaves. A selected tone is sung into a microphone as quietly and as loudly as possible to measure acoustic pressure (range of vocal output or voice dynamics).

Electrodiagnostic Testing

Electrophysiologic diagnosis of the larynx allows differentiation between neurogenic palsy and myogenic damage or ankylosis of the cricoarytenoid joint.

Testing allows for topognostic evaluation of neural lesions as well as assessment of extent of functional neural disturbance, which can be useful for surveillance.

There are three methods of testing:
- Electromyography (selective needle EMG of all or individual laryngeal muscles): voluntary and potentially pathologic spontaneous activity are evaluated;
- Neuromyography (NMG): electrostimulation of laryngeal nerves;
- Reflex myography (RMG): electrostimulation of laryngeal reflexes.
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**Treatment**

Any open injury of the larynx and trachea must receive immediate surgical care. If laryngeal injury is first detected with microlaryngoscopy, management should occur in the same session.

In healthy patients without any secondary symptoms, and with wound edges that are not more than 4 cm apart, partial ruptures of the trachea can be managed conservatively by placing a stent over an appropriate tracheal tube for 5 days.

All other injuries must receive immediate surgical care.