Chapter 23 The Respiratory System Lecture Outline

Respiratory System
Functions:
1. external respiration
2. pulmonary ventilation
3. protection
4. vocalization
5. olfaction

Upper respiratory system
nose, nasal cavity, sinuses, pharynx

Lower respiratory system
A. Conducting portion
   larynx, trachea, bronchi, bronchioles
B. Respiratory portion
   alveoli

Mucosa
Ciliated pseudostratified columnar epithelium
Goblet cells
Lamina propria
   Mucus glands: mucus
   Serous glands: lysozyme

Defense
1. Mucus
2. Cilia: mucus escalator
   Cystic fibrosis
   Smoking
3. Alveolar macrophages
   Squamous cell carcinoma

Anatomy
Upper respiratory system
1. Nose
   External nares
   Vestibule
2. Nasal cavity
   Nasal septum
   Olfactory epithelium
   Nasal conchae
   Hard & soft palate
   Internal nares
   Epistaxis
   Paranasal sinuses
      frontal, sphenoid, ethmoid, maxillae
   Rhinitis
   Sinus headache
3. Pharynx
   A. Nasopharynx
      Pseudostratified columnar epithelium
      Uvula
      Pharyngeal tonsil
      Auditory tubes
   B. Oropharynx
      Stratified squamous epithelium
      Palatine & lingual tonsils
   C. Laryngopharynx
      Stratified squamous epithelium

Lower respiratory system
4. Larynx
   Hyaline cartilage
   Glottis
   Epiglottis
   Elastic cartilage
   Vocal folds / cords
   Pitch
   Volume
   Phonation
   Speech
   Laryngitis
5. Trachea
   a. Mucosa
      Pseudostratified columnar epithelium
      Goblet cells
      Lamina propria
      Smooth muscle
      Glands
   b. Submucosa
      Mucus glands
   c. Adventitia
      Hyaline cartilage
      Trachealis muscle
6. Primary bronchi & tree
   Lung hilum
   Bronchial tree
      1. less cartilage
      2. more muscle
      3. thin epithelium, less cilia & mucus
7. Terminal bronchiole
   Sympathetic = bronchodilation
   Parasympathetic = bronchoconstriction
   Asthma
   Histamine
   Epinephrine
   Pulmonary lobule
   Respiratory bronchiole
   Alveolar sac
8. Alveoli
   Cells
      a. Type I cells
         Simple squamous epithelium
      b. Type II cells
         Simple cuboidal epithelium
         Surfactant
      c. Alveolar macrophage
   Alveolar pores
   Respiratory membrane
      a. Type I cells
      b. Basal lamina
      c. Endothelial cells
   Pneumonia
   Pulmonary embolism
Lungs: gross anatomy
Right: 3 lobes
Left: 2 lobes
Pleural cavity
Parietal pleura
Visceral pleura
Pleural fluid
Pleurisy
Respiratory physiology
1. Pulmonary ventilation
   Pneumothorax
   Atelectasis
   Boyle’s law
   Diaphragm
      contraction: ↑ volume, ↓ pressure, air in
      relaxation: ↓ volume, ↑ pressure, air out
Factors
   1. Airway resistance
   2. Alveolar surface tension
      Surfactant
      Respiratory distress syndrome
3. Compliance
   A. Connective tissue
      Emphysema
   B. Alveolar expandability
      Collapse
      Edema
   C. Thoracic mobility
Inspiration
   A. Eupnea
      Diaphragm
      External intercostals
   B. Hyperpnea
      Serratus anterior
      Pectoralis minor
      Scalenes
      Sternocleidomastoid
Expiration
   A. Eupnea
   B. Hyperpnea
      Abdominal muscles
Volumes and capacities
   Respiratory cycle
   Resting tidal volume
   Expiratory reserve volume
   Residual volume
   Inspiratory reserve volume
   Vital capacity
   Total lung capacity
   Respiratory rate
   Respiratory minute volume
   Anatomical dead space
   Alveolar ventilation
2. Gas exchange
   Partial pressure
   High altitude sickness
   Decompression sickness
Diffusion
   1. big pressure difference
   2. small distance
   3. lipid soluble
   4. large surface area
   5. coordination
3. Gas transport
   A. Transport of oxygen
      Plasma
      Hemoglobin: heme
      Carbon monoxide poisoning
      Hemoglobin saturation
         1. Bohr effect
         2. Temp
         3. BPG
         4. Pregnancy
      Hypoxia
   B. Carbon dioxide
      1. Carbonic acid
      Carbonic anhydrase
      CO$_2$ + H$_2$O $\leftrightarrow$ H$_2$CO$_3$ $\leftrightarrow$ H$^+$ + HCO$_3^-$
      2. Carbaminohemoglobin
      3. Plasma
Regulation
   1. Autoregulation
      A. Lung perfusion
      B. Alveolar ventilation
   2. Neural
      A. Respiratory rhythmicity centers
         Medulla oblongata
         1. DRG
            diaphragm, internal intercostals
            pace setting
      2. VRG
         accessory muscles
      B. Respiratory centers
         Pons
         1. Apneustic center
            stimulate DRG
         2. Pneumotaxic center
            inhibit apneustic
      C. Reflexes
         1. Chemoreceptors
         2. Baroreceptors
         3. Stretch
         4. Irritant
         5. Other
   Aging
      ↓ compliance ↓ VC
      ↓ mobility ↓ RMV
      ↓ gas exchange
Figure 22.16b: Respiratory volumes and capacities.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Adult male average value</th>
<th>Adult female average value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tidal volume (TV)</td>
<td>500 ml</td>
<td>500 ml</td>
<td>Amount of air inhaled or exhaled with each breath under resting conditions</td>
</tr>
<tr>
<td>Inspiratory reserve volume (IRV)</td>
<td>3100 ml</td>
<td>1900 ml</td>
<td>Amount of air that can be forcefully inhaled after a normal tidal volume inhalation</td>
</tr>
<tr>
<td>Expiratory reserve volume (ERV)</td>
<td>1200 ml</td>
<td>700 ml</td>
<td>Amount of air that can be forcefully exhaled after a normal tidal volume exhalation</td>
</tr>
<tr>
<td>Residual volume (RV)</td>
<td>1200 ml</td>
<td>1100 ml</td>
<td>Amount of air remaining in the lungs after a forced exhalation</td>
</tr>
<tr>
<td>Total lung capacity (TLC)</td>
<td>6000 ml</td>
<td>4200 ml</td>
<td>Maximum amount of air contained in lungs after a maximum inspiratory effort: TLC = TV + IRV + ERV + RV</td>
</tr>
<tr>
<td>Vital capacity (VC)</td>
<td>4800 ml</td>
<td>3100 ml</td>
<td>Maximum amount of air that can be expired after a maximum inspiratory effort: VC = TV + IRV + ERV (should be 80% TLC)</td>
</tr>
<tr>
<td>Inspiratory capacity (IC)</td>
<td>3600 ml</td>
<td>2400 ml</td>
<td>Maximum amount of air that can be inspired after a normal expiration: IC = TV + IRV</td>
</tr>
<tr>
<td>Functional residual capacity (FRC)</td>
<td>2400 ml</td>
<td>1800 ml</td>
<td>Volume of air remaining in the lungs after a normal tidal volume expiration: FRC = ERV + RV</td>
</tr>
</tbody>
</table>
Regulation of Respiration

Respiratory homeostasis requires that diffusion rates at peripheral capillaries (O\textsubscript{2} in CO\textsubscript{2} out) and alveolar capillaries (CO\textsubscript{2} out O\textsubscript{2} in) must match. When they do not, both respiration and cardiovascular functions will need to be altered to restore homeostasis.

Here we consider only the respiratory adjustments:

1. **Autoregulation**
   
   A. Lung perfusion
      - blood flow in lungs is constantly redirected to alveoli with high partial pressure of O\textsubscript{2}
   
   B. Alveolar ventilation
      - alveoli with high partial pressure of CO\textsubscript{2} receive increased air flow

2. **Neural regulation**
   
   A. Respiratory Rhythmicity Centers
      - located in the medulla oblongata
      - control the basic pace and depth of respiration
        1. DRG (Dorsal Respiratory Group)
           - controls diaphragm and external intercostal muscles on every breath
           - serves as the pacesetting respiratory center (active for 2 sec, inactive for 3 sec)
        2. VRG (Ventral Respiratory Group)
           - controls accessory muscles during forced breathing
   
   B. Respiratory Centers
      - located in the pons
      - influence and modify activity of the DRG and VRG to fine tune breathing rhythm and prevent lung over-inflation
      - monitor input from sensory receptors to trigger appropriate reflex to alter respiratory rate and depth of respiration to satisfy gas exchange needs
        1. Apneustic center
           - stimulates the DRG for inhalation: helps increase intensity of inhalation
           - responds to lung inflation signals from sensory receptors
        2. Pneumotaxic center
           - inhibits the apneustic center to allow exhalation
           - modifies the pace set by DRG and VRG
           - increased signaling will increase respiratory rate by decreasing duration of inhalation
           - decreased signaling will decrease respiratory rate but increase depth by allowing apneustic center to signal DRG for greater inhalation
   
   C. Respiratory Reflexes
      - respiratory centers modify activity based on input from receptors:
        1. Chemoreceptors: monitor CO\textsubscript{2}, O\textsubscript{2}, and pH in blood and CSF
        2. Baroreceptors: monitor blood pressure in aorta and carotid artery
        3. Stretch receptors: monitor inflation of the lungs (Hering-Breuer Reflex)
        4. Pulmonary irritant receptors: monitor particles in respiratory tracts and trigger cough or sneeze
        5. Other: pain, temperature, and other visceral sensations can trigger respiratory reflexes