Functional anatomy of the respiratory system

1. General characteristic of the respiratory system
2. Functional anatomy of the air passages
3. Functional anatomy of the lungs
4. Functional anatomy of the pleura
5. Development of the respiratory system
6. Examination of the respiratory organs
7. Anomalies of the respiratory organs

Author: PhD, professor Tamara Hacina
Anatomical classification of the respiratory organs:

1- the air passage:
(upper - the nasal cavity and nasal part of the pharynx; lower - the larynx, trachea, bronchi);

2 - the organs accomplishing the function of the change of the gases:
the lungs.
Structural peculiarities of the air passages

1) They *don’t collapse* (their walls contain the bones and cartilages)
2) Their walls are covered by *ciliated epithelium*
3) Epithelium consists of *goblet cells* /these are *glandular* simple columnar epithelial cells/ whose sole function is to secrete *mucin*, which dissolves in water to form *mucus* /and columnar epithelial cells, serous and mucous glands./

Functions of air passages

- warming,
- humidification,
- purification of inhaled air
Functions of the nasal mucosa

**Heat Exchange** The nose may be considered as a heat exchange system where two fluids are in thermal but not direct contact. It is the inspired air and the other fluid is the blood supply of the nose.

**Humidification** It is generally accepted that water from humidification comes directly from the serous glands which are extensive throughout the nasal mucosa.

**Nasal Reflexes** Several reflexes are initiated in the nasal mucosa. Sneezing is a protective reflex when particles foreign to the mucosa are expelled followed by the copious flow of nasal secretions help on to wash them out.

**Olfaction.** Olfactory epithelium is located at the roof of the nasal cavity and the adjoining parts of the nasal septum and the superior turbinate.

The nasal mucosa contains a series of *adjustments for treatment of the inspired air*:
1) it is covered with ciliated epithelium whose *cilia* form a carpet on which dust settles; the vibration of the cilia in the direction of the choanae drives out the settled dust;
2) the mucous membrane contains *mucous glands* whose secretions wrap around the dust and make its expulsion easier and also humidify the air;
3) the submucous tissue is rich in *veins (plexus venosus)*, which form thick networks (resembling cavernous bodies) on the inferior concha and the lower border of the middle concha; under different conditions these networks may swell and be cause of nose bleeding.
The Nose

Dorsum

Root

Apex (tip)

Columella = skin that separates the naris

Vibrissae

Naris

Ala

Columella = skin that separates the naris
• **The turn up Nose**: This type of nose is also called as the Celestial nose. It is so called because it runs continuously from the eyes towards the tip.

• **The Roman or Aquiline Nose**: This type of nose is convex in shape, like a hook. It is also known as 'hooknose' because of its shape. The word aquiline is derived from the Latin word 'aquilinus' which means 'eagle like'.

• **The Greek or Straight Nose**: This type of nose is perfectly straight with no curves or hooked like shape. It is known as Greek nose because it is generally noticed that the Greek people have this kind of nose.

• **The Nubian Nose**: This type of nose has wide nostrils. It is generally a little narrow at the top, thick and broad at the middle and wide at the end. The term 'Nubian' comes from the ethnic group 'Nubians' who belong to northern Sudan.

• **The Hawk Nose**: The hawk nose is so called because it is very convex, to the extent that it almost looks like a bow. It is very thin and sharp as well. Since it resembles the beak of a Hawk, it is known as the hawk nose.

• **Snub Nose**: This type of nose is quite short in length and is neither sharp, nor hook like nor wide. It is almost as short as a nose possibly can be. Hence, it is known as snub nose.
• Ratio of width and length of the external nose grows among the peoples of the North to the South Pole

• The anthropological literature points to the relationship of nasal index and climate: the distribution of leptorrine forms in cold and dry climates, hamerrine - in hot and humid climates

• **Congenital deformations of the external nose** are classified as follows:
  - *saddle nose* (rinolordosis) hooked nose (rinokyphosis),
  - *lateral displacement of the nasal pyramid* (rinoskoliosis),
  - *flattened nose* (platyrrine), a wide nose (brachyrrine),
  - *narrow nose* (leptorrine), long, short;
  - *soft, pliable nose* (mollirinia), combined deformation
Nasal Vestibule is the most anterior part of the *nasal cavity*. It is enclosed by the *cartilages* of nose and lined by the same *epithelium* of the *skin* (Stratified squamous, keratinized). The other part of the nasal cavity, which is lined by the *respiratory epithelium*, is called *nasal cavity proper*. Inside the vestibule are small hairs called *vibrissae*, which filter dust and other matter that you breathe in.

The forward section, within and above each nostril, is called the *vestibule*. Behind the vestibule and along each outer wall are three elevations, running generally from front to rear. Each elevation, called a *nasal concha* or *turbinate*, hangs over an air passage. Beside and above the uppermost concha is the *olfactory region* of the nasal cavity. The rest of the cavity is the *respiratory portion*. The respiratory area is lined with a moist *mucous membrane* with fine hairlike projections known as cilia, which serve to collect debris. *Mucus* from cells in the membrane wall also helps to trap particles of dust, carbon, soot, and bacteria.
Kiesselbach's area, also Kiesselbach's plexus, Kiesselbach's triangle, and Little's area, is a region in the anteroinferior part of the nasal septum, where five arteries anastomose to form a vascular plexus:

- anterior ethmoid artery
- great palatine artery
- sphenopalatine artery
- superior labial artery
- lateral nasal branch of facial artery
Epistaxis

- Anterior nasal septum is the Kiesselbach area
  - Plexus of all five arteries supplying the septum
  - Epistaxis = nose bleed
- Generally minor nose bleeds are from arterial of venous plexus
- Spurting of blood likely larger artery (e.g. sphenopalatine)
An additional adjustment for ventilation of the air are the paranasal sinuses, which are also lined with mucous membrane, a direct continuation of the nasal mucosa.
The functions of the sinuses are as follows:

1. air conditioning
2. reduction of skull weight, lighten the skull for better balance
3. heat insulation
4. flotation of skull in water
5. increasing the olfactory area
6. areas for the production of mucus to moisten the nasal chambers and inspired air
7. vocal resonance
The lower respiratory pathways is also called the **respirator tree** or **tracheobronchial tree**, to describe the branching structure of airways supplying air to the lungs, and includes:

- Larynx
- Trachea
- Main bronchi
- Lobar bronchi
- Segmental bronchi (8-10 orders)
- Lobular bronchi (18-20 orders)
- The mucous lining of the larynx:
  - Mainly stratified squamous epithelium in the upper part
  - Ciliated columnar in the lower part of the larynx.
Functions of the larynx

It acts as a valve to prevent air from escaping the lungs, e.g. weightlifting.

It prevents foreign substances from entering the lungs, trachea and glottis, e.g. while swallowing, the epiglottis covers the opening to the larynx;

It expels foreign substances which threaten the trachea, e.g. coughing.

Production of sound

Fixation of the chest This less known function of the larynx is important for increasing intra abdominal pressure. Closure of the vocal cords achieves fixation of the chest necessary to raise intra abdominal pressure required for daily activities like lifting weights, climbing and even for passing urine and stools.
Sex differences of the larynx:

• By puberty, the larynx descends to the level of C6 or C7.
• Adult males typically have longer and thicker vocal folds than females (differences occur at puberty).
• In males, the rise in testosterone at puberty stimulates the anterior growth of the thyroid notch and wide growth of the pharynx.
The right main bronchus is wider, shorter and more vertical than the left one. It is about 2.5 cm long and passes directly into the root of the lung.

The left main bronchus is about 5 cm long and passes inferolaterally, inferior to the arch of aorta, and anterior to the oesophagus and the descending aorta.

Within each lung, the bronchi divide in a constant fashion and in constant directions so that each branch supplies a clearly defined sector of the lung.

Each main bronchus divides into secondary or lobar bronchi, each of which supplies a lobe of the lung.

Each lobar bronchus divides into tertiary or segmental bronchi, which supply segments of the lung = bronchopulmonary segments.
Bronchial Structure

The walls of primary, secondary, and tertiary bronchi:
- contain progressively less cartilage and more smooth muscle
- increasing muscular effects on airway constriction and resistance
Terminal bronchioles:

- **No cartilage** as the smooth muscle is thicker to help maintain the structure.

- The internal walls are lined with *ciliated columnar mucous membrane* but as the walls extend towards the distal bronchiole this membranous layer changes to *non-ciliated cuboidal-shaped cells*.

- Split into 2 or more *respiratory bronchioles*

- Thinner walls and are lined with *ciliated columnar epithelium*

- Do not contain any *goblet cells*.

- Increased numbers of clara cells that line the lumen and secrete an agent similar to *surfactant*
Contrast of the emphysematous lung /above/ with the normal lung /below/, showing extensive alveolar destruction.
The lungs are separated from each other by the **heart and great vessels** in the **middle mediastinum**.

The lungs are attached to the **heart and trachea** by the structures in the **root of the lungs** and to the **pericardium** by the **pulmonary ligaments**.

**The Root of the Lung**

The root serves as the **attachment of the lung** and is the "highway" for the **transmission of the structures entering and leaving** the lung at the hilum.

It is surrounded by the reflection of **parietal** to **visceral pleura**.

**The Hilum of the Lung**

It contains the main bronchus, pulmonary vessels (one artery and two veins), bronchial vessels, lymph vessels, and nerves entering and leaving the lung.
The Main Differences Between the Right and Left Lungs

- The right lung has 3 lobes while the left has 2 lobes.

- The right lung is larger and heavier than the left lung, but is shorter and wider because the right dome of the diaphragm is higher and the heart and pericardium bulge more to the left.

- The anterior margin of the right lung is straight, whereas the margin of the left lung has a deep cardiac notch.

The Right Lung

- This is divided into superior (upper), middle, and inferior (lower) lobes by horizontal and oblique fissures.
- The horizontal fissure separates the superior and middle lobes.
- The oblique fissure separates the inferior lobe from the superior and middle lobes.
- The superior lobe is smaller than in the left lung, and the middle lobe is wedge-shaped.

The Left Lung

- This is divided into superior (upper) and inferior (lower) lobes by a long deep oblique fissure. This extends from its costal to its medial surface.
- The superior lobe has a large cardiac notch on its anterior border, where the lung is deficient owing to the bulge of the heart.
- The anteroinferior part of the superior lobe has a small tongue-like projection called the lingula.
- The inferior lobe of the left lung is larger than the superior lobe and lies inferoposterior to the oblique fissure.
**Impressions of the right lung**

- *above* the hilum: groove for azygous vein & for superior vena cava;
- *behind*: groove for oesophagus;
- *in front*: the cardiac impression;
  - *inferiorly*: a groove for the inferior vena cava.

**Impressions of the left lung**

- *above* the hilum, groove of the **aortic arch**, and upward from this is a groove accommodating the **left subclavian artery**;
- a slight impression in front of the latter lodges the **left innominate vein**.
- *behind* the hilum and pulmonary ligament is a vertical furrow produced by the **descending aorta**;
- in front of this, near the base of the lung, the lower part of the **esophagus** causes a shallow impression;
- *in front* of hilum: the cardiac impression.

**Differences of the right & left hilum**

*On the right*: R main bronchus is located above the pulmonary artery.

*On the left*: L pulmonary artery is located above the main bronchus.
Bronchopulmonary Segments:
10 – right;
8-9 - left
Bronchial tree
/22-23 generations of the bronchi/

Alveolar tree
/respiratory bronchioles, alveolar ducts, air sacculi with the alveoli/
Primary pulmonary lobule consists of all alveolar ducts, alveolar sacs, and alveoli distal to last respiratory bronchiole and their cognate blood, lymphatics and nerves.

Morphofunctional unit of the lungs is acinus: distal to terminal bronchiole, including respiratory bronchioles, alveolar ducts, alveolar sacs, and alveoli.

Secondary pulmonary lobule is a 1–2.5 cm structure which is the smallest unit of lung tissue invested by connective tissue septa, and contains 3 to 5 acini.
Gas Exchange Between the Blood and Alveoli

**The Respiratory Epithelium**
- For gases to exchange efficiently:
  - alveoli walls must be very thin (< 1 μm)
  - surface area must be very great (about 35 times the surface area of the body)

**Surfactant**
- It is oily secretion
- Contains the phospholipids and Proteins
- Coats alveolar surface and reduces surface tension
ABNORMALITIES OF THE PLEURAL SPACE

A closed pneumothorax is caused by air leaking into the pleural space from an opening within the lung (see A above). In this situation, there is a perforation of the visceral pleura while the outer chest wall and the parietal pleura remain intact. For example, the sharp end of a fractured rib may pierce or tear the visceral pleura, causing a closed-type pneumothorax.
Reference lines of the thorax

1 - Anterior median line
2 - Lateral sternal line
3 - Parasternal line
4 - Midclavicular line
5 - Anterior axillary line
6 - Midaxillary line
7 - Posterior axillary line
8 - Scapular line
9 - Paravertebral line
Topography of the lungs and pleura

Anterior view

Posterior view

Lateral view
1. Stomodeum  
2. Pharyngeal gut  
3. Thyroglossal duct  
4. Tracheobronchial diverticulum
A.1. Foregut 
2. Esophagotracheal septum 
3. Respiratory diverticulum 

B.1. Pharynx 
2. Lung buds 
3. Trachea 
4. Esophagus 

C.1. Lung buds 
2. Trachea 

D.1. Right upper lobe 
2. Left upper lobe 
3. Right lower lobe 
4. Left lower lobe 
5. Right middle lobe 
6. Splanchnic mesoderm 
7. Bronchial buds 
8. Visceral pleura
## Stages of the lung development

<table>
<thead>
<tr>
<th>Time period</th>
<th>Stage</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-17 weeks</td>
<td>Pseudoglandular</td>
<td>Developing lungs resemble an exocrine gland. Respiration is not possible. Fetuses born during this time <em>cannot survive</em>.</td>
</tr>
<tr>
<td>16-25 weeks</td>
<td>Canalicular</td>
<td>Terminal bronchioles divide and primitive alveolar sac develop /terminal sac/. Some respiration may be possible towards the end of this stage. Fetuses born towards the end of this period <em>can survive if given intensive care but often die anyway</em>.</td>
</tr>
<tr>
<td>24-birth</td>
<td>Terminal sac</td>
<td>Many more alveoli develop and the epithelium lining the terminal sacs become thin enough to allow respiration. Type I and type II pneumocytes develop. Type II pneumocytes begin producing pulmonary surfactant, which counteracts surface tension and facilitates expansion of the terminal sac at birth. Fetuses born <em>after 24 weeks may survive, and those born after 32 weeks have a good chance of survival</em>.</td>
</tr>
<tr>
<td>Birth-year 8</td>
<td>Alveolar</td>
<td>Respiratory bronchioles, terminals, alveolar ducts continue to increase in number.</td>
</tr>
</tbody>
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Methods of examination of the nose

A) Skin appearance - color same as face.
B) Shape - symmetrical.
C) Nares - septum midline, symmetrical
Methods of examination of the nose

A) Firmness, nodules, pain
B) Patency of nares (Have client close mouth and occlude one nares)
The larynx is positioned low in the neck and requires some special skills and tools for examination.

**Direct Laryngoscopy** this type of examination involves directly looking at the larynx. Because of the gag reflex, direct laryngoscopy is most often done in the operating room under a general anesthetic. The examiner holds an instrument called a laryngoscope in his or her hand, and looks through this instrument to examine the larynx.

**Indirect Laryngoscopy** The examiner can place a small mirror in the back of the throat and angle it down towards the larynx. Light can be reflected downward and the larynx can be seen in the mirror. Indirect laryngoscopy is quick an easy, and gives a three dimensional view of the larynx in true color.
Methods of examination of respiratory organs

Indirect laryngoscopy

Direct laryngoscopy
Direct laryngoscopy
A. Vocal folds are opened for deep inspiration

B. Vocal folds are closed: fonation position

C. The intercartilaginous part of the rima glottidis is open, as during whispering
Flexible and Rigid Endoscopy There are two special optical instruments that can assist the physician in examination of the larynx during an office visit. The instrument shown below on the left is a nasopharyngoscope. The curved part of the scope is a flexible fiberoptic cable that can be passed through the nose and through the pharynx until it gives a view of the vocal folds.

Stroboscopic Examination During speech, the vocal folds vibrate 100 times per second or more. This is too fast to be seen by our eyes. In order to more carefully examine the vocal folds in action, a special light source called a strobe light is used. The strobe sends off a very bright and very short flash of light. If the strobe flash is repeated at the exact same rate that the vocal folds are vibrating, they will appear "frozen" in time. If the firing rate is then adjusted so that it is a little faster or a little slower than the vibration rate of the folds, the folds will appear to move in slow motion. The strobe exam is extremely useful because it allows us to see how the vocal folds are functioning.
6) Inspect patient’s chest normal breathing movement.
7) Inspect patient’s chest for accessory muscle use.
8) Inspect patient’s chest for retraction of lower intercostal spaces.
9) Stand again to the right of patient and look tangentially for apical and epigastric pulsation.
10) Inspect the chest wall and skin for swelling, scars, skin eruption or engorged veins.
Pectus excavatum
Pectus carinatum
Percussion
Auscultation
Anomalies of the respiratory organs

1. Absence or agenesis of: bronchus, larynx, trachea
2. Anomaly (of): cricoid cartilage, epiglottis, thyroid cartilage, tracheal cartilage
3. Atresia (of): epiglottis, glottis, trachea
4. Cleft of the larynx
5. Congenital dilation of the trachea
6. Stenosis of the larynx, trachea
7. Diverticulum of the bronchus, trachea
8. Rudimentary tracheal bronchus
9. Congenital cystic lung
10. Agenesis, hypoplasia, and dysplasia of the lung
11. Absence of lung (lobe)
12. Hypoplasia of lung (lobe)
Laryngeal cleft
A. Tracheoesophageal fistula

Most common form (90% to 95%) of tracheoesophageal fistula. Upper segment of esophagus ending in blind pouch; lower segment originating from trachea just above bifurcation. The two segments may be connected by a solid cord.

B. Variations of tracheoesophageal fistula and rare anomalies of trachea

Upper segment of esophagus ending in trachea; lower segment of variable length.

D. Fistula without esophageal atresia

E. Esophageal atresia without fistula

F. Aplasia of trachea (lethal)

G. Stricture of trachea

H. Absence of cartilage

I. Deformity of cartilage

J. Abnormalities of bifurcation
it is the mass of tissues and organs separating the two pleural sacs

An anterior and posterior parts are distinguished in the mediastine in accordance to BNA.

The boundary between them is a frontal plane drawn through the posterior part of both pulmonary roots.
An anterior & posterior parts are distinguished in the mediastinum, the boundary between which is a frontal plane drawn through the posterior part of both pulmonary roots.
Limits of the mediastinum

Anterior – sternum

Posterior - vertebral column

Inferior : diaphragm

Superior: superior thoracic aperture

Lateral – pleural sacs
Contents of the superior mediastinum

/in planes from anterior to posterior/:

glandular plane;

venous plane;

arterial-nervous plane;

visceral plane;

lymphatic plane
Contents of anterior mediastinum
Contents of anterior inferior mediastinum

BNA

- 2/3 inf. – heart, pericardium
- 1/3 sup. (above the III-d intercostal space)

Thymus;
Brachiocephalic veins
Connective & fat tissue;
Frenic nerves
Lymph nodes
Contents of the middle mediastinum

The Middle Mediastinum is the broadest part of the interpleural space.

It contains:

- the **heart** enclosed in the pericardium,
- the **ascending aorta**,
- the **lower half of the superior vena cava** with the **azygos vein** opening into it,
- the **bifurcation of the trachea** and the two bronchi,
- the **pulmonary trunk** dividing into its two branches,
- the **right and left pulmonary veins**,
- the **phrenic nerves**,
- some **bronchial lymph nodes**.
Contents of the inferior posterior mediastinum

- Sympathetic chain
- Splanchnic nerves
- Vagus nerves
- Oesophagus
- Descending aorta
- Veins azygos, hemiazygos
- Thoracic duct
- Fat tissue
- Lymph nodes