Bio217: Pathophysiology Class Notes
Professor Linda Falkow

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 (three on right, two on left)
  • Segments
  • Lobules

Structures of the Pulmonary System

• Conducting airways (no gas exchange)
  • Upper airways
    • Nasopharynx
    • Oropharynx
    • Laryngopharynx
  • Lower airways
    • Trachea
    • Bronchi
    • Terminal bronchioles

Structures of the Pulmonary System

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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 (respiratory) membrane
  - Formed by the shared alveolar and capillary walls
  - Gas exchange occurs across this membrane

Pulmonary gas exchange – how much O₂ and CO₂ 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

Chest Wall and Pleura

- Chest wall
  - Skin, ribs, and intercostal muscles
  - 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
    \[\text{Ventilatory rate (breaths/min) \times TV}\]
  - Alveolar ventilation = vol. of gas/unit time that reaches gas exchange portion of lung
    \[= (\text{TV - dead space}) \times \text{ventilatory rate}\]
  - 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 amt. 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

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Gas Transport
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

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**
- **Hypercapnia**
- **Hyperventilation**
- **Hypocapnia**
- **Cough**
  - Acute cough
  - Chronic cough
- **Hemoptysis – cough up blood**
  - (not to be confused with hematemesis= vomiting blood)
Pulmonary Edema

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

- Atelectasis = collapse of lung tissue
  - Tends to occur after surgery, post-op patients breathe shallowly and develop thick secretions (use incentive spirometer to increase collateral ventilation between adjacent alveoli)

Pleural Abnormalities

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

Pleural Abnormalities

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

Conditions Caused by Pulmonary Disease or Injury

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

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

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Respiratory Tract Infections

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

Pneumococcal Pneumonia
**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
  - Tubercle formation (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**

- Detection of pulmonary embolism
  - Venous thrombosis
  - Release of vasoactive substances
  - Pulmonary infarction
  - Reduced cardiac output
  - Hypoxic vasoconstriction
  - Pulmonary edema
  - Shock

- Treatment options:
  - Anticoagulation
  - Diuretics and vasopressors
Pulmonary Embolism

- **Pulmonary embolism** – blockage of pulmonary vessel by embolism (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 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

- 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)

Lung Cancer

**Bronchogenic carcinomas**

- Arise from epithelium 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

**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)

- **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

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