Laryngotracheal Blunt Trauma

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Key Points

- The incidence of laryngotracheal trauma is probably underestimated because the consequence of a laryngotracheal trauma can range from mild hoarseness to complete airway compromise.
- Narrowing of the airway results in breathing difficulty. These are the patients registered in emergency archives. Among these patients, complications such as chronic stenosis and voice changes are as common as 15–25%. The team in charge of the patient has to keep in mind that the airway will become worse with time as the edema increases.
- The elasticity of the cartilage framework contributes to its recoil, saving the airway even if the external pressure or blow is strong enough to exceed the resistance of this structure.
- The larynx and trachea are vulnerable only to direct blows to the anterior of the neck. The object of contact has to approach the larynx in a horizontal manner. If the object is in vertical position relative to the body, the impact will be blocked by the facial skeleton and/or sternum and clavicle heads.
- Fiberoptic laryngoscopy has become the initial evaluation tool. In case the endolarynx cannot be assessed with flexible laryngoscopy due to laryngeal edema, direct laryngoscopy should be carried out under general anesthesia. All of the upper aerodigestive tract mucosa should be examined.
- Cartilage frame fractures are extremely rare in pediatric age group, while soft tissue edema and hematoma are more common. In elderly people, the cartilage framework is usually calcified and underwent osseous transformation. The laryngotracheal fractures in this age group are more common and usually more severe.
- Posterior or lateral dislocations of the arytenoids may occur at this stage when the thyroid cartilage is pressed against the vertebra by external pressure. Posterior dislocation of the arytenoids is reported to be more common; however,

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this is usually associated with a traumatic orotracheal intubation trauma rather than an external trauma. Dislocations can be confused with vocal cord paralysis. EMG is an important tool to differentiate the two conditions.
- In case of complete disruption between the cricoid cartilage and the trachea, the strap muscles and the surrounding fascia can rarely serve as a temporary airway until the patient is managed by intubation or tracheotomy.
- Once the injuries are addressed and the patient is stabilized and assessed, surgical repair of the larynx and cervical trauma should be done as soon as possible. A patient with minimal soft tissue edema, mobile vocal cords, and no difficulty with breathing can be observed closely.

Laryngotracheal trauma including blunt and penetrating traumas is one of the common reasons of airway compromise. The incidence of this type of injury is probably underestimated because the consequence of a laryngotracheal trauma can range from mild hoarseness to complete airway compromise. In the USA, 1 in 14,000 to 30,000 of emergency room visits is due to laryngotracheal trauma [1, 2]. Many more are unnoticed because the injured person doesn't take mild hoarseness seriously and doesn't apply to the emergency department.

The most common causes are motor vehicle accidents and sports injuries [3, 4]. A decrease in the incidence of laryngotracheal injury was observed, thanks to the safety belt and increased safety features of motor vehicles. The introduction of airbags should eliminate sudden and savage blow of the anterior neck trauma caused with the steering wheel or other hardware on the dashboard as well as injuries caused by misplaced safety belts. However, there is no objective study demonstrating this beneficial effect.

Laryngotracheal trauma due to sports injuries is not uncommon in contact sports like football, basketball, baseball, and soccer. One of the common causes of blunt larynx trauma is biking or traffic accidents, where the larynx is hit against steering bar of the bicycle or the steering wheel of the car.

The degree of injury may vary from mild soft tissue edema to severe laryngeal framework fractures and to complete separation between the larynx and trachea. Mild injuries that result in temporary voice changes or throat pain probably go unregistered in medical archives. This degree of injury is only temporary due to the extreme flexibility and resistance of the laryngotracheal framework. More severe trauma may cause injury to the framework and severe soft tissue edema or hematoma. Narrowing of the airway results in breathing difficulty. These are the patients registered in emergency archives. Among these patients, complication rates are as high as 15–25% [5, 6]. Complications include chronic airway obstruction and chronic voice changes. Injury to the laryngotracheal structure can be lethal because of airway compromise. Severe injuries with complete airway obstruction necessitate immediate airway management either with orotracheal intubation or more commonly with emergency tracheotomy. Some of these patients may not survive the time interval between the accident and arrival of medical assistance. Mortality rates are reported to be 2–35% among the severe laryngotracheal injuries [5, 6]. The principles of immediate airway management as well as long-term management of complications will be discussed in this chapter.

15.1 Injury of the Cartilage Framework of the Larynx and Cervical Trachea

The airway is well protected as it passes through the neck. Thyroid cartilage and tracheal rings provide a framework that prevents the airway from external compression. The elasticity of the

cartilage framework contributes to its recoil, saving the airway even if the external pressure or blow is strong enough to exceed the resistance of this structure. The larynx and more pronouncedly trachea can almost completely be compressed and can recoil to the original structure once the external pressure subsides. The optimal balance of strength and elasticity of the cartilage network is achieved at early adulthood. During childhood, the cartilage is much more elastic and lacks the structural strength. At this period in life, the airway is more vulnerable to external pressure resulting in complete obstruction of airway. However, the recoil effect is more pronounced as well. Once the external pressure is removed, the recoil is almost complete. Therefore, cartilage frame fractures are extremely rare in pediatric age group, while soft tissue edema and hematoma are more common [7, 8]. In elderly people, the cartilage framework is usually calcified and underwent osseous transformation. The airway is more resistant to external pressure. This increased resistance doesn't necessarily serve the airway protection. Loss of elasticity results in fractures with less forceful blows. The laryngotracheal fractures in this age group are more common and usually more severe [6, 8].

Surrounding the cartilage framework are the strap muscles, the subcutaneous fat, and the skin. These extralaryngeal soft tissues offer a buffer between the impact and laryngotracheal cartilage framework. Sternocleidomastoid muscles protect the larynx from lateral blows. The mandible often blocks the impact that comes from a superior to inferior angle. Likewise, the clavicles and sternum may block the impact that comes from an inferior direction. The larynx and trachea are vulnerable only to direct blows to the anterior of the neck. The object of contact whether it be a bat, a steering wheel, a dashboard, or a rope has to approach the larynx in a horizontal manner. If the object is in vertical position relative to the body, the impact will be blocked by the facial skeleton and/or sternum and clavicle heads [8].

The most common blunt trauma to the larynx and cervical trachea is caused by motor vehicle accidents. The steering wheel and dashboards are located at the correct angle to produce an injury to the larynx and trachea. Collision of the vehicle causes a sudden deceleration throwing the body into the steering wheel and dashboards. Safety belts help to slow the velocity of the impact, whereas airbags may help to prevent the contact totally. In the case where no seatbelt and airbag are present, the upper body is thrown violently against the steering wheel and dashboard. Even at this situation, the head is usually flexed, and the mandible serves to protect the larynx. If the larynx comes into contact with a hardware, the first impact is taken by the thyroid prominence, and the thyroid cartilage is compressed against the vertebra, displacing the thyroid alas laterally. When the point of maximal compressibility is reached, the thyroid cartilage fractures in vertical axis either medially or more commonly paramedially [8, 9] (Figs. 15.1, 15.2, and 15.3). The point of maximal compressibility varies greatly with age and from person to person. Younger victims may experience a single line of fracture, while older people may have multiple fractures.

If the impact is more inferior, the cricoid cartilage may be affected (Fig. 15.4). The cricoid cartilage is a complete cartilage ring with more rigidity compared to the tracheal rings and the thyroid cartilage. While the thyroid alas can spread laterally with the advantage of being not a completely circular structure, the cricoid cartilage cannot displace laterally but rather gets compressed into an oval shape [8]. This can result in a median fracture. More severe blows can cause the fragmentation of the cricoid cartilage and the loss of airway (Fig. 15.5). This fragmentation can also cause the injury to one or both the recurrent laryngeal nerves at the region of the cricothyroid joint with subsequent vocal cord paralysis and further narrowing of the airway.

If the impact is lower than the cricoid cartilage, a complete separation of the larynx and trachea may occur. The usual site of separation is between the cricoid cartilage and first tracheal ring [10] (Fig. 15.6). The separation can be accompanied by a cricoid cartilage fracture or

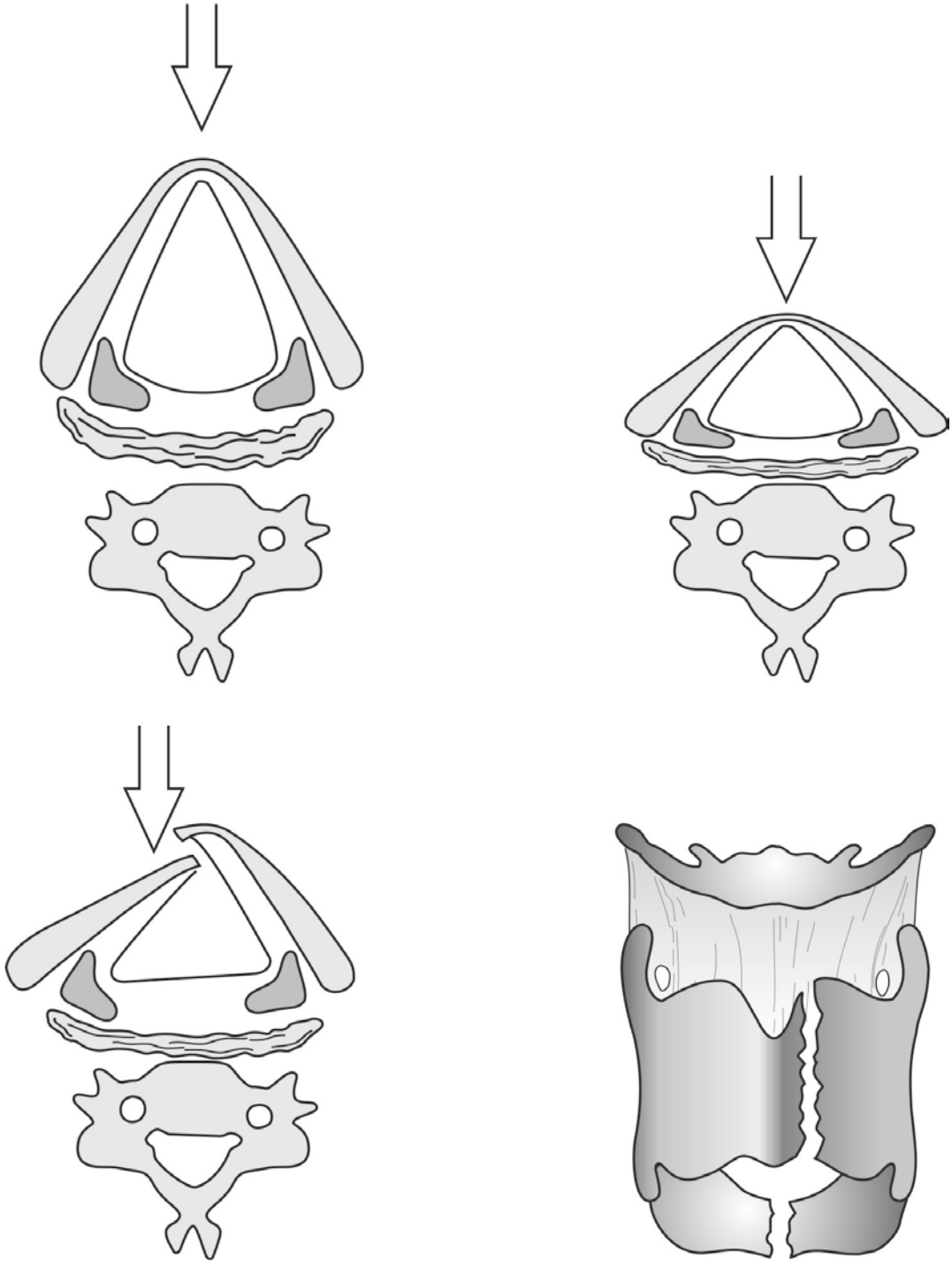

Fig. 15.1 The first impact is taken by the thyroid prominence, and thyroid cartilage is compressed against the vertebra, displacing the thyroid alas laterally. When the point of maximal compressibility is reached, the thyroid cartilage fractures in vertical axis either medially or more commonly paramedially

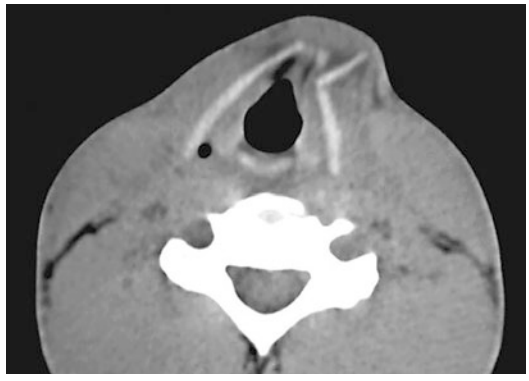

Fig. 15.2 CT image of a patient with paramedian fracture of the thyroid cartilage. A fragment of cartilage is displaced laterally. The airway appears to be patent

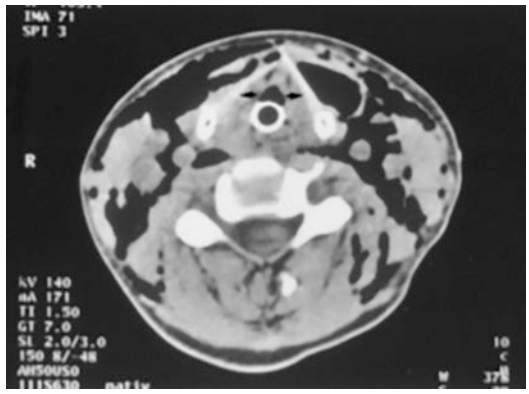

Fig. 15.3 CT image of a patient with median fracture of the thyroid cartilage. There is extensive subcutaneous emphysema in the neck suggesting soft tissue injury to the larynx. There is an endotracheal tube in the larynx

Fig. 15.4 CT image of patient with cricoid fracture. The cricoid cartilage is fractured in two places. There is an endotracheal tube in the airway

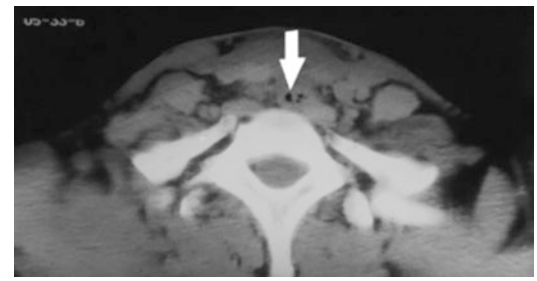

Fig. 15.5 CT image of a patient with almost complete collapse of the airway

arises without accompanying fracture. This type of injury is more commonly associated with the neck coming into contact with a fixed cable or rope while riding a motorbike, jet ski, snowmobile, and similar vehicles where the neck is not protected against outside objects.

There are two vectors of force causing the laryngotracheal separation. The first one is the compression of the cricoid cartilage and the trachea against the vertebral bodies as described above. The second vector is the "telescoping effect." When the neck comes into contact with a fixed wire or a rope while traveling fast, the neck comes to a complete stop, while the body still moves forward. This induces a pulling of the trachea from the fixed larynx causing the separation [11]. The separation can be complete or incomplete. The posterior membranous portion of the trachea may remain attached, while the anterior cartilaginous trachea is separated from the larynx. In that case, the trachea doesn't retract completely into the chest. An intubation or a tracheotomy is easier in case of incomplete separation airway, the posterior wall serving as a guide for airway management.

If the trachea is completely separated from the larynx, it retracts into the chest. This will most often result in complete and sudden loss of airway, which is fatal. The strap muscles and the surrounding fascia can rarely serve as a temporary airway until the patient is managed by intubation or tracheotomy.

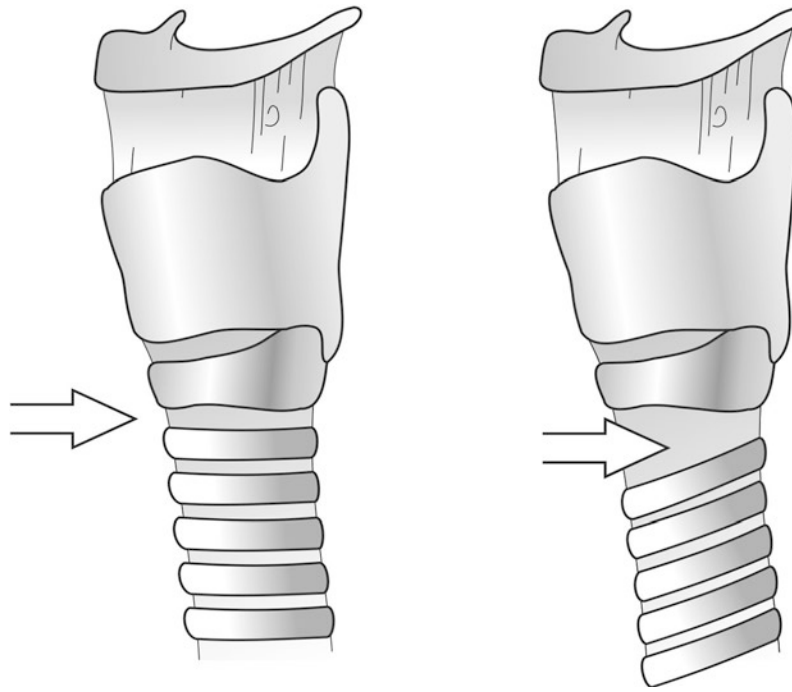

Fig. 15.6 A horizontal trauma at the level of cricoid and first thyroid cartilage usually results in cricotracheal separation. Posterior tracheal wall may still be attached

Another mechanism of injury is caused by children falling onto the handlebar of a bicycle or onto any horizontal hard object. This kind of impact may cause the cricoid cartilage to displace superiorly under the thyroid cartilage [12, 13]. This can cause a doubling of the soft tissues onto themselves and a severe soft tissue edema. Frequently, this injury happens in younger children with flexible cartilages. Fractures don't occur with this kind of trauma in younger children. Adults who experience this kind of impact present with cricoid fractures. This displacement may cause injury to one or both the recurrent laryngeal nerves with subsequent vocal cord paralysis [11–14].

15.2 Injury of the Cricoarytenoid Joint

Arytenoid cartilages are in relation with the cricoid cartilage via a joint and with the thyroid cartilage via the vocal ligament and the thyroarytenoid muscle. Arytenoid cartilages are located deep to the thyroid cartilage and the hyoid bone. In case of external laryngeal trauma, the fracture of arytenoid cartilages is prevented by the thyroid cartilage, but most importantly the extreme mobility of the cricoarytenoid joint [15]. When the thyroid cartilage is pressed against the vertebra by external pressure, the arytenoid cartilages are displaced laterally and posteriorly. Posterior or lateral dislocations of the arytenoids may occur at this stage. With the sudden release of pressure, the thyroid cartilage springs back to its original shape. This sudden springing motion pulls the arytenoid cartilages by its muscular attachments anteriorly to the thyroid cartilage [9, 16]. This motion may result in anterior luxation or subluxation of the arytenoid cartilages. Posterior dislocation of the arytenoids is reported to be more common; however, this is usually associated with a traumatic orotracheal intubation trauma rather than an external trauma [16]. Dislocations of the arytenoid cartilages are usually associated with severe soft tissue trauma. Soft tissue trauma can cause an edema masking the larynx and making the diagnosis of dislocation difficult [17]. Dislocation of the cricoarytenoid joint impairs vocal cord movement. Dislocations can be confused with vocal cord paralysis. EMG is an important tool to differentiate the two conditions. EMG would detect the

muscle contraction potentials in case of an arytenoid dislocation. These potentials would be absent in case of vocal cord paralysis.

15.3 Laryngeal Soft Tissue Injury

External blunt trauma to the larynx almost always results in soft tissue injury. The loose submucosal connective tissue is very prone to fluid collection and edema. Even the mildest trauma results in some degree of swelling of the endolarynx. This may manifest as change in voice or more seriously as breathing difficulty. As the impact of trauma increases, the likelihood of having a mucosal laceration increases as well. Lacerations may cause bleeding and contribute to airway problems. Laryngeal framework fractures are usually associated with mucosal injuries [9]. Mucosal injury may range from mild tissue edema to large lacerations. Mucosa can be crushed or caught between cartilage fragments. In case of laryngotracheal separation, the mucosa cannot withstand the pulling forces and separate as well. Large laceration of the mucosa may cause an emphysema by air leakage into the soft tissues of the neck. Air can accumulate around the strap muscles as well as in the subcutaneous plane. Extensive ecchymosis and crepitation of the skin make the diagnosis of emphysema easily recognizable. Soft tissue emphysema may contribute to airway compromise (Figs. 15.7 and 15.8). After repair of the larynx, air in the soft tissues is gradually resorbed.

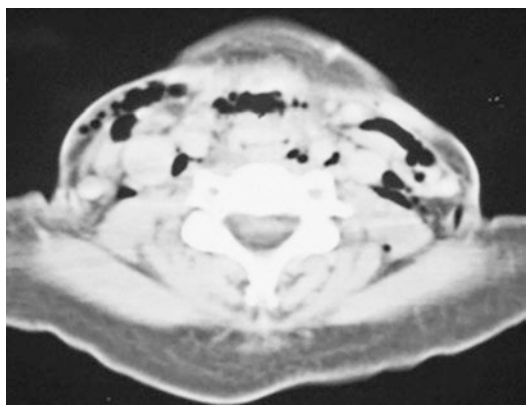

Fig. 15.7 In this CT scan, there is extensive subcutaneous emphysema, and the airway cannot be identified

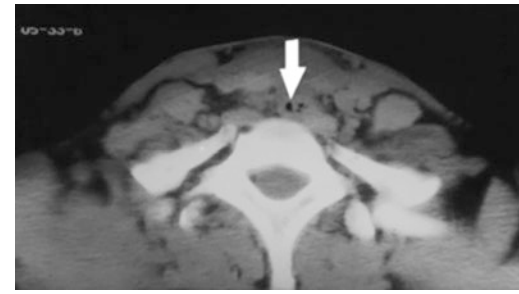

Fig. 15.8 CT scan at the level of the hyoid bone demonstrating subcutaneous emphysema. The airway can only be identified by the presence of an endotracheal tube

A distinct soft tissue injury is the rupture of thyroarytenoid muscle and ligament. As the thyroid cartilage is pressed against the vertebra and springs back, the muscle and the ligament relax and undergo a tension in a very short time period. This may result in rupture or detachment of the ligament from the thyroid cartilage at the level of the anterior commissure. As the ligament detaches from the anterior commissure, usually a small piece of cartilage also detaches. Rupture or detachment result in bunching of the vocal cord and narrowing of the airway. The injury is always accompanied by a severe edema of Reinke's space. Dislocation of the arytenoid cartilage may also accompany the injury [15].

Suicidal or accidental hanging causes trauma to the supraglottic larynx. The rope around the neck tightens at the level of the thyrohyoid membrane [18]. The external pressure causes the preepiglottic space to move posteriorly pushing the epiglottis against the arytenoid cartilages. This causes a complete obstruction of the airway. If the person survives the impact, the subsequent injury is a severe supraglottic edema. The thyrohyoid membrane may rupture, and the preepiglottic fat tissue may herniate into the airway. Hyoid bone fractures occur rarely if the rope tightens at the level of the hyoid bone [19]. Hyoid bone fractures don't have any clinical implications unless a fragment is tearing through the airway mucosa. Thyroid and cricoid cartilages can also be fractured. Laryngotracheal separation is reported to occur with hanging injuries [20].

15.4 Emergency Management of Laryngotracheal Blunt Trauma

Blunt trauma to the laryngotracheal area can be an airway emergency. All cases should be managed according to the emergency airway management protocol of the managing institute regardless of the degree and place of the trauma. Loss of precious time can be lethal in case of laryngotracheal injuries. Elaborate examination and imaging should be left for later. Management of the airway is the primary objective. If the patient is not breathing at the time of initial management, cardiopulmonary resuscitation should be carried out immediately. Many of these patients have accompanying cervical spine injuries. Care should be taken not to move the cervical spine. Unless proven otherwise, all patients should be assumed to have cervical spine injury. Endolaryngeal edema develops immediately after the laryngotracheal trauma. If the emergency team arrives soon after the trauma, orotracheal intubation may be successful. After a certain period of time, the edema is present, and an intubation may be extremely difficult necessitating a tracheotomy [1, 21]. The team in charge of the patient has to keep in mind that the airway will become worse with time as the edema increases. In case of extensive laryngotracheal trauma, intubation should be considered even if the patient is able to breathe sufficiently. As mentioned before, intubation could be difficult if not impossible as time passes. Orotracheal intubation can be achieved even in case of laryngotracheal separation. Laryngotracheal separation usually occurs in the anterior wall of the trachea between the cricoid and first tracheal rings, with the posterior wall of the trachea staying intact. If the endotracheal tube is advanced with the guidance of the posterior tracheal wall, intubation of the separated tracheal segment can be achieved. Even if the complete separation occurs, the surrounding soft tissues don't collapse immediately and can serve as a guide for intubation [1, 21] (Fig. 15.9). If orotracheal intubation can be achieved, the endotracheal tube serves as a stent preventing a possible synechia of the endolaryngeal mucosa and thus making further airway management easier. If intubation cannot be achieved after a few trials, no time should be lost before attempting the tracheotomy.

The level of tracheotomy should be decided according to the level of the trauma. For a high laryngeal injury like a hanging case, the fastest and easiest way would be a cricothyrotomy. However, if the thyroid cartilage and/or cricoid cartilage is fractured, a lower tracheotomy is necessary. The level of injury can be determined by palpation of the neck under emergency conditions. Fragments of cartilage and/or depressions in the laryngotracheal framework show the site of injury. However, the edema and hematomas developing in the soft tissues of the neck can make this examination difficult. In this case, the mechanism of injury gives clues about the injury site. As said before, the most common laryngotracheal injuries are caused by steering wheel and dashboard impacts in motor vehicle accidents, inducing an injury at the level of thyroid and cricoid cartilages. Bicycle and sports accidents also cause an injury at the same level. In this case, the best level for tracheotomy is two tracheal rings below the injury site [1, 21] (Fig. 15.9). Tracheotomy should be realized below the third tracheal ring. Laryngotracheal separation is likely in case of a jet ski or snowmobile accident where the neck comes into contact with a fixed object like a rope. Laryngotracheal separation is the hardest injury to manage in terms of airway. The airway can be secured by neck exploration and identification of the separated tracheal segment low in the neck or thorax. The endotracheal tube can be passed into the trachea from the separation. Tracheal segment should be secured to the skin incision and to the head of the clavicle with non-absorbable sutures. This step facilitates a reintubation in case of accidental extubation. Once the airway is secured, other life-threatening injuries should be addressed before any attempt to repair the laryngotracheal damages.

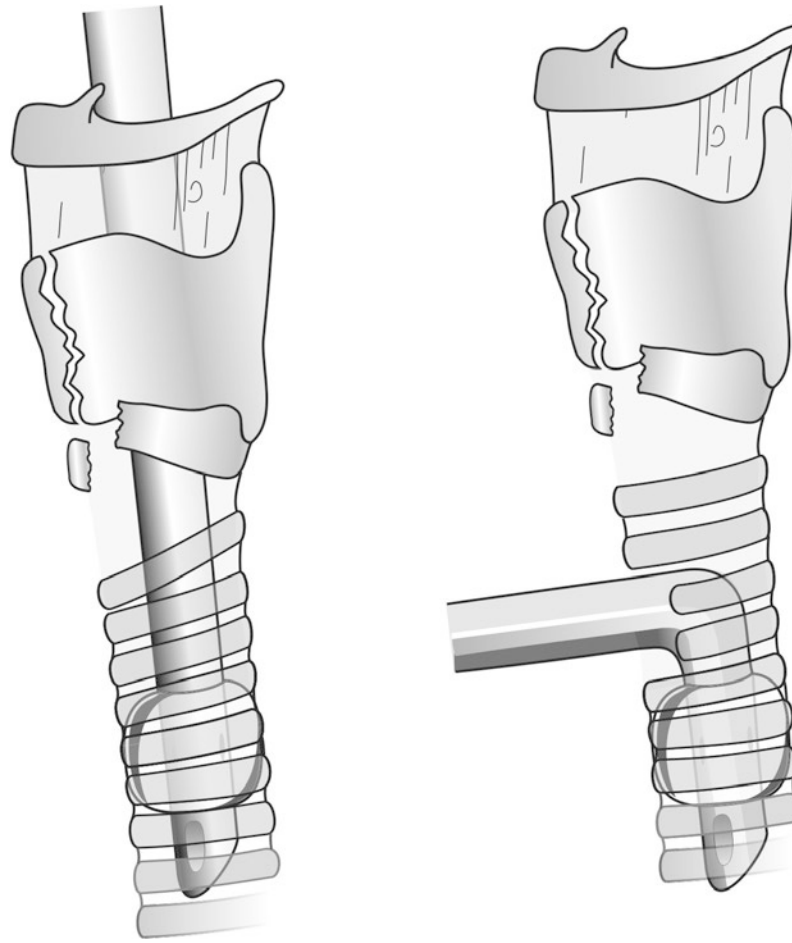

Fig. 15.9 The first option for airway management is endotracheal intubation. Posterior tracheal wall can guide the endotracheal tube in the airway even if the distant airway cannot be visualized. The second option is to perform a tracheotomy. The best place to perform a tracheotomy is two tracheal rings below the site of injury

15.5 Evaluation of Laryngotracheal Injury

Once the patient is stabilized, evaluation of damages should be done.

Endoscopic assessment is the next step. Today, fiberoptic laryngoscopy has become the initial evaluation tool. Fiberoptic laryngoscopy is less traumatic and much more comfortable for the patient. Checking the airway patency and any potential causes that might impair the airway is the first priority. Tracheotomy should be performed in case of increasing edema or hematoma. If the airway patency is adequate, the site and degree of damage should be evaluated. Mucosal lacerations, location of arytenoids, and vocal cord mobility must be assessed.

Supraglottic edema may prevent examination of glottic and subglottic areas [22]. In case the endolarynx cannot be assessed with flexible laryngoscopy due to laryngeal edema, direct laryngoscopy should be carried out under general anesthesia. All of the upper aerodigestive tract mucosa should be examined. Mobility of the arytenoid cartilages should be tested with a blunt instrument, such as a velvet tip suction or cup forceps with the tip in closed position. Additional trauma to the laryngeal mucosa should be avoided.

Bronchoscopy can also be performed to assess the trachea. The downside of direct laryngoscopy is the inability to assess the function properly.

Esophagoscopy should be carried out as well. Esophageal trauma as a result of an impact to the neck is not infrequent. Videostroboscopy is a

valuable tool to assess vocal cord injuries. Videostroboscopy can reveal even very subtle injuries to the vocal cords. If the patient is already intubated, direct laryngoscopy is indicated.

Imaging of the laryngotracheal framework can precede the direct laryngoscopy. CT scan of the neck should be performed if flexible laryngoscopy reveals an extensive soft tissue injury, a vocal cord paralysis, and a bare cartilage or if there are palpable cartilage fractures and crepitations in the neck. The CT scan should include fine cuts through the larynx. Special attention should be given to thyroid, cricoid, and tracheal cartilages, as well as the localization of arytenoid cartilages. MRI is better to assess soft tissue injuries, but CT remains the imaging of choice to assess laryngotracheal framework. Buch et al. analyzed the site of fractures on CT and reported that the most common site of fracture is the thyroid cartilage (45/55 patients), followed by cricoid fractures in 13/55 patients. Hyoid fractures were less common (8/55 patients). Multi-site fractures were observed in 12/55 patients usually associated with severe edema [23]. A postmortem evaluation of 284 cases with neck trauma showed similar injury rates with 40% fracture of the superior horn of the thyroid cartilage and 20% hyoid bone fracture [24]. Laryngeal EMG is very important to assess nerve injuries. Superior laryngeal nerve is usually not disturbed by external trauma to the larynx. However, recurrent laryngeal nerve may frequently be affected by injury involving the cricoid cartilage and laryngotracheal separation. EMG can detect contraction potentials and resting potentials even in unconscious patients.

If observation is decided, repeated fibroscopies or direct laryngoscopies can be done at 24, 48, and 72 h after surgery to monitor the endolaryngeal edema.

15.5.1 Laryngotracheal Trauma Repair

Once the lethal injuries are addressed and the patient is stabilized and assessed, if indicated, surgical repair of the larynx and cervical trauma should be done as soon as possible. Early repair has more favorable results compared to late repair [25]. About 50% of the patients reporting to the emergency department require surgical intervention [26].

Decision to repair the laryngotracheal injury should be based on the presence and severity of cartilage fragmentation, the degree of airway obstruction, and a recurrent laryngeal nerve injury (Table 15.1). A patient with minimal soft tissue edema, mobile vocal cords, and no difficulty with breathing can be observed closely. The managing team should remember that soft tissue edema may worsen with time. Close observation is necessary. Extensive soft tissue injuries necessitate either endoscopic or open repair. Table 15.2 is a list of endoscopic findings that indicate laryngeal repair. If an arytenoid dislocation is observed, the best results are obtained with early endoscopic reduction.

Presence of cartilage fractures usually requires open exploration, repair, and fixation. Single median or paramedian vertical thyroid cartilage fractures are the most common fractures. Close

Table 15.1 Indications for open surgery

Displaced single fracture of the laryngotracheal framework
Multiple fractures of the laryngotracheal framework (including non-displaced fractures)
Laryngotracheal separation
Thyroarytenoid muscle and ligament tear or detachment
Esophageal tears
Arytenoid dislocation that cannot be reduced endoscopically
Hematoma that is obstructing the airway
Denuded cartilage

Table 15.2 Endoscopic findings that require surgery

Exposed cartilage
Depressions in airway that suggest cartilage fracture
Laryngotracheal separation
Mucosal fragments that obstruct airway
Injury to the free edge of vocal cords
Cricoarytenoid dislocation
Displacement of the epiglottis
Herniation of preepiglottic contents
Thyroarytenoid muscle or ligament injury

observation can be an option if the fracture is single and not displaced, without extensive soft tissue injury or detachment of the thyroarytenoid muscle. However, fixation of the framework by an external approach is the safe alternative because the fragments of cartilage can be displaced afterward, obstructing the airway.

Penetrating tears of the esophagus should be addressed with an open neck exploration.

If there is no indication for open approach (see Table 15.1), repair can be carried out with rigid laryngoscopy. Mucosal flaps that obstruct the airway or interfere with phonation should be removed. Obtaining straight free edges of vocal cords is essential. Mucosal flaps on the free edge of the vocal cord should be positioned back in place or removed. Cold steel instruments, powered instruments, or laser can be used for removal. If the preepiglottic space contents are herniated into the airway without accompanying fractures, these tissues should be removed. In case of epiglottis obstructing the airway, part of or the entire epiglottis can be resected. This can be achieved with laser or powered instruments.

In case of cricoarytenoid luxation, repositioning of the arytenoid cartilage should be attempted. Early reduction has better results, because ankylosis will be organized in about a week. Posterior dislocation can be reduced by applying a medial and anterior force with an instrument placed posterior to the dislocated arytenoid. Laryngoscope can be used to force the arytenoids anteriorly. Anterior dislocations can be reduced by placing the rigid laryngoscope just anterior to the displaced arytenoids and applying posterior pressure. In anterior dislocations, there is a tendency of the arytenoid to displace inferiorly. In that case, a blunt right angle instrument such as a blunt hook can be placed anteriorly and inferiorly to the arytenoid, and the arytenoid can be lifted and pushed posteriorly. The maneuvers have to be very gentle. Vocal process can be fractured with forceful movements resulting in poor-quality voice after the reduction.

In some occasions, endoscopic repair can be combined with an open neck approach. Open surgery is done through a horizontal incision in a skin crease or close to the thyroid cartilage. Subplatysmal flaps are elevated; strap muscles are divided in midline and retracted laterally. Adequate exposure of the thyroid and cricoid cartilages is essential. Care should be taken not to injure the external branches of the superior laryngeal nerves or the recurrent nerves. If there is a vertical thyroid cartilage fracture, the larynx can be entered through the fracture line. Mucosal incision should preferentially be made at the midline across the anterior commissure to prevent further mucosal injury. If there is a horizontal fracture, the opening can be achieved with a midline vertical laryngofissure.

Mucosal injury should be assessed when the exposure is achieved. Reconstruction of the deep structures is the first step. Arytenoid cartilages should be restored to their original positions. Thyroarytenoid muscle or ligament tears should be repaired with sutures. If there is a thyroarytenoid muscle detachment, a strong suture can be passed through the vocal ligament and fixed to the cartilage segment corresponding to the original position of the anterior commissure (Fig. 15.10). Incorrect positioning of the vocal ligament results in poor voice quality. Once the deeper architecture is restored, the mucosal tears can be considered. The goal is to cover the entire endolaryngeal surface with mucosa to facilitate the wound healing and prevent the granuloma formation. Irreparable mucosal fragments should be removed. Remaining mucosa should be aligned and sutured with fine absorbable sutures. If there isn't enough mucosa to cover the all larynx, priority should be given to the glottic area and especially the anterior commissure. Anterior commissure is indeed the most common site of scar and synechia formation. Keels can be used to prevent web formation as well. The second important area is the arytenoid cartilages. Adequate covering of arytenoids will prevent the ankylosis of the joint by scar formation. Local mucosal flaps can be raised to facilitate the mucosal redraping. Laterally based piriform sinus flaps and posteriorly based postcricoid flaps can be used to cover the arytenoid region. Epiglottic flaps can be used to cover the anterior commissure. If there is an extensive mucosal and cartilage fragmentation in the anterior commissure,

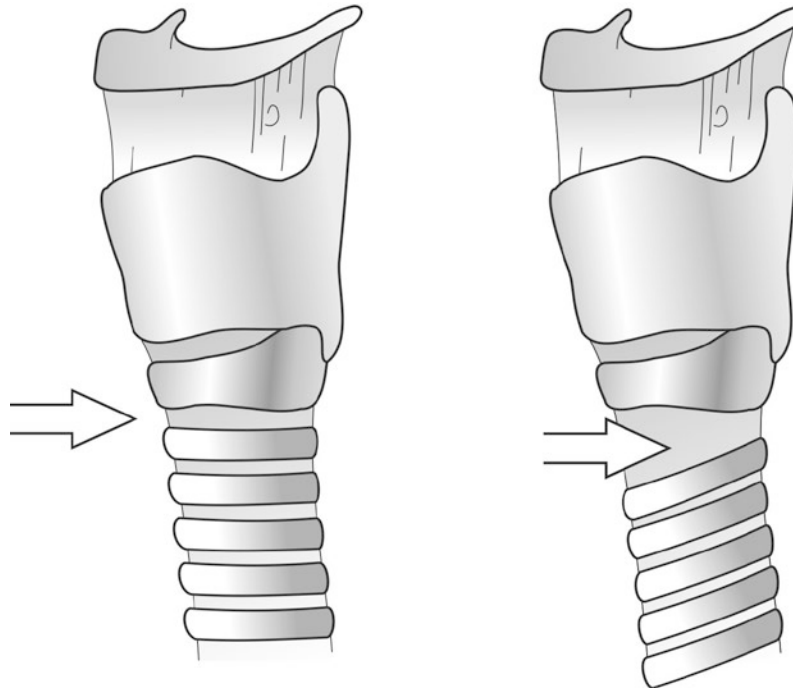

Fig. 15.10 In the case of detachment of anterior commissure, the vocal ligaments should be suspended to the cartilage fragment that corresponds to the cartilage potion of the anterior commissure with non-absorbable sutures

the epiglottic cartilage can be mobilized from its anterior attachments and pulled inferiorly to cover both the mucosal and cartilage defects.

In case of epiglottis displacement and herniation of the preepiglottic contents, these epiglottic contents should be removed and the epiglottis tracted anteriorly and fixed to the hyoid bone with strong absorbable sutures. Removal of part of the epiglottis should be considered if the traction cannot be achieved.

When the endolaryngeal repairing is achieved, it must be decided to put a stent or not. Stents are useful in preventing synechia. If there are an extensive mucosal injury and the likelihood of synechia formation, a stent should be placed. There are several commercially available stents. A custom-made stent can be constructed from a finger of a surgical glove or a Penrose drain filled with sponge and tied at both ends with silk sutures. Stents should be fixed to the neck skin to prevent any dislocation. Strong silk sutures are passed through the stent and brought to the neck skin and tied on a button to prevent the pulling on the sutures and the irritation of the neck skin. Stents can be taken out endoscopically after 3–5 weeks. In case of anterior commissure injury, a keel should be placed and secured to the skin (see Chap. 12b—Lichtenberger—anterior commissure).

The next step is the reconstruction of the laryngotracheal framework. Each cartilage fragment has to be identified and positioned in the correct alignment. The perfusion of the cartilage is through the perichondrium. Free cartilage fragments can still be used as free grafts as long as they are covered with well-perfused tissue. Comminuted pieces that cannot be fixed should be removed. A complete reconstruction of the cartilage frame is not necessary as long as the three-dimensional shape of the larynx can be achieved. Miniplates and recently introduced absorbable plates are the best materials to join the cartilage fragments (Fig. 15.11). Single fractures that assume the natural shape once brought together can be repaired with wire or sutures, but miniplates should be used if they are available. Miniplates of 1.0–1.4 mm thickness should be preferred because they are easy to shape and their thinner profile is not visible through the skin. If the remaining cartilage is not sufficient to reconstruct the framework, free cartilage grafts, such as nasal septal cartilage and costal cartilage, can be used. The epiglottis is another source of carti-

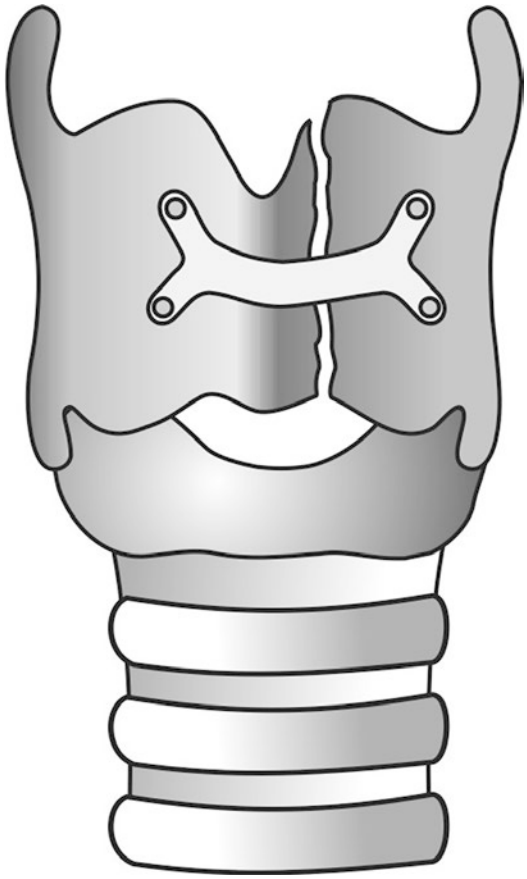

Fig. 15.11 External fixation of the tracheal cartilage with miniplates gives excellent reconstructive results

lage and has the advantage of providing a pedicled flap. Correct placement of the vocal ligaments is essential to obtain a good-quality voice after reconstruction. The cartilage fragment attached to the vocal ligaments must be exactly positioned at the level of a normal anterior commissure. If one of the vocal ligaments is detached, it has to be reattached at exactly the same level of the contralateral ligament with a sturdy suture. If the vocal ligament cannot be attached to a cartilage fragment, the suture can be tied on a plate. In this case, a non-absorbable suture and plate should be preferred to avoid any detachment.

Laryngotracheal separation is repaired by end-to-end anastomosis. If the tracheotomy tube is placed in the tracheal segment, it has to be removed and placed through a tracheotomy incision 2–3 rings below the avulsed site as the first step of reconstruction. If the tracheal ring is severed, it should be removed.

The tracheal ring should be suspended to the cricoid ring with sturdy absorbable sutures that are as much as possible outside. Ideally, the stitches are also extra-mucosal. The reason for these precautions is the prevention of granuloma and stenosis. If the end-to-end anastomosis cannot perfectly be performed and if the larynx reconstruction is not stable, a T-tube is put in place to serve as a stent, allowing voice production and breathing. According to the trauma and the reconstruction, this tube can stay in place from 3 weeks to 3–4 months.

All additional neck injuries should be addressed as the neck is being explored. Esophageal tears should be repaired as soon as possible. Leak from the esophagus may have life-threatening consequences, like a mediastinitis. Tears should be closed in a watertight fashion. We currently prefer absorbable sutures placed in a running mattress style. A second layer of muscle should be closed over the suture line. A nasogastric feeding tube can be placed during surgery to allow postoperative feeding.

If a recurrent nerve injury is observed, an attempt to find the separated segments should be made. It might be difficult to find both ends of the recurrent laryngeal nerve in the trauma field. The nerve might part intralaryngeally or more frequently right where it enters the larynx. If both ends of the nerve are found, end-to-end anastomosis should be done. Primary repair of the recurrent laryngeal nerve doesn't have favorable results. Abduction and adduction functions may not return. However, if tonus to the vocal cord is achieved, vocal rehabilitation is easier.

Additional repairs may be necessary after the initial surgical repair. Laryngotracheal separation has a high stenosis rate after primary anastomosis. Anterior commissure injuries are associated with anterior web formation. Synechiae and granulomas may develop after extensive soft tissue injuries. The secondary repairs are beyond the scope of this chapter and are addressed in different chapters. Unilateral vocal cord paralysis can be treated by vocal cord injection or medialization thyroplasty.

15.6 Postoperative Management

Last but not least, postoperative care is crucial. Voice rest and adequate humidification help the healing process. Antibiotics are administered to prevent chondritis. Antireflux medications should be administered. Steroids may be used to limit endolaryngeal edema in patients without tracheotomies. However, patients with tracheotomy should not receive steroids, as they might impair tissue healing. Stents and keels are usually removed 3–5 weeks after placement.

Closing of tracheotomy should be delayed until the tissue edema disappears and the patient becomes able to clear secretions adequately. Permanent tracheotomy may be necessary with some patients, in case of severe stenosis or bilateral vocal cord paralysis. Speech therapy is an important part of postoperative care. Speech therapy should be started as soon as the tissue edema disappears.

15.7 Tips and Pearls

- The level of injury can be determined by palpation of the neck under emergency conditions. Fragments of cartilage and/or depressions in the laryngotracheal framework show the site of injury. However, the edema and hematomas developing in the soft tissues of the neck can make this examination difficult. In this case, the mechanism of injury gives clues about the injury site.
- Suicidal or accidental hanging causes trauma to the supraglottic larynx. The most common laryngotracheal injuries are caused by steering wheel and dashboard impacts in motor vehicle accidents, inducing an injury at the level of thyroid and cricoid cartilages. Bicycle and sports accidents also cause an injury at the same level. Laryngotracheal separation is likely in case of a jet ski or snowmobile accident where the neck comes into contact with a fixed object like a rope.
- Large laceration of the mucosa may cause emphysema by air leakage into the soft tissues of the neck. Extensive ecchymosis and crepitation of the skin make the diagnosis of emphysema easily recognizable.
- Intubation or tracheotomy is easier in case of incomplete separation airway, with the posterior wall serving as a guide for airway management.
- In some occasions, endoscopic repair can be combined with an open neck approach.
- If there is a vertical thyroid cartilage fracture, the larynx can be entered through the fracture line. If there is a horizontal fracture, the opening can be achieved with a midline vertical laryngofissure. Mucosal incision should preferentially be made at the midline across the anterior commissure to prevent further mucosal injury.
- If there is not enough mucosa to cover the all larynx, priority should be given to the glottic area and especially the anterior commissure.
- A complete reconstruction of the cartilage frame is not necessary as long as the three-dimensional shape of the larynx can be achieved.
- Miniplates and recently introduced absorbable plates are the best materials to join the cartilage fragments.
- If the reconstruction is not stable, a T-tube is put in place to serve as a stent, allowing voice production and breathing.

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