Unit VII: Respiratory System Disorders

Chapter 25: Structure & Function of Pulmonary System
Chapter 26: Alterations of Pulmonary Function

Structure and Function of the Pulmonary System

Chapter 25

Structures of the Pulmonary System

• Conducting Airways
• Pulmonary circulation
• Lungs
  • Lobes (______________)
• Segments
• Lobules

Structures of the Pulmonary System

• Conducting airways (___________)
• Upper airways
  • Nasopharynx
  • Oropharynx
  • Laryngopharynx
• Lower airways
  • Trachea
  • Bronchi
  • Terminal bronchioles

Diagram showing structures of the pulmonary system.
Structures of the Pulmonary System

- Gas-exchange airways
  - Respiratory bronchioles
  - Alveolar ducts
  - Alveoli
- Epithelial cells
  - Type I alveolar cells
    - Alveolar structure
  - Type II alveolar cells
    - Surfactant production

Pulmonary and Bronchial Circulation

- Pulmonary circulation has lower pressure than systemic circulation (~1/5 pressure)
- Pulmonary artery divides and enters lung at hilus
- Each bronchus and bronchiole has an accompanying artery or arteriole
- Alveolocapillary (__________) membrane
  - Formed by the shared alveolar and capillary walls
  - Gas exchange occurs across this membrane

Chest Wall and Pleura

- Alveolar gas exchange – how much $O_2$ and $CO_2$ trade places in alveoli?
- Ventilation to perfusion ratio (V/Q) - depends on amt. of air in alveoli (ventilation) to amt. of air in blood (perfusion)
- Normal lung: Alveoli rec. air ~4 L/min
- Capillaries supply blood ~5 L/min
  $= 4:5 = 0.8$

- Thoracic cavity
- Pleura
  - Serous membrane
  - Parietal and visceral layers
  - Pleural space (cavity)
  - Pleural fluid
Function of the Pulmonary System

- **Ventilation**
  - Mechanical movement of gas or air into and out of lungs
  - Minute volume (L/min) • total volume of air entering lungs/min
    \[ \text{TV} = \text{Ventilatory rate (breaths/min)} \times \text{TV} \]
  - Alveolar ventilation • vol. of gas/unit time that reaches gas exchange portion of lung
    \[ \text{Alveolar ventilation} = (\text{TV} - \text{dead space}) \times \text{ventilatory rate} \]
  - PFTs (Pulmonary function tests) measure lung volumes and rates to diagnose disorders

Ventilation

- **Neurochemical control**
  - Respiratory center
    - Dorsal respiratory group - rhythm of respiration
    - Ventral respiratory group - becomes active during increased respiration
    - Pneumotaxic center - limits amount of inspired air
    - Apneustic center - prevents overinflation of lungs
  - Central chemoreceptors - respond to pH, pCO₂, pO₂
  - Peripheral chemoreceptors (carotid & aortic bodies)
    - Respond to decre. pO₂

Mechanics of Breathing

- **Alveolar surface tension and ventilation**
- **Function of surfactant**
- **Elastic properties of the lung and chest wall**
  - Elastic recoil - lungs return to resting state
  - Compliance - distensibility of lung and chest wall (opposite of elasticity)
- **Airway resistance** - depends on R and flow
- **Work of breathing** - effort of muscles for ventilation
Mechanics of Breathing

Gas Transport

- Diffusion of O₂
  - Ventilation of the lungs
  - Diffusion of oxygen from alveoli into capillary blood
  - Perfusion of systemic capillaries with oxygenated blood
  - Diffusion of oxygen from systemic capillaries into cells
- Diffusion of CO₂ occurs in reverse order

Measurement of Gas Pressure

Gas Transport

- Oxygen transport
  - Diffusion across the alveolocapillary membrane
  - Determinants of arterial oxygenation
    - Hemoglobin binding, oxygen saturation
    - Oxyhemoglobin association and dissociation
    - Oxyhemoglobin dissociation curve
    - Bohr effect

Measurement of Gas Pressure

Gas Transport

- Carbon dioxide transport
  - Dissolved in plasma
  - Bicarbonate
  - Carbamino compounds
  - Haldane effect
  - effect of O₂ on CO₂ transport out of blood
1. The cilia of the bronchial wall:
   - A. Ingest bacteria
   - B. Trigger sneeze reflex
   - C. Trap and remove bacteria
   - D. Propel mucus and trapped bacteria toward oropharynx

2. As the terminal bronchioles are approached:
   - A. Epithelium becomes thicker
   - B. Mucus-producing glands increase
   - C. Epithelium becomes thinner
   - D. Cartilage support increases
   - E. SMC layer thickens

3. The left primary bronchus:
   - A. Is shorter and wider than the right
   - B. Is symmetrical to the right
   - C. Is more vertical than the right bronchus
   - D. Is more angled than the right

4. Alveoli are excellent for gas exchange due to:
   - A. Large surface area
   - B. Thin epithelial layer
   - C. Extensive vascularization
   - D. All of the above

5. When the diaphragm and ext. intercostals contract:
   - A. Intrathoracic V increases
   - B. Intrathoracic P increases
   - C. Intrathoracic V decreases
   - D. None of the above

6. A shift to the right in the O2-Hb dissociation curve:
   - A. Prevents O2 release at cell level
   - B. Cause O2 to bind tighter to Hb
   - C. Improves O2 release at cell level
   - D. Both a and b

7. The DRG of neurons:
   - A. Sets the automatic rhythm of respiration
   - B. Modifies the rhythm of respiration
   - C. Is active when increase ventilation is required
   - D. None of the above

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Alterations of Pulmonary Function

Chapter 26

Signs and Symptoms of Pulmonary Disease

- **Dyspnea**
  - Subjective sensation of uncomfortable breathing
  - Orthopnea
    - Dyspnea when a person is lying down
  - Paroxysmal nocturnal dyspnea (PND)

- **Abnormal breathing patterns**
  - Kussmaul respirations (hyperpnea) – due to increased exercise or metabolic acidosis
  - Cheyne-Stokes respirations – alternating deep and shallow breathing (due to slowed blood flow to brainstem)

- **Hypoventilation**

- **Hyperventilation**

- **Cough**
  - Acute cough
  - Chronic cough

- **Hemoptysis** –
  - (not to be confused with hematemesis= vomiting blood)
Pulmonary Edema

- Pulmonary edema = ____________
  - Most common cause is heart disease (LV fails → increased pulm. cap. hydrostatic pressure; inhalation of toxic gas; lymphatic system blockage)

- Atelectasis = ____________
  - Tends to occur after surgery, post-op patients breathe shallowly and develop thick secretions (→ Incentive spirometer to increase collateral ventilation between adjacent alveoli)

Pleural Abnormalities

- Pneumothorax
  - _____ in pleural cavity due to rupture of visceral or parietal pleura

Conditions Caused by Pulmonary Disease or Injury

- Abscess formation and cavitation
- Abscess
- Consolidation
- Cavitation
- Pulmonary fibrosis
- Excessive amount of ____________ in the lung

Pleural Abnormalities

- Pleural effusion – fluid in pleural space
  - Transudative (watery) or exudative (high WBCs) effusion
  - Hemothorax - _____ in pleural cavity
  - Empyema – pus in pleural cavity

Pulmonary Disorders

Progression of ARDS:

- Assault to pulmonary system
- Respiratory distress
- Decreased lung compliance (distensibility of lung and chest wall)
- Severe respiratory failure
Pulmonary Disorders

- Postoperative respiratory failure
- Atelectasis
- Pneumonia
- Pulmonary edema
- Pulmonary emboli
- Prevention
  - Frequent turning, deep breathing, early ambulation, air humidification, and incentive spirometry

Obstructive Pulmonary Disease

- Airway obstruction that is worse with expiration
- Common signs and symptoms
  - Dyspnea and wheezing
- Common obstructive disorders
  - Asthma
  - Emphysema
  - Chronic bronchitis

Chronic Obstructive Pulmonary Disease

- Airway obstruction that is worse with expiration
- Common signs and symptoms
  - Dyspnea and wheezing
- Common obstructive disorders
  - Asthma
  - Emphysema
  - Chronic bronchitis

Respiratory Tract Infections

- Pneumonia – acute infection of lung (__________) that impairs gas exchange usually
- Classified:
  - Origin: bacterial, viral, fungal
  - Location
    - Bronchopneumonia (distal airways & alveoli);
    - Lobar pneumonia (in part or entire lobe)
- Type
  - Primary (inhaler or aspirate pathogen)
  - Secondary (may occur after lung damage following chemical insult or from bacteria in blood)

Pneumococcal Pneumonia

- Aspiration of Streptococcus pneumonia
- Inflammatory response: infiltration of neutrophils; release of inflammatory mediators, accumulation of the gas exchange, red blood cells, and bacteria
- Necrosis of infection: neutrophils and foreign material, gas exchange impaired, fibrosis, and tissue death
Common causal microbes

- Streptococcus pneumoniae (aka Pneumococcus)
  - high mortality rate in elderly
- Mycoplasma pneumoniae
  - common in young people esp. living in close quarters
- Influenza – most common viral pneumonia
  - Legionella species → Legionnaire’s disease
  - Pseudomonas aeruginosa, S. aureus – most common nosocomial infectious agents

Pathophysiology

- Aspiration of secretions (oro- and laryngopharynx)
- Inhale microbes from infected persons (cough, sneeze…)
- Lines of defense
  - microbes expelled from naso- and oropharynx
  - alveolar macrophages
  - Activation of inflammatory and immune responses
  - alveolar edema

Characteristics

- Bacterial (Streptococcal)
  - sudden onset chill, temp 102 to 104°F
  - follows upper resp. tract infection
- Viral (Influenza)
  - cough, cyanosis, high fever, substernal pain, headache, myalgia

- Avian Influenza (H5N1)
  - highly pathogenic virus caused infection in poultry in Asia and infected humans in 1997
  - At first infected humans who had close contact with birds
  - Several cases mutated virus spread from human to human
  - Fever, cough, sore throat, muscle aches, eye infections
- Swine flu (H1N1)
  - Pandemic flu April 2009 – June 2010
  - Similar symptoms to seasonal flu
  - CDC reported ~61 million cases (12,500 deaths)

Respiratory Tract Infections

- Tuberculosis – infectious disease that affects mostly lungs, can involve other systems
  - Due to exposure to Mycobacterium tuberculosis
  - Airborne transmission – cough or sneeze spreads infected droplets
  - (granulomatous lesion) – macrophages ingest bacilli → tubercles →
  - Caseous necrosis and scar tissue
  - Positive tuberculin skin test (PPD)
  - Once bacilli isolated in tubercles → immunity and dormancy

Pulmonary Embolism

- Thrombus forms in deep vein
  - Release of endogenous tissue factor
  - Activated factor X
  - Formation of thrombus
  - Release of histamine and serotonin
  - Development of pulmonary embolism

- Hemodynamic changes
  - Reduced cardiac output
  - Hypotension
  - Cyanosis
  - Respiratory distress
  - Pulmonary edema
  - Acute respiratory distress syndrome
  - Shock
**Pulmonary Embolism**

- **Pulmonary embolism** – blockage of pulmonary vessel by ________ (blood clot, tissue, lipid, foreign object or air)
- Risk factors – conditions ➔ blood clotting
  - (venous stasis, hypercoagulability, injury to endothelial lining, genetic)
- Pathophysiology
  - Massive occlusion ➔ blockage of pulmonary artery
  - Embolism w/ infarction – large enough to cause tissue death
  - Embolism w/out infarction – no permanent damage if no infarction clots are dissolved.

**Pulmonary Embolism**

- Most clots dev. in lower extremities, DVT.
- Clinical:
  - Sudden onset chest pain, dyspnea, tachypnea, tachycardia ➔ severe pulmonary HT and shock
- Treatment:
  - Prevention is best
  - Leg elevation, ambulation, calf compression
  - Anticoagulants (heparin) and antithrombotics
  - Surgery (thrombectomy)

**Pulmonary Vascular Disease**

- **Pulmonary hypertension**
  - Mean pulmonary artery pressure 5 to 10 mm Hg above normal or above 20 mm Hg
  - Primary pulmonary HT (PPH)
    - Idiopathic, rare
    - Malfunction of endothelium ➔ incr. VC (thromboxane) and decr. VD (prostacyclin)
    - Vessel wall changes (thick & fibrous) ➔ VC ➔ incr. R ➔ incr. P in pulmonary arteries
  - Secondary pulmonary HT
    - Due to respiratory disease (hypoxemia, arterial VC)
    - Pulmonary venous HT – due to CHF

**Pulmonary Hypertension**

**Lung Cancer**

- Bronchogenic carcinomas
  - Arise from ____________ of resp. tract
  - Epidemic in US (most common cause of cancer death)
- Most common cause is cigarette smoking
  - Heavy smokers have a 20 times greater chance of developing lung cancer than nonsmokers
  - Smoking is related to cancers of the larynx, oral cavity, esophagus, and urinary bladder
- Environmental or occupational risk factors are also associated with lung cancer

**Lung Cancer**

- **Non–small cell lung cancer**
  - Squamous cell carcinoma (slow)
  - Adenocarcinoma (moderate)
  - Large cell carcinoma (undifferentiated, rapid)
  - Small cell carcinoma (very rapid)
Lung Cancer
• Pathophysiology
  • Tobacco smoke >30 carcinogens → 80-90% of lung cancers
  • Genetic predisposition
  • Both lead to genetic abnormalities in bronchial cells
    • Loss of tumor suppressing genes
    • Tumor progression due to growth factors
    • Mucosa suffers from chronic exposure to smoke → metaplasia → carcinoma → spreads in lung → metastasis (brain, bone, liver)

Lung Cancer
• Evaluation and treatment
  • TNM classification
    • Tumor
      • Nodal involvement
      • Metastasis
      • Surgery, chemotherapy, and radiation

Matching:
• ___1. Kussmaul resp. a. Alveolar collapse
• ___2. Hemptysis b. Cough blood
• ___3. Cyanosis c. Decr. arterial oxygenation
• ___4. Cheyne-Stokes d. Apnea, incr. vent., apnea
• ___5. Atelectasis e. Incr. vent. rate, effortless TV, no exp. pause

• 6. Pulmonary edema may be caused by abnormal
  – A. Capillary hydrostatic press.
  – B. Capillary oncotic pressure
  – C. Cap. Permeability
  – D. All of the above

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Matching:
• ___7. pneumonia a. Originate from thrombi in legs
• ___8. TB b. Caused by air pollutants
• ___9. chronic bronchitis c. Caused by aerobic bacillus
• ___10. pulmonary emboli d. May be caused by mycoplasms

11. The metastasis of lung squamous cell carcinoma is:
   A. Late
   B. Very early and widespread
   C. Early
   D. Never seen