Paparella: Volume III: Head and Neck

Section 2: Disorders of the Head and Neck

Part 5: The Larynx, Trachea, and Esophagus

Chapter 27: Laryngeal Trauma

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Airway disruption is second only to intracranial injury as the most common cause of death following head and neck trauma. This is not surprising, as the relatively exposed area contained within the mandible above, the sternoclavicular complex below, and the cervical spine posteriorly is very vulnerable to injury. Laryngotracheal injuries, in general, necessitate immediate attention not only as a lifesaving measure but also to prevent delayed complications.

Many classifications have been proposed for laryngeal trauma. Ogura and Bryce classified according to site, that is, supraglottic, glottic, subglottic, and tracheal, whereas Richardson classified according to the tissue injured, for example, cartilage, mucosa, ligaments, nerve, and joints. Olson classified according to severity, varying from mild to severe. In this chapter, the classification used will be according to the cause of the trauma, with the injury subdivided according to the structures damaged (Table 1).

Table 1. Classification of Laryngeal Trauma

External trauma
- Open
- Closed

Intubation
Tracheostomy
Cricothyrotomy
Burns and scalds
Radiation
Miscellaneous
- Nasogastric tube
- Foreign bodies
- Iatrogenic: endoscopy, laser, polytetrafluoroethylene injection.

External Trauma

Approximately two thirds of all external injuries are due to blunt trauma and one third are due to penetrating trauma.

Open Injuries

Although open injuries are most commonly seen in combat situations, they are unfortunately increasing in civilian life because of an upsurge in violent crime. Open injuries are usually secondary to a knife or gunshot wound. Knife wounds are generally clean and have sharp edges, with the knife blade entering the larynx through the cricothyroid and thyrohyoid membranes after being deflected off the laryngeal skeleton. Gunshot wounds are associated with extensive tissue loss with a higher morbidity, particularly when high-powered military arms, which may result in massive damage, are involved. Low-powered civilian guns cause less damage and may be deflected from vital structures. In all penetrating injuries, associated structures are vulnerable to damage, particularly the great vessels of the neck and the cervical spine. Therefore, careful evaluation of these structures should be included in the assessment of these patients.

Clinical Features

The two immediate problems encountered, besides the obvious neck wound, are respiratory obstruction and hemorrhage. The *obstruction* may be due to impaction of cartilage or soft tissue into the airway, hematoma of the soft tissue, increasing surgical emphysema, or hemorrhage into the laryngotracheal tree. *Hemorrhage* may be massive, and the surgeon responsible for the patient or the surgeon's assistant should be well versed in the management of vascular lacerations when exploring the neck. Although there may be obvious evidence of vascular injury, the changes may be more subtle, with a slowly expanding hematoma, audible bruit, and loss of pulse. Angiography, therefore, should be performed prior to exploration if feasible. In any event, the carotid sheaths should always be examined at the time of surgical exploration.

Treatment

The patient with an open neck wound and damage to the laryngotracheal system usually requires emergency resuscitation and exploration. Basic principles include restoration of the airway and control of the hemorrhage. Frequently, the airway may be controlled by intubating the patient through the wound, thereby avoiding compounding the tissue injury by performing a hurried tracheostomy. Once the patient has been anesthetized, any foreign body should be removed, adequate debridement performed, and the great vessels carefully inspected. Once encountered, the laryngotracheal injury should be meticulously repaired. An elective tracheostomy is always performed. Antibiotics and tetanus toxoid should be administered. Other points of management are similar to those used in closed injuries (see further on).

Closed Injuries

Blunt trauma to the larynx is usually caused by motor vehicle accidents, but it may be sustained in sports (eg, karate, basketball, or ice hockey), or it may result from attempts at strangulation or hanging. Also, accidents related to recreational vehicles, for example, dirt bikes, three-wheelers, and snowmobiles, are increasing in frequency. In spite of the incredible carnage

on the roads, it does not appear that only is there a decline in the number of motor vehicle accidents, but also in the incidence of serious injuries. This decline is due to a combination of public awareness of the dangers of drinking and driving, more stringent laws to punish drunk drivers, increased use of seatbelts, and improved legislation for the protection of child passengers, insisting on mandatory effective restraints for children.

In motor vehicle accidents, the factors most influencing the type of injury sustained include whether or not seatbelts are worn, the type of seatbelts used, the length of the front compartment, and the height of the individual. The occupant of the car who is most vulnerable to head and neck trauma is the passenger in the front seat.

In the most common situation of sudden deceleration, the person not wearing a seatbelt would be thrown forward, striking the dashboard, steering wheel, or windshield, with resultant injury to the head, thorax, or neck. If a two-point seatbelt is work, the individual will pivot at the waist and strike the steering wheel or dashboard; the type of injury sustained depends on the height of the individual and the length of the compartment. If the distance is short, an injury to the maxillofacial structures will occur. If the distance is greater, the neck becomes hyperextended, exposing the vulnerable laryngotracheal complex to the protruding dashboard. The laryngeal skeleton is crushed between the dashboard and the cervical spine. If the chin is thrust forward and comes into contact with the dashboard or steering wheel, the spine may be acutely hyperextended, resulting in a fracture of the neural arch of the axis (C2). This fracture is the same that occurs during judicial hanging, hence the term *hangman's fracture*. The only real effective seatbelts in preventing laryngotracheal injury, therefore, are those with shoulder belts. Hopefully inflatable air bags will become mandatory in the future, with a further decrease in the incidence of laryngeal trauma.

It is of interest that in closed injuries, the surrounding nerves and vessels usually escape injury because of their pliable nature.

Types of Injury

This section will classify injuries according to the laryngotracheal structures damaged.

Soft Tissue

Hematoma and edema spread through preformed tissue planes in the larynx. Extension into the subglottis is limited by the conus elasticus, and therefore the swelling is redirected in a circumferential manner, with the hematoma spreading from the ipsilateral paraglottic space through the pre-epiglottic space to the contralateral paraglottic space. Depending on the severity of the injury, multiple mucosal tears may develop.

Hyoid Bone

Fractures of the hyoid bone usually occur in younger people, often as a result of a sport injury. They result in severe, painful dysphagia caused by crepitus at the fracture site. There is no associated respiratory distress. The only clinical sign is point tenderness over the fracture.

Thyroid Cartilage

If the thyroid cartilage is uncalcified, which usually occurs in young patients, the cartilage is forced against the cervical spine, flattens, and springs back once the compressing forces have been removed. This results in a linear fracture down the thyroid prominence with varying degrees of internal derangement. The epiglottis may become dislodged just above the anterior commissure and fall back into the lumen, the vocal cords may be avulsed from the anterior attachments or vocal processes, or the arytenoid cartilages may become dislocated.

If the thyroid cartilage is calcified (ie, in older adults), it is compressed against the spine, shattering the cartilage and flattening the neck. There are usually multiple stellate fractures with an intact external perichondrium. The internal perichondrium is usually breached, with pieces of cartilage exposed in the laryngeal lumen. This results in a markedly shorted anteroposterior diameter of the larynx. In addition, internal derangement, similar to that already described, may result.

Cricoid Cartilage

A cricoid cartilage injury is often associated with a fractured thyroid cartilage. Because the cricoid cartilage is a complete ring, it usually fractures in two places, that is, anteriorly and posteriorly, but occasionally it may be completely crushed. There is a high associated incidence of recurrent laryngeal nerve injury resulting from the close proximity of this nerve. This cartilage should always be exposed when exploring the larynx.

Trachea

In severe trauma, the trachea may be avulsed from the cricoid by a tear through the cricotracheal membrane. This results in severe respiratory obstruction and massive surgical emphysema. Most patients will probably die at the scene of the accident. This disruption may be complete or incomplete, with the trachea retracting into the retrosternal position.

Pharynx and Esophagus

When dealing with severe blunt trauma in the neck, the possibility of injury to the hypopharynx or cervical esophagus should always be considered. This usually results in increasing surgical emphysema, but the diagnosis may be missed because of the preoccupation with the laryngotracheal injury. If there is any suspicion of such an injury, an esophagogram should be performed at the time of the initial evaluation.

Diagnosis

Early diagnosis and treatment of laryngeal fractures is absolutely crucial to successful management. With increasing awareness, many of these cases are now being evaluated by otolaryngologists in the emergency room. However, in a distressingly large number of cases, a delay in evaluation still occurs. The usual reason for this is the preoccupation with the other life-threatening injuries, with the laryngeal problem becoming apparent only when decannulation or extubation is attempted at a later date. Although this is unavoidable in some situations, in general, it should not occur, and only education of the emergency room physicians and nonotolaryngologists about the disastrous late sequelae of neglected laryngeal trauma will alter this situation.

Symptoms

Unfortunately, many cases of blunt laryngeal trauma may be virtually asymptomatic in the early stages. This may lull the attending physician into a false sense of security.

Voice Change. Hoarseness and dysphonia with air wastage may be present, depending on the type and degree of the vocal cord injury. Hematoma commonly results in hoarseness, whereas an avulsed cord will result in a weak voice.

Pain. Pain may vary in severity and is usually aggravated by coughing or swallowing, particularly if there is a fracture of the hyoid bone.

Dyspnea. Stridor may not be apparent in the early stages, as edema, hematoma, and surgical emphysema may not be severe enough initially to cause airway obstruction. It is not uncommon for the stridor to gradually progress in the ensuing hours and, for this reason, all patients who have sustained laryngeal trauma, no matter how minor, should be observed in hospital overnight.

Dysphagia. Dysphagia may be noted if bruising or laceration of the cervical esophagus has occurred. Odynophagia can also occur with a laryngeal fracture.

Cough. An irritative cough may be the first symptoms of internal derangement.

Hemoptysis. Bleeding from the upper airway may result in hemoptysis, which may be severe enough to cause respiratory distress.

Signs

The appearance of the neck may be misleading, and a dangerous laryngotracheal injury may exist beneath apparently normal overlying tissue. On observation, there may be mild external bruising or laceration, or there may be flattening of the neck with loss of the thyroid prominence. A subtle sign of laryngeal edema is the loss of palpable crepitus of the laryngeal skeleton on the

vertebrae.

On palpation, the neck may feel slightly edematous, the fracture line may be palpable, and subcutaneous emphysema may be obvious. The surgical emphysema may increase in severity and is often exacerbated by coughing. Causes of surgical emphysema include disruption of the laryngotracheal complex or pharyngoesophagus, or it may occasionally follow a pneumothorax.

Every attempt should be made to visualize the endolarynx. If, for technical reasons, indirect laryngoscopy using a mirror is not feasible, the fiberoptic scope is used. This may reveal internal derangement of the endolarynx, hematoma, or even a laceration of the hypopharynx. Obviously, these findings may influence the subsequent management.

Special Investigations

If the facilities are available and the emergency management of the patient is not compromised, radiologic assessment of the patient is invaluable. Anteroposterior and lateral soft tissue radiographs may demonstrate endolaryngeal swelling, a shift in position of the epiglottis, or subcutaneous emphysema. A fracture of an ossified cartilage may also be visible. Most importantly, the cervical spine may be evaluated by this means.

X-ray studies of the chest should be performed routinely. A contrast swallow to rule out perforation of the esophagus is indicated, particularly if there is evidence of surgical emphysema.

Computerized tomography (CT) has replaced contrast laryngograms, xeroradiograms, and tomograms as the definitive radiographic means of evaluating the larynx. It is patently obvious that a CT scan need not be performed in all cases of laryngeal trauma, particularly in the very mild case, in which it is not likely to be cost-effective, as it will not influence the management. Likewise in very severe injuries, in which open exploration is mandatory, it is not particularly helpful and is probably unnecessary except perhaps to aid in the planning of the surgical procedure. In the moderately severe case, in which the indications for surgery are equivocal, it may obviate the need for open exploration by diagnosing hematoma or an undisplaced fracture, for example, a cricoid cartilage fracture, and is most cost-effective.

Management

As has been emphasized repeatedly, the key to successful management of laryngotracheal injury begins in the emergency room. Prompt attention by the emergency room physician, or better still by the otolaryngologist, will not only minimize the long-term consequences of the injury but may also, in fact, be essential to saving the patient's life.

Although ideally a methodical approach to the problem is recommended, with clinical history and examination followed by special investigations to aid in establishing the type and severity of the injury, it is frequently not possible, particularly if there are other, more serious life-threatening injuries necessitating emergency care. In addition, if the laryngeal injury is severe

enough, no history taking will be possible because the patient will be rendered aphonic from the injury or may already have been intubated by the paramedics at the scene of the accident.

If there is respiratory difficulty or profuse hemorrhage, resuscitation should be performed, and an immediate attempt should be made to stop the hemorrhage and secure the airway by whatever means seems appropriate, depending on the type of injury encountered. This obviously takes precedence over all else, and only after the hemorrhage has been stopped and the airway secured should other steps be taken to clarify the injury. In this situation, one should always assume the worst and manage the patient as though the cervical spine has been damaged and there may be associated injuries, for example, to the pharynx and chest. Once the acute crisis is over, further management is dependent on the severity and type of the injury.

Mild Cases

Patients with minimal symptoms and signs on external examination and fiberoptic laryngoscopy, for example, mild bruising or edema of the larynx and superficial lacerations of the mucosa, are included in the group of mild cases. Depending on the cause of the injury, no further special investigations need to be performed, and the patient is simply observed. If surgical emphysema is present, a chest x-ray study and a contrast study of the esophagus should be performed. CT scanning can be performed if a laryngeal cartilage fracture is suspected, but it is of little value in mild cases. All these patients should be admitted for observations for at least 24 hours. Supportive therapy should be instituted. This consists of bed rest, a soft diet, adequate humidification, voice rest, and antibiotics if lacerations are present. If mild to moderate laryngeal edema is present, systemic steroids and racemic epinephrine should be used in an attempt to diminish it. The patient should be examined at regular intervals, and if there is any deterioration, he or she is taken to the operating room and tracheostomy and direct laryngoscopy performed. It is better to be safe than sorry.

Severe Cases

The more severe cases require urgent admission, either to an intensive care setting or straight to the operating room. If feasible, the following investigations should be performed as time permits: fiberoptic endoscopy, x-ray chest films, anteroposterior and lateral x-ray studies of the neck, and an esophagogram, particularly if there is surgical emphysema. As already stated, a CT scan and angiography are performed only if necessary and time permits.

The patient is then observed in a surgical intensive care setting or, if the situation is more urgent, is taken immediately to the operating room at which point tracheostomy is performed to secure the airway and examination is performed under anesthesia. Cricothyrotomy has been suggested as an alternative to tracheostomy, but this may further compound the damage and may not get below the site of injury. Likewise, an initial attempt at intubation may only worsen the situation by increasing edema and bleeding.

If tracheostomy is performed in the operating room, the opportunity should always be taken to perform an endoscopy - that is, laryngoscopy and bronchoscopy - to better assess the situation. Two pitfalls should always be considered. The first is the danger of aggravating a cervical spine injury; therefore, the spine should not be unnecessarily manipulated if it is unknown whether or not there is truly a spine injury. The second is the danger of missing an avulsed epiglottis, which will be lifted out of the way by the tip of the scope but will prolapse back into the lumen after laryngoscope has been withdrawn.

Once the type of injury has been assessed, the next decision to be made is whether an open exploration is indicated. The indications are listed in Table 2.

Table 2. Indications for Open Surgical Exploration

Upper airway obstruction that is sufficient to warrant tracheostomy (if not due to edema or hematoma alone)
Displaced fracture of the laryngeal skeleton (diagnosed clinically or by CT scan)
Increasing surgical emphysema
Evidence of internal derangement
Hemorrhage
If there is any doubt about the extent of the injury.

The timing of the open exploration is controversial. Most authorities recommend operating within 24 hours, if feasible, and other suggest waiting 3 to 5 days to allow edema to subside. Our own policy is to operate at the time of tracheostomy and endoscopy to obviate the need for a second anesthetic procedure.

The management of an individual case depends on the specific pathologic condition encountered. The larynx is explored through a transverse incision at the level of the upper end of the thyroid cartilage. Flaps are elevated, allowing visualization of the whole larynx. If a perforated esophagus or hypopharynx is suspected, these structures should be carefully explored.

Fractured Hyoid

There is obviously no acute emergency in treating a fractured hyoid. However, if the intense pain persists, the simplest and most effective treatment is to excise bone on either side of the fracture to prevent crepitus.

Thyroid Cartilage Fracture

If a displaced linear fracture is encountered and no internal derangements are noted on endoscopy, it is sufficient to realign the fracture and fix it into position with No 34 wire or 3-0 nylon suture. An attempt should be made to meticulously reapproximate the external perichondrium. There is no indication, therefore, for a formal laryngofissure. If an internal derangement is suspected (eg, an avulsed cord or displaced epiglottis), the laryngeal lumen should

be explored, usually through the fracture itself. In contrast, if the thyroid cartilage is calcified and less resilient (eg, in an older patient), the cartilage usually shatters, as has already been described. In this scenario, the external perichondrium is usually intact, although the internal perichondrium is breached. A formal midline laryngofissure needs to be performed in order to gain access to the lumen.

Once in the lumen, the internal derangement is repaired, usually with a permanent suture, and mucosal repair is undertaken with meticulous care, using absorbable suture with the knots buried to reduce granuloma formation. If there is extensive mucosal loss, the defect may be grafted using free mucosal grafts from the buccal mucosa or skin or dermis. A dislocated arytenoid cartilage may be gently relocated.

A decision then has to be made whether to use a stent. In a linear fracture that is easily reduced, a stent is not necessary to maintain support. A silicone keel may be all that is required to prevent webbing if the anterior commissure mucosa has been denuded. This should remain in place for 3 to 4 weeks.

A stent should be inserted if the injury necessitates extensive mucosal grafting or in a markedly comminuted and displaced fracture that requires support. Stenting is not a benign procedure and may induce granuloma formation with subsequent scarring, leading to stenosis and affecting vocal cord mobility. For this reason, stenting should not be performed unnecessarily and should be done only with good reason. A wide variety of both hollow and molded stents made of non-reactive materials are available for use. These stents are made of silicone, polytetrafluoroethylene (Teflon), acrylic, polymeric silicone (Silastic), and rubber finger cots filled with packing, to name a few, but they all tend to cause a reaction to their presence, and the ideal stent still has not been determined. The length of time a stent is kept in place remains controversial but should be tailored to the individual case. Stenting purely for the purpose of supporting a graft to replace mucosal loss may require it to be in place for only 7 to 10 days, whereas it may need to be kept in place for 3 months for cartilage comminution. The stents usually are fixed into position with a transfixion suture of 2-0 nylon or stainless steel or are attached to the tracheostomy tube. The stent is removed endoscopically after the suture is cut.

Once the stent has been placed, the thyroid cartilage fragments are wired together. In the severely comminuted fracture, however, this may not be possible, but rather a very conservative debridement of the smaller segments should be performed and the larger segments wired. The external perichondrium is sutured.

Fractured Cricoid Cartilage

A fractured cricoid cartilage usually is associated with a fractured thyroid cartilage. If the fracture is undisplaced, stabilization by suturing the perichondrium or actual wiring of the cartilage itself for stabilization may be all that is required. In this situation, there is no need to insert a stent. If, conversely, the segments are unstable, a soft stent should be inserted and kept in place for 4 to 6 weeks. Great care should be exercised not to insert too large a stent, as this

may produce necrosis of the cartilage. For this reason, a piece of rolled polymeric silicone may be the ideal stent in this situation. In those situations in which the cricoid is severely crushed beyond repair, it is usually better to wait 5 to 10 days, then to excise the affected area, usually the anterior half, and replace it with a hyoid bone graft, a rib graft, or an epiglottic "pull-down" procedure.

The incidence of concomitant recurrent laryngeal nerve palsy is high in cricoid fractures because of the close relationship of the nerve to the cartilage. The management of this injury is extremely controversial. The diagnosis of vocal cord paralysis is made preoperatively by indirect or direct laryngoscopy. This injury, however, may be caused by contusion or interruption of the nerve and may be difficult to define during the exploratory surgery. During surgery, any displaced cartilage that may affect nerve function should be reduced. However, dissection to identify the nerves in an already contused area may further damage a possibly intact nerve. If the ends of the nerve are easily identified, particularly if both recurrent nerves have been sectioned, primary anastomosis should be attempted. Whether anastomosis of severed nerves will result in restoration of normal vocal cord function is unclear. However, rehabilitation following bilateral palsy is so poor that nothing is lost by attempting at least one anastomosis, even with the risk of subsequent synkinesis.

Cricotracheal Avulsion

This injury is invariably fatal and will only rarely present to the emergency room. Airway control should be attained by oral intubation, as tracheostomy is hazardous and difficult because the trachea retracts into the chest. The principal objective in repair is to attain a tension-free anastomosis. The tracheal is carefully mobilized, avoiding extensive lateral dissection to prevent damage to the blood supply and recurrent laryngeal nerves. If necessary, a suprahyoid release may be used. Closure is double-layered with absorbable sutures to approximate the mucosa and submucosal No 34 braided stainless steel wire around the first tracheal ring and cricoid cartilage. An internal splint is usually not required.

Associated Pharyngoesophageal Trauma

In suspected esophageal injury, a contrast swallow is very helpful and is more useful than intraoperative endoscopy to localize the site of the laceration. Intraoperative methylene blue may also be used to identify the perforation, but we have found this somewhat unsatisfactory. Simple hypopharyngeal or cervical esophageal lacerations are closed using a two-layered closure. If a severe thoracic esophageal perforation associated with laryngotracheal injury is encountered, however, a proximal diversion should be performed initially, with the definitive closure being performed at a later date. This is because of the high complication rate that occurs when combined tracheoesophageal injuries are operated on simultaneously. These complications include pneumonia, esophageal leaks, tracheoesophageal fistula, and mediastinal abscess. If primary repair is undertaken, a muscle flap should be inserted between the trachea and esophagus to minimize the risk of subsequent tracheoesophageal fistula.

Results

Even under the most ideal circumstances, it is extremely difficult to restore the anatomy of a delicate structure such as the larynx. In fact, even in the best of hands, a poor airway results in 71 per cent and poor voice in 21 per cent of patients.

Of even greater concern is the late presentation of a laryngeal fracture with well-established stricture formation. This results in dysphonia, chronic aspiration, and respiratory distress. Although the situation may be resolved relatively easily (eg, by division of a glottic web or by arytenoidectomy), the problem is usually infinitely more complex and may entail a combination of supraglottic, glottic, and subglottic stenosis associated with vocal cord palsy. Such patients require careful evaluation prior to surgical reconstruction. The surgery may consist of incising or excising scar tissue, with grafting and stenting as the need dictates. Techniques such as free cartilage grafts and hyoid arch transposition have proved useful in replacing necrosed cartilage or as a wedge to increase cricoid circumference.

Even under the best of circumstances, these patients may require multistaged procedures and it may even be necessary too resort to a modified supraglottic or hemilaryngectomy to improve the airway.

Intubation Injuries

Intubation with an endotracheal tube is not only an integral part of general anesthesia but is also essential for basic life support in an intensive care setting.

Intubation may result in injury not only to the larynx but also to other areas of the upper aerodigestive tract. These injuries can be classified into two types: (1) acute injuries resulting from traumatic intubation and (2) delayed injuries, usually caused by prolonged intubation (Table 3).

Acute and Subacute Injuries

Traumatic intubation is more likely to occur when performed in an emergency setting as opposed to the controlled environment in which general anesthesia is used, but it can occur in both situations. Predisposing factors to injury include inexperience of the individual performing the intubation and an abnormal anatomy, for example, a cervical spine abnormality, a short and thick neck, a recessed mandible, trismus, and so on. Although many of the injuries sustained are minor, compared with the importance of gaining control of the airway, a significant disability may result.

It is obviously beyond the scope of this chapter to discuss the many types of injuries to the upper aerodigestive tract that may result from a traumatic intubation. It is always amazing how much damage can be inflicted by a relatively soft tube! Mucosal lacerations of the tonsillar pillars, soft palate, and pharynx are by far the most common. They tend to heal with few

sequelae. Perforation of the nasopharynx (in nasal intubation), as well as perforation of the pyriform sinuses, has been observed and may even require open exploration and surgical closure. Damage to teeth, crowns, and various dental prostheses may occur. The danger in this situation is not in the actual damage sustained, but more importantly, the fact that if not recognized a dislodged tooth may subsequently be aspirated and a potentially life-threatening situation may develop.

Table 3. Intubation Injuries

- **Acute**
  - Edema
  - Laceration
  - Hematoma
  - Vocal cord avulsion
  - Vocal cord paralysis
  - Arytenoid cartilage dislocation
- **Delayed**
  - Supraglottic
    - Stenosis
  - Glottic
    - Edema
    - Cricoarytenoid joint dysfunction
    - Granuloma
    - Vocal cord paralysis
    - Interarytenoid fibrosis
  - Subglottic
    - Edema
    - Granuloma
    - Stenosis
  - Tracheal
    - Granuloma
    - Tracheomalacia
    - Stenosis
    - Tracheoesophageal fistula.

A traumatic injury to the larynx itself may result in a dislocated arytenoid cartilage or injury to the vocal cords themselves, with secondary edema, hematoma, or mucosal lacerations with ulcer formation and subsequent scarring, or even avulsion of the vocal cords.

The incidence of *arytenoid cartilage dislocation* following intubation is extremely rare, probably because of the wide range of movement allowed by the cricoarytenoid joint. When dislocation does occur, it is characterized by pain and discomfort in the throat associated with a hoarse voice, which persists longer than the customary day or two seen after uncomplicated intubation. The arytenoid cartilage is displaced posterolaterally with the cord lying in abduction.

Examination confirms the presence of vocal cord paresis and swelling of the arytenoid mound. In addition to the dysphonia and discomfort, the patient may experience aspiration because of the incompetent larynx. Recommended treatment is relocation of the arytenoid cartilage endoscopically, either under local or general anesthetic, using a laryngeal spatula. Although good results have been described, personal experience has not been very satisfactory.

Vocal cord paralysis following intubation is an unusual complication, which, if bilateral, may lead to acute respiratory distress with stridor necessitating tracheostomy. Usually, however, this condition is unilateral. Many theories regarding its cause have been proposed, including the possibility that the anterior rami of recurrent laryngeal nerve may get compressed between the arytenoid cartilage and the thyroid lamina, particularly if the endotracheal tube cuff rides up the trachea into the immediate subglottis, thereby pushing the arytenoid cartilages posteriorly.

With the advent of laser surgery, metal- and aluminum-wrapped tubes have come into vogue. Although they protect the tubes from the laser, they are also more likely to result in increased trauma to the larynx.

Delayed Complications

The increasing use of endotracheal tubes for patients requiring assisted ventilation has resulted in a significant increase in complications, particularly subglottic and tracheal stenosis. This has led to many centers recommending early tracheostomy, but this, too, is not without complications. All patients who have been intubated for prolonged periods should be carefully examined after extubation and monitored to ensure that all ulceration and granulations have completely resolved.

Predisposing Factors to Laryngotracheal Injury

Prolonged Intubation. Controversy continues to rage as to the length of time that is permissible before intubation will result in severe complications. The answer in a particular case lies in the multiple other factors that come into play. It is, however, generally accepted that if an endotracheal tube is required beyond 10 days, a tracheostomy should be performed. It is of interest that young children appear to tolerate prolonged intubation better than adults do.

Size of Tube. A tube that is too large is more liable to traumatize the endolarynx, trachea, and particularly the subglottis. Decreasing the size of the tube will lessen the incidence of subglottic stenosis but will have no effect on the injury at the glottic level and, in fact, simply allows the tube-tissue interface to move more posteriorly into the interarytenoid space.

Type of Tube. The red rubber tubes popular until the 1960s were more likely to result in injury than the more modern tubes made of nonreactive materials - for example, polymeric silicone, polyvinyl chloride. Changes in cuff design have also diminished the incidence of injury and subsequent stenosis. High-pressure cuffs cause considerably more damage than low-pressure cuffs.

Shape of Tube. Endotracheal tubes designed to better conform to the normal anatomy of the upper aerodigestive tract are less liable to result in laryngeal trauma, but they do not prevent the friction that may still result at the tissue-tube interface.

Local Infection. May aggravate the pressure necrosis, leading to early cartilage exposure and stricture formation.

Repeated Trauma. If a restless patient constantly moves the head or if repeated intubation is required, the trauma to the larynx will obviously increase. Adaptors to the ventilator that decrease the effects of movement have helped diminish the incidence of complications.

Nasal Versus Oral Intubation. The obvious advantage of nasal intubation over oral intubation is that manipulation of the oral cavity is not required, thereby making it the preferred intubation technique in cases of mandible fractures. It is also better tolerated by the conscious patient, and once in place is less likely to be dislodged. It does not require extension of the neck for placement, thereby rendering it safer in cases of suspected cervical spine injury. It is, however, a more difficult technique in less experienced hands.

Of greater import is that the frequency of laryngeal injury after nasotracheal intubation is 50 per cent of that seen in orotracheal intubation. The reasons for this include the smaller sized tubes used, the decreased curvature of the tube in nasotracheal intubation with less pressure on the posterior larynx, and finally the decreased friction between the tube and the larynx secondary to the greater stability of the nasotracheal tube.

Pathogenesis

The presumptive pathogenesis of stenosis is the initial development of ischemic necrosis - first of the mucosa then of the underlying cartilage. Superficial mucosal ulceration will result from pressure ischemia alone in 3 hours, from exposure of the perichondrium in 48 hours, from ulceration of the perichondrium in 72 hours, and from cartilage destruction in 96 hours. The injury sustained depends on the anatomy of the area affected.

The tracheal lumen is not circular, with cartilage occupying only the anterior and lateral walls. When the cuff of an endotracheal tube is inflated, the posterior wall is less liable to be damaged, as it is able to distend into the esophagus. The thin mucosa overlying the cartilage is, however, extremely vulnerable to pressure necrosis, with resultant exposure of the underlying cartilage. Fortunately, newer tubes and improvement in cuff design have decreased the incidence of tracheal stenosis.

The cricoid cartilage is even more susceptible to injury because it completely encircles the lumen. In the neonatal airway, this area is the smallest cross section, and therefore it is most vulnerable to trauma.

In the larynx, the posterior commissure bears the brunt of the pressure from the tube and this, together with arytenoid movement and thin mucosa, predisposes to local injury.

Types of Injuries

Larynx

Although tracheal injuries are usually caused by prolonged intubation, a high tracheostomy or cricothyrotomy may also result in laryngeal injury.

Supraglottic. Hematoma and lacerations usually resolve spontaneously, although rarely a hematoma may require evacuation. Theoretically, if a supraglottic injury is severe enough, it could result in supraglottic scarring and subsequent stenosis.

Glottic. Subacute injuries that may occur include laryngeal ulceration, particularly over the arytenoid mounds, the vocal processes, and the interarytenoid areas. The distribution of this ulceration results from the position of the tube in the posterior larynx, with the severity of the ulceration influenced by the duration of the intubation. This may progress to intubation granulomas or even interarytenoid fibrosis, with resultant stenosis and impaired voice.

A temporary functional limitation of cord mobility may result secondary to intubation. This is probably caused by a traumatic cricoarytenoid joint dysfunction. Cord mobility usually returns within a 4-month period; however, during this period of impaired function, phonation is affected and glottic incompetence occurs, which predisposes to aspiration.

Subglottic. The circumferential cricoid cartilage renders the subglottic mucosa vulnerable to ischemic necrosis from the endotracheal tube. All the predisposing factors already described come into play in the development of stenosis in this area. Therefore, particularly in the debilitated patient, early tracheostomy should be considered to decrease the incidence of this complication. Mucosal ulceration initially occurs, followed by granuloma formation, perichondritis, chondritis with secondary chondromalacia, and finally stenosis. Children are particularly vulnerable to subglottic injury.

Management. Following prolonged intubation, all patients should undergo fiberoptic laryngoscopy. If only edema and ulceration of the subglottic are seen, treatment can be expectant with systemic or inhalant steroids, or both, and racemic epinephrine can be given if indicated. Since bacterial infection plays a significant role in the evolution of subglottic stenosis, culture-directed antibiotics should be used when infected mucosa, with or without ulceration, is detected.

Once true subglottic stenosis has developed, treatment depends on the severity and the exact extent of the scarring. Many therapeutic modalities have been suggested, including dilatation, endoscopic laser surgery, stenting, and open reconstruction.

If a limited soft tissue stenosis is detected, it is possible to have success with repeated dilatation and administration of systemic steroids (particularly if the stenosis is still soft). After 3 months, and if the scarring is mature, dilatation does not seem to work, and endoscopic laser ablation may be of value. This is effective only if the stenosis is short and composed purely of soft tissue. If the stenosis is caused by cartilage collapse, it has not real value. If the stenosis is relatively mild and the laser surgery is atraumatic, a tracheostomy need not be performed, but if there is any doubt regarding the airway, it is better to perform one.

Once chondritis and chondromalacia have occurred, the problem becomes infinitely more complicated and usually necessitates open exploration and surgical repair. Endoscopic cryosurgery and stabilization have been described for this degree of stenosis, with apparently satisfactory results.

Open exploration should consist of a laryngofissure and division of the cricoid anteriorly. If, on spreading of the incision, a sufficient lumen is obtained, a stent may be inserted and the anterior defect held open by an appropriate graft consisting of costal cartilage or free of vascularized hyoid bone. If correctly grafted, a stent may not be necessary.

If the anterior split does not establish an adequate lumen, a posterior cricoid split should be performed, followed by stent insertion and anterior wall grafting. A posterior graft is difficult to keep in place. In general, it is preferable not to excise mucosa-covered scar. If this does become necessary, grafting with buccal mucosa grafts should be used to fill the defect created.

The stent should be left in place for 3 months and then removed endoscopically. At this time, a bronchoscopy is performed, but the tracheostomy tube is only removed 3 months later after a further bronchoscopy is performed to ensure that the lumen has stabilized.

Trachea

Stenosis at the Cuff Site. This condition occurs with equal frequency secondary to tracheostomy and endotracheal tubes, although it is less common today with improved cuff design. The affected area is usually 2 cm in length and involves the anterior and lateral walls with minimal involvement of the posterior wall because of its capacity to distend into the esophagus. The resultant stenosis is, therefore, usually horse-shoe-shaped, although circumferential stenosis may occur.

Management. Prevention is by far the most important aspect of management. This includes regularly deflating the cuff, not exceeding the recommended cuff pressure, and using an uncuffed tube when possible.

Management of this problem will be discussed in more detail elsewhere in this volume. If the stenosis is mild, repeated dilatation may be of some value, but if it is well established, this mode of therapy is invariably unsuccessful. A long tracheostomy tube or T-tube can be used to stent the stenosis and should be left in place for 3 to 6 months. The CO_2 laser may be used to

break up the stenosis. This is useful if the stenosis is short and fibrotic, but it is of no value in the long, circumferential stenosis with chondromalacia.

In the more severe cases, the only successful form of therapy is resection and end-to-end anastomosis. This technique allows resection of up to 6 cm of trachea provided that adequate mobilization of the trachea is obtained. The easiest and most effective means of mobilization is to perform a release of the suprahyoid musculature. If the scarring is confined to the anterolateral walls, it is possible that a wedge excision of this area with direct anastomosis will suffice.

Stenosis Caused by Trauma from Tip of Tube. This injury has characteristics similar to the injury secondary to the cuff, but occurs at a much lower level, frequently close to the carina. Management is similar, but resection is hampered by the close proximity to the carina.

Cricothyrotomy Injuries

The clear advantage of cricothyrotomy over tracheostomy is the rapidity and ease with which it can be accomplished. The disadvantage is that it may cause immediate direct damage to the larynx, for example, to the vocal cords, or delayed injury by pressure necrosis involving the cricoid cartilage and resultant stenosis. Also, more subtle complications may arise because of trauma to the cricothyroid and vocalis muscles. For this reason, most surgeons recommend early conversion to a standard tracheostomy.

Tracheostomy Injuries

Tracheostomy is the oldest technique described for relief of airway obstruction, gaining popularity in the early 1800s when it was used in the treatment of diphtheria. Although it has many advantages over endotracheal intubation in that it bypasses the larynx and is well tolerated by a conscious patient, it is not a benign procedure, with estimates in overall morbidity varying from 17 to 49 per cent. These injuries are particularly prone to occur if the procedure is performed in an emergency situation. Immediate injuries to the airway include sectioning of the recurrent laryngeal nerve, tracheoesophageal fistula formation, pneumothorax, and damage to the larynx, particularly the cricoid cartilage if too high a tracheostomy is performed.

Tracheal stenosis may develop at the site of the tracheostomy at the cuff site or at the tip of the tracheostomy tube. Stricture at the site of the tracheostomy is invariably confined to the anterior and lateral walls and is due to chondromalacia with collapse of that segment. The reported incidence of tracheal stenosis at the site of the stoma varies from as low as 0.5 per cent to as high as 100 per cent. This discrepancy exists because every healed stoma site does leave some degree of stenosis, but an obstruction of up to 75 per cent may occur before normal exercise tolerance is compromised.

Predisposing Factors

1. Size: A tracheostomy tube that is too large may be more liable to cause problems because of increased mucosal contact.

2. Site of tracheostomy: If the tracheostomy is placed too high, it is possible to damage the cricoid cartilage with subsequent stenosis. Chevalier Jackson, in a classic paper, reported on 100 cases of chronic laryngeal stenosis and attributed 93 per cent of them to a high tracheostomy involving the cricoid cartilage.

3. Secondary infection.

4. Type of incision - studies comparing the various incisions, that is, vertical, transverse, cruciate, and window, failed to demonstrate that any one incision offered a decreased incidence of stenosis.

Management. Because of the type of stenosis encountered, dilatation may be of some value. If this fails, a wedge excision of the anterolateral wall with direct anastomosis may suffice. If necessary, complete excision of the involved segment and end-to-end anastomosis may be warranted.

Burns and Scalds

Burns of the larynx may be of two types: thermal and chemical. Thermal injury is most rare because the thermal regulating system of the nose and oral cavity is able to dissipate the heat. If the air inhaled is supersaturated with steam, this injury may occur. Chemical burns may result from inhaled smoke, inhaled gases (eg, ammonia gas), or the ingestion of caustic substances (eg, lye, other alkalis, and acids).

If hot air is inhaled, significant laryngeal edema occurs before there is any pulmonary injury. If smoke is inhaled, however, necrotizing tracheitis, bronchitis, and intra-alveolar hemorrhagic edema also develops.

Lye, which is the most commonly ingested caustic agent, is a strong alkali and causes liquefaction necrosis as opposed to acids, which cause coagulation necrosis and, therefore, a greater depth of necrosis. Inhaled ammonia gas forms ammonium hydroxide when it comes into contact with moist mucosa, producing injuries similar to those from other alkalis. As a result, edema plus superficial ulceration and slough all cause laryngeal narrowing, which is often aggravated by laryngeal spasm. The supraglottis is usually predominantly involved. In general, the larynx usually protects the lower respiratory tract from injury. Diagnosis of airway burn may be difficult, and all patients should be carefully observed over 24 hours, as laryngeal edema may develop late. Coughing up of blood-stained sputum may be diagnostic.

In mild airway distress, pulmonary toilet, serial chest x-ray films, and blood gas determinations for follow-up are the mainstay of treatment. The patient is kept at bed rest and with adequate humidification and oxygen as needed. Prophylactic antibiotics and corticosteroids are generally not recommended in these mild cases.

In severe burns, a tracheostomy is performed, steroids and antibiotics are administered, and frequent toilette of both the upper and lower airway to remove slough and debris is performed. This may necessitate repeated bronchoscopy.

Extensive supraglottic and glottic involvement may subsequently result in scarring and stenosis.

Radiation

Unfortunately, even today severe laryngeal chondritis secondary to a poorly designed course of irradiation may be seen. The process is usually insidious, with gradual progressive necrosis of the cartilage. The clinical picture of pain and stridor may be confused with recurrence of the tumor. The treatment consists of elimination of any secondary infection by intravenous antibiotics, steroids and, if indicated, tracheostomy. Sequestrectomy may occasionally be indicated.

Miscellaneous

Other rare causes of laryngeal trauma include granuloma formation following polytetrafluoroethylene injection, nasogastric tube-induced cricoid erosion with secondary chondritis, and foreign body-induced damage. With adequate precautions, most of these occurrences can obviously be prevented.

The CO_2 laser is used extensively today for surgery of the larynx and trachea, with its major advantage being that it causes less edema and hemorrhage and is more accurate. Complications do, however, occur, with web formation, vocal muscle damage, and even cricoid perichondritis and severe hemorrhage being reported.

Of even greater importance is the development of a laser-induced fire, which may result in great damage to the laryngotracheal tree with subsequent stenosis and even death.