Chapter 8
The Respiratory System / Adult
Objectives

- Identify the main structures in the thorax and describe their functions.
- Identify and describe the primary and accessory muscles of breathing.
- Describe how the pulmonary and bronchial circulations are organized and their functions.
Objectives (cont.)

- Describe how somatic and autonomic nervous systems connect to and control the lungs and respiratory muscles.

- Identify the major structures of the upper respiratory tract and how they function.

- Describe how the lungs are organized into lobes and segments and the airways that supply them with ventilation.
Objectives (cont.)

- Describe how and why airways produce and move mucus.

- Describe how the structures in the respiratory bronchioles and alveoli are organized.

- Describe the blood-gas barrier and the threats to it.
Introduction to the Respiratory System

- Primary function is the absorption of O$_2$ and excretion of CO$_2$ called “external respiration”

- “Internal respiration” gas exchange between tissue cells and systemic capillary blood

- During a lifetime, about 250 million liters partake in external respiration.
  - Performed with minimal work

- Secondary function: filters both inhaled contaminants and small clots or chemicals from blood
Genetics Mutations and the Respiratory System

- Cystic fibrosis – a defect on chromosome 7 results in pulmonary, gastrointestinal, and endocrine dysfunction

- Emphysema can result from an $\alpha_1$-antitrypsin deficiency due to mutation on chromosome 14.

- Asthma may be associated with multiple gene alterations.
  - Affects about 10% of population
Adult Respiratory System

- Thoracic surface features
  - Imaginary lines establish reference points and thoracic landmarks.
    - See Figures 8-13, 8-14, and 8-15.

- Chest wall
  - Cone-shaped cavity contains vital organs.
  - Functions to protect those organs
  - Ability to change shape facilitates breathing.
Thoracic Wall Cross Section

Skin: epidermis and dermis
Subcutaneous fat
Fascia
Skeletal muscles
Internal intercostal muscle
External intercostal muscle
Rib
Vein, artery, and nerve
Parietal pleura
Intrapleural space
Visceral pleura
Lung parenchyma

(From Hilsen GH: Cardiopulmonary anatomy and physiology. Philadelphia, 2000. WB Saunders.)
Components of Thoracic Wall

- Skin, fat, skeletal muscles, and bony structures form outer portion of wall.

- The inner layer is lined with serous membrane – parietal pleura

- This contacts a serous membrane that covers the lungs – visceral pleura

- Pleura separated by thin fluid layer.
  - This area is called the pleural space.
Components of Thoracic Wall (cont.)

- Sternum composed of: manubrium, body, and xiphoid process (see Figure 8-18, A).
  - Sternal angle at joining of body and manubrium
    - External landmark for tracheal division into mainstem bronchi

- 12 pairs of ribs, pairs 1 to 7 (true ribs) connect directly to the sternum
  - Immediately below each rib run the artery, vein, and nerves for that portion of chest wall.
Rib Movement: Facilitate Breathing

- Pair 1: raise slightly, pulling sternum up, which increases AP diameter

- Rib pairs 2 to 7 move in two directions (see Figure 8-20).
  - Increase AP diameter, “pump action”
  - Increase lateral space, “bucket handle”

- Rib pairs 8 to 10 move similar to 2 to 7.
  - However, slight reduction of AP diameter
  - While lateral space increases
Respiratory Muscles

• Diaphragm and intercostals are primary muscles of respiration.
  ➢ Active during resting breathing
  ➢ 75% of work performed by diaphragm
  ➢ Muscle relaxation results in passive exhalation.

• Accessory muscles of inspiration
  ➢ Active only during increased demand
  ➢ Primarily scalene and sternocleidomastoids
  ➢ See Table 8-4.
Accessory Muscles of Expiration

- During resting, breathing exhalation is passive

- During times of increased demand, expiratory muscle contraction increases speed of exhalation.
  - Compression of abdomen by an array of abdominal muscles
  - Ribs pulled down and together by internal intercostal muscles
  - See Table 8-5.
Diaphragm

- Normal diaphragmatic excursion 1 to 2 cm
  - With maximal inspiration may be 10 cm

- Hyperinflation flattens domes.
  - Contraction may decrease AP diameter.
  - Decreased efficiency with increased work of breathing
  - Seen in severe asthma and COPD
Diaphragm (cont.)

- Innervated by phrenic nerves that arise from C3, C4, and C5

- Prolonged diaphragmatic contraction concurrent with abdominal muscle contraction aids in compression of abdomen for:
  - vomiting, coughing, defecation, parturition
Pleural Membranes, Space, and Fluid

- Visceral and parietal pleural are actually two sides of one membrane – form sac or space
  - Filled with ~10 ml of pleural fluid

- Fluid acts as lubricant, decreasing lung friction as lungs slide across inner chest wall.

- Pleural pressure is negative due to opposing tendency of lung to collapse and thorax to expand.

- Costophrenic angle is formed where parietal pleural departs chest wall to diaphragm.
Lungs

- Cone-shaped, sponge-like organs

- The apices extend 1 to 2 cm above clavicles

- Each lung has two (left) or three (right) lobes, which are separated by fissures (see Figure 8-28).
  - Left upper and lower lobes divided by oblique fissure.
  - Right lower lobe is also delineated by oblique fissure, while the transverse fissure separates the upper and middle lobes.

- Lungs elasticity results from alveolar surface tension and elastic and connective tissue.
Pulmonary Circulation

- Arises from RV, carries entire CO through the lungs to left heart.

- Capillaries cover about 90% of alveolar surface.

- Functions of lungs
  - Gas exchange at the alveolar-capillary (A/C) membrane (primary function)
    - Pick up oxygen and drop off CO₂
  - A/C membrane controls fluid exchange in lung.
  - Production, processing, and clearance of variety of chemicals and blood clots
Pulmonary Circulation (cont.)

(From Hicks GH: Cardiopulmonary anatomy and physiology. Philadelphia, 2000, WB Saunders.)
Pulmonary vs. Systemic Circulation

- Hemodynamic values are very different between systems.
  - Pulmonary: low pressure, low resistance
  - Systemic: high pressure, high resistance

<table>
<thead>
<tr>
<th>TABLE 8-6</th>
<th>Resting Hemodynamic Values in Adult Systemic and Pulmonary Vascular Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Systemic Circuit</td>
</tr>
<tr>
<td>Blood flow (cardiac output, L/min)</td>
<td>5</td>
</tr>
<tr>
<td>Arterial blood pressure (mm Hg)</td>
<td>120/80</td>
</tr>
<tr>
<td>Vascular resistance (dynes · sec · cm⁻⁵)</td>
<td>1200</td>
</tr>
</tbody>
</table>
Bronchial Circulation

- This systemic artery supplies blood to the larger lung structures (1% to 2% CO).

- Lung metabolic demands are fairly low.
  - Much of lung parenchyma gets oxygen directly from inspired gas.

- Bronchial veins drain via various routes.
  - Some drain to pulmonary veins, contributing to anatomic shunt.
  - When pulmonary circulation is compromised, bronchial flow increases, and vice versa.
Nervous Control of the Lungs

- Somatic nerves innervate chest wall and respiratory muscles.

- Autonomic (sympathetic and parasympathetic) nerves innervate
  - Airway smooth muscles and glands
  - Pulmonary arteriole smooth muscle
  - Result in balanced control of:
    - Bronchodilation/bronchoconstriction
    - Vasodilation/vasoconstriction
    - Glandular secretion
Lung Reflexes

- Inflation (Hering-Breuer) reflex
  - Stretch receptors function to limit further stretch.
  - Probably inactive during resting breathing.

- Irritant receptors are found in posterior of trachea and bifurcations of larger bronchi
  - When stimulated, can result in cough, sneeze, bronchospasm, hyperpnea, and vagal response.
Upper Respiratory Tract (URT)

- The URT is composed of
  - Nasal cavities and sinuses
  - Oral cavity
  - Pharynx
  - Larynx
Nasal Cavity

- External nares give entrance into cavities.

- Vestibules contain gross hairs that work as a filter.

- Concha or turbinates are three shelf-like bones projecting from lateral walls.
  - Function to increase surface area for filtering, warming, and humidifying of inhaled gases
Nasal Cavity (cont.)

- Contain olfactory cells, which provide sense of smell
- Surface fluid is provided by goblet cells and submucosal glands in cavity and sinuses.
Sinuses

- Hollow spaces in the facial bones

- Four sets of sinuses
  - Frontal, ethmoid, sphenoid, maxillary

- Function of sinuses
  - Reduce weight of head
  - Strengthen the skull
  - Modify the voice during phonation
Oral Cavity

- Forms a common passage for air, food, and fluids
- The tip of soft palate, the uvula, marks posterior aspect of cavity.
- Posterior portion of the tongue has nerve endings that trigger gag reflex to protect airway.
**Pharynx**

- Oral and nasal cavities open into the pharynx.
  - **Nasopharynx** (from nasal cavity to uvula)
    - Adenoids lie right where many particles impact.
    - Eustachian tubes link to middle ear.
  - **Oropharynx** (from uvula to tip of epiglottis)
    - Palatine tonsils (removed in tonsillectomy)
  - **Laryngopharynx** (tip epiglottis to larynx)
    - Anatomic location where the respiratory and digestive tracts divide
Larynx

- Contains nine cartilages (see Figure 8-39)
  - Thyroid (Adam’s apple)
  - Cricoid falls just below the thyroid cartilage
  - Epiglottis attaches to thyroid cartilage
    - With thyroid, closes laryngeal opening during swallowing
    - Fold between it and tongue forms vallecula
      - Key landmark for oral intubation
  - Three paired cartilages involved in phonation
    - Arytenoid, corniculate, and cuneiform
Patent Upper Airway

- Relative positions of oral cavity, pharynx, and larynx are major determinant of patency, particularly in unconscious patient.
  - Head tilts forward, partial or total occlusion can occur
  - Extend head into “sniff position” to open airway and facilitate artificial airway insertion
Lower Respiratory Tract

- Everything distal to the larynx

- Made up of conducting and respiratory airways

- Conducting airways – first 15 generations
  - Only purpose is convey gas from URT to area of gas exchange (lung parenchyma)

- Respiratory airways
  - Microscopic airways distal to conducting zone
  - Participate in gas exchange with the blood
Trachea and Bronchi

- Trachea: extends below cricoid cartilage to sternal angle
- Anterior and sides supported by 16 to 20 C-shaped cartilage
- Trachealis muscle connects tips of C-shaped cartilage and forms posterior wall
Trachea and Bronchi (cont.)

- Right and left mainstem bronchi bifurcate at carina.

- Right bronchus branches at 20 to 30-degree angle.
  - Due to angle, most foreign aspirate goes to right lower lobe.

- Left bronchus branches at 45 to 55-degree angle.
Lobar and Segmental Pulmonary Anatomy

- Each lung is divided into lobes and segments.

- Right lung has 3 lobes and 10 segments.

- Left lung has 2 lobes and 8 or 10 segments.
  - See Table 8-8.
Lobar and Segmental Pulmonary Anatomy (cont.)

- Each segment is supplied by a segmental bronchus

- These further divide numerous times until the conducting airways end in terminal bronchioles.
  - All airways up to this point constitute anatomic deadspace.
    - ~2 ml/kg of lean body weight, typically 150 ml
Histology of the Airway Wall
Respiratory Zone Airways

• Respiratory bronchioles arise from terminal bronchioles and have two functions.
  ➢ Conduct gas deeper into respiratory zone
  ➢ Participate in gas exchange
    • The bronchiole walls sprout alveoli

• All structures distal to one terminal bronchiole form a primary lobule or acinus, each composed of:
  ➢ respiratory bronchioles, alveolar ducts, alveolar sacs, and about 10,000 alveoli
  ➢ See Figures 8-51 and 8-52.
The Alveoli

- Saclike growths that sprout on walls of respiratory bronchioles, alveolar ducts, and alveolar sacs
  - Primary function is gas exchange

- Type I pneumocytes are very flat and cover about 93% of alveolar surface.
  - They are very thin which facilitates gas exchange
  - Form very tight joints, which limits movement of materials into alveolar space
The Alveoli (cont.)

- Type II pneumocytes are cuboidal.
  - Twice as many as type I cells
  - Manufacture and storage of surfactant
    - Reduces surface tension and alveolar tendency to collapse
    - Increases compliance and decreases work of breathing
  - “Stem” cells of alveoli can differentiate into type I cells, so as to repair damage areas.

- Alveolar macrophages provide defense.
Blood-Gas Barrier

- A/C membrane provides area for gas exchange (typically about 140 m² and 1 µm thick).
  - O₂ and CO₂ diffuse from alveoli through
    - Surfactant layer
    - Type I cell
    - Basement membrane
    - Interstitial space containing basement membrane, elastin and collagen fibers, and capillaries
    - Capillary endothelial cells
    - Plasma
    - Finally, into erythrocytes (RBCs)