Bio217: Pathophysiology Class Notes
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Unit VII: Respiratory System Disorders

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

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

- Upper respiratory tract
- Nasopharynx
- Oropharynx
- Laryngopharynx
- Trachea

Structures of the Pulmonary System

- Bronchi
- Bronchioles
- Alveoli

Structures of the Pulmonary System

- Respiratory unit
- Conducting airways
- Respiratory bronchioles
- Alveoli

Structures of the Pulmonary System

- Generation
  - 8
  - 16
  - 24
  - 32

Diagram showing generations of respiratory units.
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

Chest Wall and Pleura

- Alveolar 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
  - 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
    \[ \text{Ventilatory rate (breaths/min) x TV} \]
  - Alveolar ventilation - vol. of gas/unit time that reaches gas exchange portion of lung
    \[ \text{(TV- dead space) x ventilatory rate} \]
- PFTs (Pulmonary function tests) measure lung volumes and rates to diagnose disorders

Ventilation

- Neurochemical control
  - Respiratory center
    - Dorsal respiratory group - rhythm of respiration
    - Ventr al 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 decr. 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 O$_2$
  - 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 CO$_2$ 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

- Carbon dioxide transport
  - Dissolved in plasma
  - Bicarbonate
  - Carbamino compounds
  - Haldane effect
    - effect of O$_2$ on CO$_2$ 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

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 (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

**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 (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**

- **Aspiration of Streptococcus pneumoniae**
- **Adherence to alveolar macrophages**
- **Inflammatory response**
  - Release of neutrophils, release of inflammatory mediators, accumulation of fluid within airways
- **Resolution of infection**
  - Neutrophil migration, resolution of neutrophils, fibroblasts, and bacteria
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

- Increased venous pressure
  - Redistribution of pelvis and pulmonary circulation
  - Release of microscopic and macroscopic pulmonary emboli
  - Fatigue, dyspnea, tachypnea, cyanosis
  - Pulmonary edema
  - Ascending emboli
  - Directed to main renal artery or major mesenteric arteries
Pulmonary Embolism

- **Pulmonary embolism** – blockage of pulmonary vessel by embolism (blood clot, tissue, lipid, foreign object or air)
- **Risk factors** – conditions → blood cloting
  - (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

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