Anatomy of the Lower Airways – Larynx and Trachea

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The larynx, trachea and the main bronchi together form the extrapulmonary lower airways. Warm and moist air in the upper airways (nose and pharynx) enters the larynx—the guardian of the airways. The larynx separates the trachea from the esophagus and is the organ associated with voice production. The air then passes through the tube-shaped trachea, which terminally bifurcates into two main bronchi, which then split apart to form the bronchial tree. Inside the lungs, the air reaches its destination in the small bronchioles and in the adjoining alveoli, where gas exchange occurs. This article provides an extensive overview of the lower airways—larynx and trachea.

Larynx: Location and Function

The larynx is an anatomically complex structure composed of important cartilages and muscles that constitute a barrier between the pharynx and the trachea, forming the transition from upper to lower airways. The epiglottis is a kind of flexible cartilage lid, which closes off the larynx from the esophagus to prevent the aspiration of fluids or foods when swallowing.
However, if food happens to enter the larynx, the coughing reflex ensures that the foreign material is catapulted out of the airways. The vocal folds represent another closing mechanism on the inside of the laryngeal tube. They consist of 2 ‘sails’ of muscular and connective tissue attached to the 2 cartilages separated by the glottis. Complete closure of the glottis allows minimal to no air passage.

The closure of the glottis and contraction of the diaphragm and the abdominal muscles raise the intra-abdominal pressure, which facilitates laryngeal function in abdominal muscular pressure. Modulation of airflow via glottis is important for phonation. Paralysis of the laryngeal muscles due to a lesion of the vagal nerve or its branches - superior laryngeal nerve and recurrent laryngeal nerve - results in incorrect or permanent closure of the glottis, which in turn leads to difficulty swallowing, hoarseness, or when there are lesions bilaterally - even respiratory distress. Innervation of the larynx is thus a very popular topic in medical exams.

Anatomical Composition of the Larynx

In order to comprehend the anatomy of the larynx, 1 should definitely take a closer look at the respective images in the anatomical atlas. In the straight head posture, the larynx is situated at the level of the 5th and 6th cervical vertebrae, which is slightly higher in women and children. In the longitudinal axis, it is divided into 3 levels based on histological variation (different epithelia of the pharynx and trachea) and anatomical differences. Knowledge of these three laryngeal levels is essential to understand the location of laryngeal carcinomas in clinical practice.

- Supraglottis extending from the entrance to the larynx to the vestibular folds (plicae vestibulares)
- **Glottis** spanning across the vestibular folds to the vocal folds (plicae vocales)
- **Subglottis** extending from the vocal folds to the lower margin of the cricoid cartilage

**Cartilages of the larynx**

The cartilage structure of the larynx is complex presenting from the top to bottom:

- **Epiglottis**, which is elastic cartilage, closes when swallowing.
- **Thyroid cartilage** is hyaline cartilage similar to a shield, with the anterior laryngeal prominence representing Adam’s apple. In men, it is clearly noticeable through the skin.
- **Cricoid cartilage** is hyaline cartilage shaped like a signet ring.

These 3 cartilages are connected to each other via elastic ligaments to the tongue bone (os hyoideum) cranially, and to the trachea caudally.

**Two additional small, paired cartilages exist inside the laryngeal frame:**

- **Arytenoid cartilage** is hyaline cartilage that changes the vocal fold position.
- **Corniculate cartilage** is elastic cartilage situated at the apex of the respective arytenoid cartilage.
Muscles of the Larynx

The classification of the laryngeal muscles is hard to understand at 1st glance. It is worthwhile to refer to the anatomical atlas or to watch instructional videos on the internet in order to obtain a better understanding of its structure.

The infrahyoid and suprathyroid muscles and the inferior pharyngeal constrictor muscle facilitate the swallowing of food. The small laryngeal muscles are responsible for the fine movements of the vocal folds.

Extrinsic muscles of the larynx

| Cricothyroid muscle | Its contraction tilts the cricoid cartilage backward and tightens the vocal cords. |

Intrinsic muscles of the larynx

The inner muscles of the larynx originate in the arytenoid cartilage and change the position of the vocal cords via contraction.

<table>
<thead>
<tr>
<th>Name</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posterior cricoarytenoid muscle (posticus)</td>
<td>Opening of the glottis (Note: only opener of the glottis)</td>
</tr>
<tr>
<td>Lateral cricoarytenoid muscle (lateralis)</td>
<td>Also known as phonation muscle, it consists of two components: the pars intermembranacea and the pars intercartilaginea, which close and open a part of the glottis, respectively.</td>
</tr>
<tr>
<td>Transverse cricoarytenoid muscle</td>
<td>Closure of the vocal folds</td>
</tr>
<tr>
<td>Thyroarytenoid muscle</td>
<td>Closure of the vocal folds</td>
</tr>
<tr>
<td>Vocal muscle</td>
<td>Tension of the vocal folds</td>
</tr>
</tbody>
</table>
Innervation and functional failures of the larynx

Branches of the vagal nerve ensure the motor and sensory innervation of the larynx. The **extrinsic laryngeal muscle is the only one that is innervated by the superior laryngeal nerve (external ramus)**. The internal ramus supplies the mucosa sensorily above the vocal folds.

The **inferior laryngeal nerve (out of the recurrent laryngeal nerve of the vagal nerve) is associated with motor innervation of the intrinsic laryngeal muscles**. It also ensures sensory innervation of the laryngeal mucosa below the vocal folds. Injury to the vagal nerve in the brainstem or along with its peripheral course results in failure of the laryngeal muscles. Thyroid surgery or local tumors increase the **risk of injury**.

Histology of the Larynx

Since the larynx represents transition of the pharynx (**stratified non-keratinizing squamous epithelium**) to the trachea (ciliated respiratory epithelium), it shows
differences in histological tissue composition. The interior of the larynx is divided into 2 pairs of folds: false/vestibular cords (*plicae vestibulares*) and the aforementioned true/vocal cords (*plicae vocales*).

Histological cross-sections mostly show the transition of the 2 areas, i.e., a part of the **vestibular folds** (cranial; *stratified non-keratinizing squamous epithelium*; *seromucous glands*) and the **vocal folds** (distal; *both stratified non-keratinizing squamous epithelium and ciliated respiratory epithelium*; *no glands*!). The individual **vocal fold** consists of the **vocal ligament** and the **vocal muscle** (innermost part of the thyroarytenoid muscle). Between the vocal ligament and the epithelium, there is a loose connective tissue layer, **Reinke's space**.

**Reinke's edema** is induced by excessive fluid in this space resulting in swelling that **impairs phonation and causes hoarseness**. Such edema can also be triggered by chronic irritation due to cigarette smoke, which results in the typical smoker's voice.

### Structure of the Trachea and Bronchial Tree

The **trachea** is approx. 10-12 cm (3.9-4.7 in) long and is an air-conducting **flexible tube**. It begins directly below the larynx and runs within the thoracic cage in the middle mediastinum, dorsally to the vessels close to the heart. **At the level of the 3rd or 4th thoracic vertebra, the trachea bifurcates into the left and right main bronchi**. The trachea is divided into 2 parts: **pars cervicalis** and **pars thoracica**.

<table>
<thead>
<tr>
<th>Location</th>
<th>Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cranial</td>
<td>Larynx</td>
</tr>
<tr>
<td>Ventral</td>
<td>Thyroid gland</td>
</tr>
<tr>
<td>Dorsal</td>
<td>Esophagus</td>
</tr>
<tr>
<td>Ventral</td>
<td>Aortic arch (front!), brachiocephalic trunk (right!) left common carotid (left!)</td>
</tr>
</tbody>
</table>

### Bronchial System

Since the **bronchi bifurcate repeatedly in order to distribute the respiratory air completely into the left and right pulmonary lobes**, it is also referred to as the bronchial tree or bronchial system. At the 1st bifurcation (**at the level of thoracic vertebrae Th3/Th4**), the trachea splits into the left and right main bronchi. **The right main bronchus runs steeper than the left one**. The branching of the bronchial system has real-life implications: aspirated foreign objects are frequently found in the right main bronchus. Due to the position of the heart and the slightly asymmetric position of the heart, the left main bronchus is slightly longer than the right one.

The main bronchi **bifurcate up to 23 times after entering the lungs. First, they split into lobar bronchi (2 on the left, and 3 on the right), and later split into segmental bronchi**. The smallest units are the bronchioles (bronchioles, terminal bronchioles, respiratory bronchioles), which direct the air into the alveoli, the seat of gas exchange in the lungs.

### Histology of the Trachea and Bronchi

The trachea consists of a **scaffold of 16-20 semicircular cartilage rings (hyaline cartilage)**, which are reinforced by collagenous connective tissue. The posterior wall of the trachea is free of cartilage. In this area, the **pars membranacea** forms a plate out of
the smooth muscles (tracheal muscle) and connective tissue, the border to the dorsally running esophagus. This supporting apparatus is histologically referred to as the fibromusculocartilaginous layer (tunica fibro-musculo-cartilaginea). A tunica adventitia composed of loose connective tissue surrounds the trachea.

The mucosa (tunica mucosa) of the trachea and bronchi is covered by the ciliated respiratory epithelium. The lamina propria contains seromucous glands, the tracheal glands. Interspersed, slime-producing goblet cells without kinocilia can be found within the epithelium.

The bronchial wall also consists of 3 layers: mucosa with pseudostratified ciliated respiratory epithelium, bronchial glands and goblet cells, a muscular layer, a support frame of hyaline cartilage and peribronchial connective tissue. All branches of the bronchial tree that contain cartilage tissue and seromucous glands are bronchi. Bronchioles have neither cartilage nor glands!

Smoking tobacco decreases the secretions from the tracheal and bronchial glands, which impairs the elimination of slime via movement of the kinocilia in the ciliated epithelium. Hence, airways are engaged in self-cleaning function.

Anatomy of the Larynx and Trachea in Clinical Presentations

Ventilation with laryngeal masks

The laryngeal mask, a ventilation mask, is used in anesthesia. It is positioned on the epiglottis and safely encloses the airways. The patient is ventilated using an attached tube. Compared with other procedures, no ventilation tubes are inserted through the glottis into the trachea (thereby, decreasing the risk of hoarseness and
injury). Thus, the laryngeal mask seals the airways better than with a facial mask.

![Image: Laryngeal mask with inflated bead, here a version with a channel for a gastric tube. By ignis, License: CC BY-SA 3.0](image)

**Cricothyrotomy**

Cricothyrotomy is the surgical opening of the airways via an incision of the cricothyroid membrane. It is a lifesaving medical emergency procedure frequently used when endotracheal intubation is impossible or contraindicated, and there is an impending loss of the airway.

*During cricothyrotomy, the membrane between the cricoid and thyroid cartilages in the larynx, which can be easily palpated at the throat, is opened via an incision or puncture.* The endotracheal tube is inserted in order to ensure oxygen supply to the patient.

**Tracheotomy and tracheostoma**

In intensive care, tracheotomy is defined as the operational insertion of access to the trachea for patients who depend on long-term ventilation. With a tracheostoma (the tracheal cannula used to create a connection of the trachea to the outside), patients can breathe spontaneously and independently. If needed, however, a ventilation device can be connected.

In addition to long-term ventilation, tracheotomy is indicated in injury to the larynx, the lack of swallowing reflexes, laryngeal or tracheal lesions due to long-term ventilation, certain jaw or ENT surgeries, or diseases or tumors of the upper airways, which are contraindicated for intubation.

Permanent tracheostoma (plastic tracheostoma) is applied in the case of laryngectomy (laryngeal carcinoma). In this case, the opening is created under the thyroid gland in the jugular fossa.
Diseases of the Larynx

See also: An Overview of the Larynx

Inflammation of the larynx (laryngitis)

Laryngeal inflammation can occur after nasal or pharyngeal infection triggered by viruses or bacteria. Also, excessive vocal exertion in a room full of dry air can lead to symptoms of laryngitis: reddened pharyngeal mucosa, burning sore throat, and hoarseness or loss of voice.

In addition to the treatment of the underlying cause (e.g., antibiotics for purulent inflammations), patients should speak as little as possible. Abstinence from nicotine exposure, heat treatment (hot throat compresses and warm beverages), and inhalation of chamomile extract are also part of the symptomatic treatment.

Other clinically significant types of inflammation of the lower airways, especially of the larynx, include acute epiglottitis and laryngitis subglottica (croup), which are treated using ENT medicine based on their clinical stage.
Laryngeal cancer (laryngeal carcinoma)

Laryngeal carcinoma is a **squamious cell carcinoma and the most frequent malignant tumor in ENT medicine.** Laryngeal carcinomas are located in the glottis in 2/3rds of the cases, in the supraglottis in 1/3rd of the cases, and rarely in the subglottis. An early symptom is a **long-lasting hoarseness. Difficulty swallowing and a foreign body sensation (globus sensation)** can also occur.

Any event of hoarseness that lasts more than three months should be evaluated for laryngeal carcinoma! The presence of laryngeal carcinomas is closely related to noxious agents such as tobacco smoke, but can also be associated with alcohol. Therapeutically, a partial (in the earlier tumor stages), and in most cases complete removal of the larynx (laryngectomy), removal of cervical lymph nodes (neck dissection) and radiation are necessary.

The **application of tracheostoma is mandatory in patients with the larynx removed** (see below). Tracheostoma can be used to create permanent access to the trachea, which is separated from the larynx, through the cervical skin. After this operation, patients no longer have vocal cords and are fitted with a **voice prosthesis** between the trachea and esophagus via laryngeal surgery. However, patients need to relearn speech.

**References**


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