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. After air has been warmed and moistened in the upper airways (nose and pharynx), it passes through the larynx - the guardian of the airways. The larynx separates the trachea from the esophagus and is the organ from which voice is produced. The air then passes the tube-shaped trachea, which bifurcates into two main bronchi at its end, which then split apart to form the bronchial tree. Intrapulmonary, the air reaches its destination in the small bronchioles and in the adjoining alveoli, where gas exchange takes place. This article provides you with an extensive overview of the lower airways - larynx and trachea.

Larynx: Location and Function

The larynx is an anatomically complex structure. It is helpful to recall the anatomy of the cervical area: The larynx is an anatomical-functional unit composed of important cartilages and muscles that build a barrier between the pharynx and the trachea, thus forming the transition from upper to lower airways. The epiglottis, being a kind of flexible cartilage cover, closes off the larynx from the esophagus whereby it prevents
the aspiration of fluids or foods when swallowing.

However, if food happens to get past the larynx, the coughing reflex makes sure that the foreign material is catapulted out of the airways. The **vocal folds (plicae vocales)** build another closing mechanism on the inside of the laryngeal tube. They consist of two ‘sails’ of muscular and connective tissue that are fixated at two cartilages. The gap between them is called the **glottis (rima glottis)**. If the glottis is completely closed, minimal to no air can pass through it.

Closing the glottis and contracting the diaphragm and the abdominal muscles raises the intra-abdominal pressure, which makes the larynx play a functional role in the abdominal muscular pressure. Modulation of airflow via the 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 - can result in incorrect or permanent closure of the glottis, which in turn leads to difficulty swallowing, hoarseness, or - when there are lesions on both sides - even respiratory distress.** Innervation of the larynx is thus a very popular subject in medical exams.

**Anatomical Composition of the Larynx**

In order to comprehend the anatomy of the larynx, one should definitely take a closer look at the respective images in the anatomical atlas. At straight head posture, the larynx is situated **on the level of the fifth and sixth cervical vertebra, which is slightly higher in women and children.** In the longitudinal axis, it is divided into three levels. This division is due to histological differences (different epithelia of the pharynx and
tracheal area) and differences in anatomical structure. Knowing these three laryngeal levels is essential, not only for exam purposes but also to comprehend the location of laryngeal carcinomas in clinical practice.

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

### Cartilages of the Larynx

The cartilaginous frame of the larynx is structured in a complex manner. **The following laryngeal cartilages can be found from top to bottom:**

- **Epiglottis**: elastic cartilage, closes when swallowing
- **Thyroid cartilage (cartilago thyroidea)**: hyaline cartilage, looks like a shield, the anterior laryngeal prominence represents the Adam’s apple. In men, it can be noticeable through the skin.
- **Cricoid cartilage (cartilago cricoidea)**: hyaline cartilage, it is shaped like a signet ring.

Through elastic ligaments, these three cartilages are connected to each other; to the tongue bone (os hyoideum) cranially, and to the trachea caudally.
On the inside of the laryngeal frame, there are two more small, paired cartilages:

- **Arytenoid cartilage (cartilago arytaenoidea):** hyaline cartilage, changes the position of the vocal folds
- **Corniculate cartilage (cartilago corniculata):** elastic cartilage (this one really sits on the apex of the respective arytenoid cartilage)

**Muscles of the Larynx**

The classification of the laryngeal muscles is hard to understand at first glance. It is worthwhile to look it up in the anatomical atlas or to watch instructional videos on the internet in order to get a better understanding of its structure. Once understood, a lot of functions and questions concerning the larynx can be deduced logically, which saves a lot of learning effort.

During swallowing, the larynx is moved as a complete structure by the infrahyoid and suprahyoid muscles and the inferior pharyngeal constrictor muscle. The small laryngeal muscles are responsible for the fine movements of the vocal folds. Their individual tasks and innervations are popular subjects in exams.

**Extrinsic Muscles of the Larynx**

| Cricothyroid muscle | Tension of the vocal folds. Its contraction tilts the cricoid cartilage backwards and tautens the vocal cords. |

**Intrinsic Muscles of the Larynx**

The inner muscles of the larynx originate from the arytenoid cartilage and change the position of the vocal cords by contracting.

| Posterior cricoarytenoid muscle (posticus) | Opening of the glottis (Note: only opener of the glottis) |
| Lateral cricoarytenoid muscle (lateralis) | Closes (pars intermembranacea) and opens (pars intercartilaginea) a part of the glottis, respectively. Also referred to as phonation muscle. |
| Transverse cricoarytenoid muscle | Closure of the vocal folds |
| Thyroarytenoid muscle | Closure of the vocal folds |
| Vocal muscle | Tension of the vocal folds |
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 intrinsic laryngeal muscles’ motor innervation is performed by the inferior laryngeal nerve (out of the recurrent laryngeal nerve of the vagal nerve). It also ensures the sensory innervation of the laryngeal mucosa below the vocal folds. If the vagal nerve is injured in the brainstem or in its peripheral course, specific failures of the laryngeal muscles occur. There is a possible risk of injury during thyroid surgery or by local tumors.
Histology of the Larynx

Since the larynx represents the transition of the pharynx (stratified non-keratinizing squamous epithelium) to the trachea (ciliated respiratory epithelium), there are differences in its histological tissue composition. The interior of the larynx is divided by two pairs of folds: false/vestibular cords (plicae vestibulares) and the already mentioned true/vocal cords (plicae vocales).

Histological cross-sections mostly show the transition of the two 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 (plica vocalis) is made up of the vocal ligament (ligamentum vocale) 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 occurs when there is too much fluid in this space. The result is a swelling that impairs phonation and makes the patient's voice hoarse. Such an 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 a roughly 10-12 cm long, 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 third or fourth thoracic vertebra, the trachea bifurcates into the left and right main bronchus. With respect to its pathway, the trachea is divided into two parts: pars cervicalis and pars thoracica. Relations concerning the location of the trachea in the thorax are important and a common topic in exams:

<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 further and further in order to sufficiently spread 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 first bifurcation (bifurcation tracheae at the level of Thoracic Vertebrae Th3/Th4), the trachea splits into the left and right main bronchus. The right main bronchus runs steeper than the left one. This fact about the bronchial system also has real life applications: aspirated foreign objects are frequently found in the right main bronchus. Due to the position of the heart and the resulting 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 (two on the left, three on the right), and then later split
into segmental bronchi. The smallest units are the bronchioles (bronchioles, terminal bronchioles, respiratory bronchioles), which direct air entry into the alveoli, the place in the lungs where gas exchange takes place.

**Histology of the Trachea and Bronchi**

The trachea consists of a **support frame 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 **paries 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 a ciliated respiratory epithelium. The lamina propria contains sero-mucous glands, the **tracheal glands** (**glandulae tracheales**). Interspersed, slime producing **goblet cells** without kinocilia can be found within the epithelium.

The **bronchial wall** also consists of **three layers**: **mucosa** with pseudostratified ciliated respiratory epithelium, glands (glandulae bronchiales) 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 sero-mucous glands are bronchi. **Bronchioles neither have cartilage nor glands!**

Smoking tobacco can decrease the production of secretion from the tracheal and the bronchial glands, which impairs the elimination of slime via the movement of the kinocilia of the ciliated epithelium and, hence, the self-cleaning function of the airways.
Anatomy of the Larynx and Trachea in Clinical Presentations

Ventilation with Laryngeal Masks

The laryngeal mask, a ventilation mask, is used in anesthesia. It lies on the epiglottis and safely encloses the airways. The person is ventilated using an attached tube. Compared to other procedures, this method has an advantage in that no ventilation tubes have to be pushed through the glottis into the trachea (risk of hoarseness and injury) and the airways are even better sealed than with a facial mask.

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 not possible or attempts failed and there is impending loss of the airway.

In a cricothyrotomy, the membrane between the cricoid and thyroid cartilage of the larynx, which can easily be palpated at the throat, is opened via an incision or puncture. Then, an endotracheal tube is inserted in order to ensure oxygen supply to the patient. Learning this procedure might only benefit you for exam purposes, but later on it will only be useful if you aspire to become an emergency doctor.

Tracheotomy and tracheostoma

In intensive care, the tracheotomy method is applied, i.e., the operational insertion of an access to the trachea for patients who depend on longterm ventilation. With a tracheostoma (the tracheal cannula which creates a connection of the trachea to the outside), patients can breath spontaneously by themselves. If need arises, however, a ventilation device can be connected.

Besides long-term ventilation, other applications of tracheotomy include 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 could make intubation unfeasible or dangerous.
A 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)

An inflammation of the larynx can occur after an infection of the nose and pharynx region due to viruses or bacteria. Also, an overload of voice in a dry air room environment can lead to symptoms of laryngitis: redened pharyngeal mucosa, burning sore throat, and hoarseness or loss of voice.

Besides treatment of the causes (antibiotics for purulent inflammations), the patients should speak as little as possible. Nicotine abstinence, heat treatment (hot throat compresses and warm beverages), and the inhalation of chamomile extract are also part of the symptomatic treatment.

Other clinically significant inflammations of the lower airways, especially of the larynx,
are the acute epiglottitis and the laryngitis subglottica (croup), which are treated using ENT medicine in their clinical stage.

Laryngeal Cancer (Laryngeal Carcinoma)

Laryngeal carcinoma is a squamous cell carcinoma and the most frequent malignant tumor in ENT medicine. Laryngeal carcinomas are located in the glottis in two-thirds of the cases, in the supraglottis in one-third of the cases, and very seldom in the subglottis. An early symptom is a long lasting hoarseness. Difficulty swallowing and a foreign body sensation (globus sensation) can also occur.

At the event of hoarseness that lasts more than three months, laryngeal carcinoma always must be ruled out! The formation of laryngeal carcinomas is closely related to noxae like tobacco smoke, but can also be associated with alcohol. Therapeutically, a partial (at earlier tumor stages), in most cases complete removal of the larynx (laryngectomy), removal of cervical lymph nodes (Neck dissection) and radiation are necessary.

The removal of the larynx makes the application of a tracheostoma obligatory (see below). With tracheostoma, permanent access to the trachea, which is separated from the larynx, is made to the cervical skin. After this operation, patients no longer have vocal chords and can be fitted with a ‘voice prosthesis’ between the trachea and esophagus during this larynx surgery. However, speech has to be relearned.

Review Questions

Solutions can be found below the references.

1. Which of the statements concerning the laryngeal muscles is not correct?
   
   A. Closure of the vocal folds – transverse arytenoid muscle
   B. Opening and closure of the vocal folds – lateral cricoarytenoid muscle
   C. Tension of the vocal folds – cricothyroid muscle, vocal muscle
   D. Closure of the vocal folds – posticus muscle

2. Which of the following structures of the larynx is punctured during cricothyrotomy?
   
   A. Medial part of the thyroid cartilage.
   B. Cricothyroid ligament between cricoid cartilage and thyroid cartilage.
C. Thyrohyoid membrane between the tongue bone and the thyroid cartilage.
D. The puncture is made via the thyroid gland.
E. Puncturing the larynx is not possible.

3. At which level is the bifurcation of the trachea located?
   A. At the level of the thoracic aperture.
   B. C5/C6
   C. Th10
   D. Th1/C7
   E. Th3/Th4

4. A little boy is brought to the emergency room due to acute dyspnea. Where is an aspirated foreign body most likely to be found in imaging modalities?
   A. Esophagus
   B. Tracheal bifurcation
   C. Trachea
   D. Right main bronchus
   E. Left main bronchus

References


Correct answers: 1D, 2B, 3E, 4Dv

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