An Overview of the Larynx

The larynx, or voice box, is a cylindrical space which lies at the upper end of the trachea opposite to the 3rd—6th cervical cartilages. It is a cartilaginous structure made up of 6 different types of cartilages. Major structures forming the framework of the larynx are the thyroid cartilage, cricoid cartilage, and epiglottis. The unpaired cartilages are three in number, namely arytenoids, corniculate and cuneiform. Cricoid cartilage forms a complete ring which lies below the thyroid cartilage. Vocal cords are attached to the thyroid and arytenoid cartilages. Various muscles wrap the cartilages which produce movements at the cricoarytenoid and cricothyroid joints.

Definition of the Larynx

The larynx is the organ tasked with phonation, coughing and more importantly protection of the lower airway by preventing entry of foreign objects into the airway by a mechanical stimulation upon which it closes abruptly.

Structure and Function of the Muscles of the
Larynx

The innermost layer of the larynx is the mucous membrane, which consists of pseudostratified columnar ciliated epithelium, except at the vocal cords, which are lined by stratified squamous epithelium.

Anatomy of the Larynx

The larynx is located superior to the trachea and anterior to the pharynx on the latter’s inferior portion. It composes of three small and paired cartilages which include the arytenoid, corniculate and cuneiform cartilages, and three large unpaired cartilages which include the epiglottis, cricoid and thyroid cartilages. It also contains other structures such as ligaments, muscles, nerves, and vessels.

Muscles of the larynx are classified into two types:

1. **Extrinsic muscles** attach inside the larynx to the hyoid bone. They are further divided into two groups:

   - Suprahyoid group: consisting of digastric, geniohyoid, mylohyoid, and stylohyoid muscles collectively helpful to lift the larynx
   - Infrahyoid group: contains omohyoid, thyrohyoid, sternohyoid, and sternothyroid muscles to lower the larynx and hyoid bone
2. Intrinsic muscles are located inside the larynx that is meant to control stress over glottis and vocal cords. This group includes the thyroarytenoid, cricothyroid, posterior cricoarytenoid, transverse arytenoid, and lateral cricoarytenoid muscles.

In adults, the larynx is located at the level of C6 and lifts to C4 with swallowing. In infants, the larynx is a conical space with soft and compressible cartilages situated a bit higher against the C3 or C4 vertebrae and reaches C1 or C2 while swallowing.

Larynx functions

- Protects the lower airways (prevents large foreign bodies from reaching the lungs)
- Produces voice with assistance from the lips, tongue, palate, and pharynx
- Assists in respiration/breathing (controls the air column and the amount of air that passes through it)
- Plays a role in the Valsalva maneuver, the production of a cough and in increasing intraabdominal pressure during delivery or defecation

Plays a significant role in the direction of food into the esophagus through epiglottis thereby protecting the trachea from choking.

A Clinical Approach to the Larynx

The larynx creates an inlet to the airways and is exposed to bacteria and viruses, which can lead to a number of infections. Even trauma can lead to the disturbance of laryngotracheal anatomy and physiology.

Laryngotracheal Trauma

Road traffic accidents, a direct blow to the neck, strangulation, penetrating injuries, and gunshot wounds can cause injury to the larynx.

Laryngotracheal trauma should be suspected if the following signs and
Symptoms are present after a traumatic event:

1. Hoarseness of the voice
2. Pain or difficulty in swallowing, or aspiration of food particles
3. Dyspnea, with or without stridor
4. Hemoptysis
5. Bruises on the neck’s skin, with or without tenderness on palpation
6. Displacement of cartilages due to fracture, with or without bony crepitus
7. Swelling in the neck
8. Difficulty in speaking or generating sound
9. Laryngeal edema, hematoma or mucosal tear with asymmetry of the glottis (defined as the part of the larynx consisting of the vocal cords, and the slit-like opening between them), or the laryngeal inlet (the opening that connects the pharynx and the larynx), revealed after a laryngoscopy confirming the presence of the injury

Management

Any patient in the emergency department who is suffering from respiratory distress should be evaluated and managed depending on the severity of the presentation. Humidification and nebulization with steroids and bronchodilators can relieve edema and swelling, along with the respiratory distress.

If respiratory distress does not improve, the airway is secured, but not by endotracheal intubation, as it may be difficult and hazardous, instead, tracheostomy or, as an emergency, cricothyroidotomy is done.

Three to four days later, when the patient becomes stable, open reduction of the fractures is performed and mucosal tears are repaired using an absorbable material such as catgut. Normal anatomy is restored by repositioning of the structures using various techniques by the ENT surgeon.

Broad-spectrum antibiotics with appropriate upper respiratory tract coverage, like clarithromycin, amoxicillin or cephalosporin, are administered to prevent chondritis and cartilage necrosis.

Inflammation of the Larynx

Laryngitis
Acute inflammation of the larynx can be infectious or non-infectious. Infection is usually viral, however, superimposed bacterial infection is common. Inflammation results in fever, hoarseness, pain, or an irritating cough, which worsens at night along with a dry throat and malaise. Running nose and headache may be associated symptoms. The symptoms may last for two to three weeks even the voice kept at rest.

Common bacterial agents are *Streptococcus pneumoniae*, *Haemophilus influenzae* and *Moraxella catarrhalis*.

Laryngoscope would show erythema and edema of the epiglottis. Later, the swelling worsens and the redness increases, increasing the severity of the symptoms. Laryngitis secondary to *diphtheria* or tonsillitis is called acute membranous laryngitis.

Management

Nebulizers with steam and steroids improve the edema. Voice rest and avoiding irritants such as smoke, along with cough suppressants and pain-killers relieve the discomfort. If a productive cough starts along with a fever, antibiotics should be prescribed.

Chronic Laryngitis

After recurrent infections of the larynx, vocal cords and the surrounding structures become constantly inflamed. Repeated infections of the larynx, exposure to dust, cigarette smoking, alcohol consumption, fumes, smoke, or vocal abuse can predispose to chronic inflammation. Usually, patients complain of hoarseness, dry cough, constant aching and pain in the throat. Local examination shows dull red, rounded vocal cords with viscous mucus around them.

Management

Avoiding irritants, voice rest, speech therapy, steam inhalation and expectorants are given to relieve the symptoms. Antibiotic treatment is given for 7—10 days to protect against infections.

Reinke’s edema

Reinke’s space (Superficial Lamina Propria) is a layer just underneath the surface lining of the vocal fold. Composed of cells, special fibers, and other substances (extracellular matrix), Reinke’s space has a key role in vocal fold vibration.
**edema** is characterized by the “sac-like” appearance of the fluid-filled vocal cords. The **swelling** of the vocal folds causes the voice to become deep and hoarse. It’s common in smokers and can lead to laryngitis.

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**Epiglottitis**

Acute inflammation of the epiglottis and surrounding structures in the supraglottic space is more life-threatening and sudden on onset than laryngitis, mostly affecting children who are aged 2—7 years. *H. influenza* is the culprit in children. Patients present with dysphagia and sore throat along with dyspnea, with or without stridor. **Vaccination** is available and should be pursued. It has drastically decreased the number of cases with epiglottitis in the United States. Two or three doses should be given before six months of age. In the United States, a fourth dose is recommended between 12 and 15 months of age.

Examination of the oral cavity and laryngoscopy reveal edema and congestion of the **supraglottic structures**. Physical examination in the Emergency Room is usually avoided as it may precipitate obstruction of the airway. It can be done in an **ICU setting**. A **thumb sign** on an X-ray of the soft tissues of the neck (lateral view) can confirm the diagnosis. X-ray is avoided until the airway is secure as agitation in children may provoke danger of sudden obstruction. A throat swab and blood cultures can also be helpful.
Management

Hospitalization should be considered depending on the severity of the disease. Antibiotics like ampicillin or third generation cephalosporin are effective against *H. influenzae.* Analgesics such as aspirin and ibuprofen is prescribed to control fever and pain. Dexamethasone or hydrocortisone is given to relieve edema and inflammation. Oxygen inhalation and nebulization along with increased hydration are recommended.

**CROUP: Acute Laryngotracheobronchitis**
Inflammation of the larynx, trachea, and bronchi is mostly viral (Parainfluenza virus), affecting children aged up to 3 years. It is most common life threatening pediatric illness. Patients complain of flu-like symptoms and a characteristic seal like a barking cough accompanied by inspiratory stridor.

The presence of the steeple sign on x-ray (also called wine bottle sign, it refers to the tapering of the upper trachea on a frontal chest radiograph reminiscent of a church steeple) indicates a possible diagnosis of croup.

Management

Patients come to the emergency room presenting with a barking cough. Nebulization with adrenaline, normal saline and bronchodilators are all actions taken to relieve the distress. After hospitalization, steroids like hydrocortisone are given along with antibiotics. Tracheostomy is considered if the respiratory distress worsens. Many cases of croup have been prevented by immunization for influenza and diphtheria.

Laryngeal Diphtheria
Formation of a pseudo-membrane over the larynx, pharynx, and tonsils is caused by infection of the \textit{C. diphtheriae}. Its exotoxins can also cause \textit{myocarditis}. A patient presents with a sore throat, malaise, a low-grade fever, croupy cough, dyspnea, and stridor. On examination, a whitish membranes are observed over the throat and larynx. Lymphadenopathy leading to a “bull’s neck appearance” is a characteristic of this disease.

Management

Complete bed rest, antibiotic prescription, and antitoxins can be lifesaving. \textit{Benzyl penicillin} is the antibiotic of choice. Diphtheria antitoxin 20,000 to 100,000 units I.V in a normal saline drip for 5 days is recommended.

Other infections of the larynx secondary to diseases:

The larynx can be affected by other disease like \textit{tuberculosis}, \textit{lupus erythematosus}, \textit{syphilis}, leprosy and \textit{scleroderma}.

Congenital Lesions of the Larynx

\textbf{Laryngomalacia}

Excessive flaccidity of the \textit{supraglottic larynx} leads it to be sucked out of position during inspiration, which can produce stridor. This condition manifests at birth and disappears after 2 years of age. A laryngoscopy confirms the diagnosis.
Vocal cord paralysis

Vocal cord paralysis is the second most common congenital anomaly of the larynx caused secondary to central neuromuscular immaturity. Paralysis may occur due to lesions in the central nervous system due to hydrocephalus, spina bifida, etc. An inspiratory stridor at rest is the key symptom gets worsen on agitation in children. It requires urgent airway intervention by intubation.

Laryngeal web

Incomplete recanalization of the larynx produces a congenital weak cry and airway obstruction. Thin webs can be cut using a scalpel or CO$_2$ laser. Thick webs need excision and placement of dilators.

Laryngoele

This is the dilatation of the laryngeal saccule, the space between the true and false vocal cords. It may be internal, external or combined. Treatment is excision through endoscopy.

Local Changes in the Larynx
Non-Neoplastic Lesions

Vocal Nodules
Trauma to the vocal cords after vocal abuse or misuse leads to the formation of a pin head to half pea sized nodules symmetrically located on both cords, which is usually called singer’s nodules. Edema and hemorrhage in the sub mucosal space become nodular after fibrosis. Hoarseness, vocal fatigue and pain in the neck on prolonged use of voice are symptoms of laryngeal nodules.

These singer’s/screamer’s nodules can be managed conservatively through voice rest, speech therapy as well as by educating the patients on the cause. Otherwise, excision can be done under an operating microscope. Professional singers and people who have a lot of vocal demands are often affected by nodules.

Vocal Polyp

Finger-like projections called polyps are often formed after vocal abuse or misuse mostly in adulthood and old age. It can also occur after some allergic response or as a result of smoking.

The patient usually presents with hoarseness. If the polyp is large, it can lead to stridor or intermittent choking. Vocal polyps are managed by surgical excision followed by speech therapy.
Contact Ulcer

Vocal misuse in which laryngeal cartilages rub against each other leads to ulceration and granuloma formation. Patients usually complain of hoarseness and discomfort in the throat. An ulcer is visible on examination.

Intubation Granuloma

Granulomas can result after prolonged endotracheal intubation or after an injury to the vocal processes during intubation. The mucosal ulceration which is initially produced is followed by granuloma formation and produces hoarseness and even dyspnea. Voice rest and endoscopic removal are recommended.

Neoplastic Lesions

Squamous Papillomas

Juvenile papillomas mostly occur in infants and children. These are usually viral in origin and multiple in number, producing hoarseness and stridor. Local examination shows glistening white irregular growths, which may be pedunculated or sessile, and usually bleed easily.

Management

Complete excision, cryotherapy, micro-electrocautery, or CO₂ laser are the various treatment options.

Chondroma: Tumor of the Cartilages

The most commonly cartilage affected by chondromas is the cricoid cartilage. It causes dyspnea or even dysphagia.

Hemangioma

Capillary type hemangiomas occur in infants, while cavernous types is common in adults.

Granular Cell Tumor

Mostly, it is submucosal and arises from the Schwann cells. It can differentiate into a malignant tumor.

Laryngeal Carcinoma

Larynx cancer (better known as laryngeal cancer), is a disease in which cancer cells form in the tissues of the larynx. Laryngeal cancer is more common in males. Incidence is increasing due to various risk factors. This malignant disease is seen in adult males after age 40.

The various risk factors include:

- Smoking
- Alcohol use
- Air pollution
- Carcinogens exposure
- Radiation exposure
- Exposure to asbestos, mustard gas, petroleum products

Supraglottic Cancer

Usually, a silent invasion occurs in the surrounding structures. Early metastasis occurs into the lymph nodes, more often into the upper and middle jugular lymph nodes. The patient presents with throat pain, dysphagia, tender enlarged lymph nodes, and
weight loss. Hoarseness is a late symptom.

Glottic Cancer

Vocal cords become fixed due to tumor formation, and as a result, hoarseness develops. Hence diagnosing the disease can be done earlier relative to other laryngeal cancers. Stridor may result after the development of edema.

Subglottic Cancer

This condition is usually rare, but it involves the structures below the glottis, including the trachea. Hoarseness is a late symptom. Metastasis occurs on the prelaryngeal, pretracheal and paratracheal lymph nodes.

Classification of laryngeal carcinoma according to the site by the American joint committee of cancer:

<table>
<thead>
<tr>
<th>Sites</th>
<th>Subsites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supraglottis</td>
<td>Suprathyroid and infrathyroid epiglottis</td>
</tr>
<tr>
<td></td>
<td>Aryepiglottic folds</td>
</tr>
<tr>
<td></td>
<td>Arytenoids</td>
</tr>
<tr>
<td></td>
<td>False cords</td>
</tr>
<tr>
<td>Glottis</td>
<td>True cords with the anterior and posterior commissure</td>
</tr>
<tr>
<td>Subglottis</td>
<td>Up to the lower border of the cricoid cartilage</td>
</tr>
</tbody>
</table>

Grade of Cancer

The grade of cancer tells you to what extent the cancer cells look like normal cells under a microscope. There are 3 grades of laryngeal cancer:

- **Grade 1** (low grade) – well differentiated
- **Grade 2** (intermediate grade) – moderately differentiated
- **Grade 3** (high grade) – poorly differentiated

TNM Stages of Cancer of the Larynx

TNM stands for Tumor, Node, and Metastasis. The system describes:

- The size of a primary tumor (T)
- Whether the lymph nodes have cancer cells in them (N)
- Whether the cancer has spread to a different part of the body (M)

American Joint Committee on Cancer gave the TNM Classification of Laryngeal Carcinoma

T in TNM classification
- **Tx** - Primary tumor which cannot be assessed
- **To** - No evidence of primary tumor
- **Tis** - Carcinoma in situ
- **T1** - Tumor less than or equal to 2 cm in greatest dimension
- **T2** - Tumor greater than 2 cm in greatest dimension but < 4 cm
- **T3** - Tumor greater than 4 cm in greatest dimension
- **T4a** - Moderately advanced local disease
- **T4b** - Very advanced local disease

**N stages of laryngeal cancer**
There are 4 main lymph node stages in cancer of the larynx. N2 is divided into N2a, N2b and N2c. The important point here is presence or absence of cancer in any of the nodes, and in case of the former, the size and site of the involved lymph node.

- **N0** - no lymph nodes containing cancer cells
- **N1** - one movable lymph node involved on the same side of the neck which is less than 3 cm in size
- **N2a** - one movable lymph node on the same side of the neck, 3 cm—6 cm in size
- **N2b** - more than one lymph node, but none are more than 6 cm in greatest dimension; all the nodes must be on the same side of the neck as the cancer
- **N2c** - lymph nodes on the other side of the neck from the tumor or in nodes on both sides of the neck, but none is more than 6 cm in size
- **N3** - at least one lymph node containing cancer larger than 6 cm in size

**M stages of laryngeal cancer**
There are two stages to describe whether cancer of the larynx has spread:

- **M0** - there is no cancer spread
- **M1** - cancer has spread to other parts of the body, such as the lungs

**Diagnosis of Cancer**

Hoarseness of 3 weeks that does not improve is an important point in the history of the disease. Dyspnea, dysphagia, stridor, pain and swelling with an irritating cough, anorexia and cachexia are the representing symptoms of the disease. Examination of the neck is
important to find palpable lymph nodes. **The following investigations need to be carried out:**

**Laryngoscopy**

The appearance of the lesion can be ulcerative (infrahyoid epiglottic involvement), exophytic (suprahyoid epiglottic involvement), or nodular (glottis). Vocal cords may be fixed showing invasion or involvement of the recurrent laryngeal nerve. **After laryngoscopy, the following radiological tests should be performed:**

1. **Chest x-ray** to investigate any associated lung disease and mediastinal lymph nodes
2. Contrast-enhanced CT scan or MRI for soft tissue lateral view of the neck
3. Positron emission tomography-computerized tomography scan (PET-CT). This is a radiologic tool that detects metabolic signals from cells with high metabolic activity like cancer cells.
4. Fine needle aspiration (FNA) of a neck mass may be useful to diagnose malignant lymphadenopathy from a laryngeal tumor and may be an alternative means of establishing a diagnosis rather than direct biopsy via direct laryngoscopy.

**Treatment Options for Laryngeal Carcinoma**

**Radiotherapy**

Radiotherapy is effective with a 70—90 % cure rate if...

- ...cords are not fixed.
- ...no subglottic extension.
- ...cartilage is not involved.
- ...no lymph node is involved.
- ...no signs of invasion.

It shows good result in early diagnosis and preserves voice with side effects like dryness, skin excoriation, dysphagia, hair loss, etc.

**Surgery**

1. **Conservative surgery includes**
   1. Cordectomy through a laryngofissure
   2. Partial fronto-lateral laryngectomy
   3. Partial horizontal laryngectomy (excision of supraglottis)

2. **Total laryngectomy: Block dissection is done along with laryngectomy. It is an option if:**
   1. Fixed cords with a T3 stage tumor
   2. All T4 lesions
   3. Cartilages are involved
   4. Failure to cure the disease by radiotherapy or conservative surgery
   5. Tran glottic cancers which involve supraglottic and glottis

**Combined Therapy**

Combining surgery with radiotherapy is also very effective. Radiation treatment before and after surgery can decrease incidences of recurrence.
Vocal Rehabilitation after Treatment

Esophageal Speech

Patients are taught to swallow air and keep it in the upper esophagus and slowly eject it. A rough voice is produced but the patient can speak 6—10 words.

Artificial Larynx

An electrolarynx is a device used to produce voice. Another device is called transoral pneumatic device which uses expired air from the tacheostome to vibrate the diaphragm and produce sound.

Vocal Cord Paresis

Paralysis of the vocal cords can be unilateral or bilateral due to the involvement of the nerves supplying the larynx, i.e. recurrent laryngeal nerve, superficial laryngeal nerve.

Causes

1. Lesions in the nuclei of the nerves: Nucleus Ambiguus in the medulla. Vascular disturbance or tumor compressing the medulla may also be a cause. Poliomyelitis and syringomyelia can also affect the larynx.
2. Higher lesions of the Vagus nerve: in the skull or parapharyngeal space. For example, tubercular meningitis, nasopharyngeal cancer, glomus tumor, metastatic lymph nodes, lymphoma.
3. Low vagal injury, i.e. recurrent laryngeal nerve injury
4. Systemic causes, like syphilis, diabetes, diphtheria, viral infections
5. Idiopathic (30% of the cases)

Causes of recurrent laryngeal nerve paralysis:

1. Trauma to the neck
2. Thyroid surgery
3. Thyroid disease
4. Thyroid cancer
5. Cervical and mediastinal lymphadenopathy
6. Esophageal cancer
7. Enlarged left auricle
8. Aortic aneurysm

Semon’s law states that in a progressive lesion of the recurrent laryngeal nerve, the abductors are paralyzed before the adductors.

Wagner and Grossman theory

It states that: incomplete paralysis of recurrent laryngeal nerve, the vocal cord lies in the paramedian position because the intact cricothyroid muscle adducts the cord (due to an intact superior laryngeal nerve). If the superior laryngeal nerve is also paralyzed, the cord will assume an intermediate position because of the loss of addictive force.

Clinical features
Unilateral paralysis is usually asymptomatic; some patients may have voice problems, but issues regarding aspiration or airway obstruction are rare. It may present sudden onset of breathy, weak, low-pitched dysphonia. They feel shortness of breath.

In bilateral paralysis, cords are in median or paramedian position. The airway is inadequate and dyspnea with or without stridor can develop. The condition becomes worse on exertion.

**Treatment**

Unilateral paralysis needs no treatment.

Patients with bilateral paralysis present in the emergency department and often need a **tracheostomy**. Later, either a permanent tracheostomy is done with a speaking valve, or alternatively, surgery is performed.

**Surgical treatment: lateralization of the cord**

- Arytenoidectomy
- Thyroplasty type II
- Cordectomy with CO₂ laser via endoscopy
- Nerve-muscle implant

**Complete (combined) paralysis of the larynx:**

If both the nerves supplying the cords are involved, complete paralysis of the cords occurs. Thyroid surgery is the most common cause. Patients present with hoarseness of the voice and aspiration of liquids. Treatment includes speech therapy and surgically medialization of the cords through injection of Teflon paste, thyroplasty type I or arthrodesis of the cricoarytenoid joint.

**Review Questions**

Solutions can be found below the references.

1. **A child, 4 years old, presented to the emergency with an acute attack of a severe cough and respiratory distress. While he was in the hospital, he also developed stridor. He has had a history of a sore throat for the last 2 days. On examination, supraglottic structures were edematous and congested. Which of the following most common causative agents in this disease is the child suffering from?**
   
   - A. Coli
   - B. Pneumonae
   - C. Influenza
   - D. Diphtherae

2. **A child came to the family physician with hoarseness and respiratory difficulty along with flu-like symptoms. He was referred to an ENT surgeon who investigated the disease and did a laryngeal endoscopy. The figure shows the larynx of the child. In addition, the child has a history of a chronic cough and noisy breathing.**
   
   - A. Chronic bronchitis
   - B. Croup
   - C. Vocal cyst
   - D. Squamous papilloma of the larynx
   - E. Asthma
References


Correct Answers: 1C, 2D

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