Alterations of Pulmonary Function
Pathophysicsiology 2
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Signs and Symptoms of Pulmonary Disease

• Dyspnea
  • Subjective sensation of uncomfortable breathing
• Orthopnea
  • Dyspnea when a person is lying down
• Paroxysmal nocturnal dyspnea (PND)
Signs and Symptoms of Pulmonary Disease (cont’d)

- Cough
  - Acute cough
  - Chronic cough
- Abnormal sputum
- Hemoptysis
- Abnormal breathing patterns:
  - Kussmaul respirations (hyperpnea)
  - Cheyne-Stokes respirations
Signs and Symptoms of Pulmonary Disease (cont’d)

- Hypoventilation
  - Hypercapnia
- Hyperventilation
  - Hypocapnia
- Cyanosis
- Clubbing
- Pain
Finger clubbing is characterized by enlarged fingertips and a loss of the normal angle at the nail bed.
Clubbing

Clubbing — early

Clubbing — moderate

Clubbing — severe

(Modified from Seidel HM et al: Mosby’s guide to physical examination, ed 7, St Louis, 2011, Mosby.)
Conditions Caused by Pulmonary Disease or Injury

- Hypercapnia
- Hypoxemia
  - Hypoxemia versus hypoxia
  - Ventilation-perfusion abnormalities
    - Shunting
- Acute respiratory failure
Chest Wall Disorders

• Chest wall restriction
  • Compromised chest wall
    • Deformation, immobilization, and/or obesity
• Flail chest
  • Instability of a portion of the chest wall
FLAIL CHEST: PARADOXICAL BREATHING

A patient with a blunt chest injury may develop flail chest, in which a portion of the chest “caves in.” This results in paradoxical breathing, described below.

**Inhalation**
- Injured chest wall collapses in.
- Uninjured chest wall moves out.

**Exhalation**
- Injured chest wall moves out.
- Uninjured chest wall moves in.
Flail Chest
Pleural Abnormalities

- Pneumothorax
  - Open pneumothorax
  - Tension pneumothorax
  - Spontaneous pneumothorax
  - Secondary pneumothorax
Pneumothorax

- Trachea
- Right lung
- Ribs
- Upper lobe
- Middle lobe
- Lower lobe
- Left main bronchus
- Heart

Small pneumothorax
Air collects between the lung and the chest wall

Large pneumothorax
A lot of air collects and pushes on the lung and heart

Treatment of a large pneumothorax
Trapped air is removed by using a chest tube

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Pneumothorax

Outside air enters because of disruption of chest wall and parietal pleura.

Lung air enters because of disruption of visceral pleura.

- Normal lung
- Chest wall
- Pleural space
- Mediastinum
- Diaphragm
Pleural Abnormalities

- Pleural effusion
  - Transudative effusion
  - Exudative effusion
- Hemothorax
- Empyema
  - Infected pleural effusion
- Chylothorax
Pleural Effusion

- Ribs
- Pleural space
- Pleural effusion
Chest X-Ray with Pleural Effusion on the Left
Diagram showing how a pleural effusion is drained.
Pulmonary Disorders

• Restrictive lung diseases:
  • Aspiration
    • Passage of fluid and solid particles into the lungs
  • Atelectasis
    • Compression atelectasis
    • Absorption atelectasis
  • Bronchiectasis
    • Persistent abnormal dilation of the bronchi
Pneumothorax

Hydrothorax

A
COLLAPSE

B
COMPRESSiona

C
OBSTRUCTION

Air

Fluid

Tumor
Pulmonary Disorders

• Restrictive lung diseases:
  • Bronchiolitis
    • Inflammatory obstruction of the small airways
    • Most common in children
    • Occurs in adults with chronic bronchitis, in association with a viral infection, or with inhalation of toxic gases
  • Pulmonary fibrosis
    • Ideopathic
Pulmonary Disorders (cont’d)

• Restrictive lung diseases (cont’d)
  • Inhalation disorders:
    • Toxic gases
    • Pneumoconiosis
      • Silica
      • Asbestos
      • Coal
    • Allergic alveolitis
      • Extrinsic allergic alveolitis (hypersensitivity pneumonitis)
Pulmonary Disorders (cont’d)

- Restrictive lung diseases (cont’d)
  - Pulmonary edema
  - Excess water in the lungs
Pulmonary Edema

Valvular dysfunction
Coronary artery disease
Left ventricular dysfunction

Increased left atrial pressure

Increased pulmonary capillary hydrostatic pressure

Injury to capillary endothelium

Increased capillary permeability and disruption of surfactant production by alveoli

Movement of fluid and plasma proteins from capillary to interstitial space (alveolar septum) and alveoli

Pulmonary edema

Inability to remove excess fluid from interstitial space

Accumulation of fluid in interstitial space

Blockage of lymphatic vessels
Pulmonary Disorders

- Restrictive lung diseases (cont’d)
  - Acute respiratory distress syndrome (ARDS)
    - Fulminant form of respiratory failure characterized by acute lung inflammation and diffuse alveolocapillary injury
    - Injury to the pulmonary capillary endothelium
    - Inflammation and platelet activation
    - Surfactant inactivation
    - Atelectasis
Pulmonary Disorders (cont’d)

- Restrictive lung diseases (cont’d)
  - Acute respiratory distress syndrome (ARDS)
    - Manifestations:
      - Hyperventilation
      - Respiratory alkalosis
      - Dyspnea and hypoxemia
      - Metabolic acidosis
      - Hypoventilation
      - Respiratory acidosis
      - Further hypoxemia
      - Hypotension, decreased cardiac output, death
Pulmonary Disorders (cont’d)

• Restrictive lung diseases (cont’d)
  • Acute respiratory distress syndrome (ARDS) (cont’d)
  • Evaluation and treatment
    • Physical examination, blood gases, and radiologic examination
    • Supportive therapy with oxygenation and ventilation and prevention of infection
    • Surfactant to improve compliance
Acute Respiratory Distress Syndrome

Indirect or direct lung injury

- Alveolar epithelial injury
- Type II pneumocyte damage
- Decreased surfactant
- Atelectasis and decreased lung compliance
- Decreased tidal volume (hypercapnia)

Capillary endothelial injury

- Activation of platelets, neutrophils and macrophages
- Release of inflammatory cytokines (e.g., TNF, IL-1, ROS)

Activation of complement

- Increase alveolocapillary permeability and alveolar flooding (edema)
- $\dot{V}/\dot{Q}$ mismatch (hypoxemia)
- Vasoconstriction

Release of growth factors (e.g., TGF-β)
- Fibrosing alveolitis
- Chronic pulmonary insufficiency
Pulmonary Disorders

• Obstructive lung diseases
  • Airway obstruction that is worse with expiration
  • Common signs and symptoms
    • Dyspnea and wheezing
  • Common obstructive disorders:
    • Asthma
    • COPD
    • Emphysema
    • Chronic bronchitis
Asthma
Why asthma makes it hard to breathe

Air enters the respiratory system from the nose and mouth and travels through the bronchial tubes.

In an asthmatic person, the muscles of the bronchial tubes tighten and thicken, and the air passages become inflamed and mucus-filled, making it difficult for air to move.

In a non-asthmatic person, the muscles around the bronchial tubes are relaxed and the tissue thin, allowing for easy airflow.

Inflamed bronchial tube of an asthmatic

Normal bronchial tube

Source: American Academy of Allergy, Asthma and Immunology
Pulmonary Disorders

• Obstructive lung diseases: Asthma
  • Chronic inflammatory disorder of the airways
  • Inflammation results from hyperresponsiveness of the airways
  • Can lead to obstruction and status asthmaticus
  • Symptoms include expiratory wheezing, dyspnea, and tachypnea
  • Peak flow meters, oral corticosteroids, inhaled beta-agonists, and anti-inflammatories used to treat
Obstructive Pulmonary Disease

(Modified from Des Jardins T, Burton GG: Clinical manifestations and assessment of respiratory disease, ed 5, St Louis, 2006, Mosby.)
Chronic Obstructive Pulmonary Disease

Tobacco smoke
Air pollution

Inflammation of the airway epithelium

Infiltration of inflammatory cells and release of cytokines (neutrophils, macrophages, lymphocytes, leukotrienes, interleukins)

Systemic effects (muscle weakness, weight loss)

Continuous bronchial irritation and inflammation

Chronic bronchitis (bronchial edema, hypersecretion of mucus, bacterial colonization of airways)

Increased protease activity with breakdown of elastin in connective tissue of lungs (elastases, cathepsins, etc.)

Emphysema (destruction of alveolar septa and loss of elastic recoil of bronchial walls)

Airway obstruction
Air trapping
Loss of surface area for gas exchange
Frequent exacerbations (infections, bronchospasm)

Dyspnea
Cough
Hypoxemia
Hypercapnia
Cor pulmonale

Inhibition of normal endogenous antiproteases

Inherited α1-antitrypsin deficiency
Chronic Obstructive Pulmonary Disease

Air movement during INSPIRATION

Mucous plug

Alveolar walls

Air movement during EXPIRATION

Muscle

Bronchial walls collapse

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Pulmonary Disorders

- Obstructive lung diseases: chronic bronchitis
  - Hypersecretion of mucus and chronic productive cough that lasts for at least 3 months of the year and for at least 2 consecutive years
  - Inspired irritants increase mucus production and the size and number of mucous glands
  - The mucus is thicker than normal
  - Bronchodilators, expectorants, and chest physical therapy used to treat
Pulmonary Disorders (cont’d)

- Obstructive lung diseases: emphysema
  - Abnormal permanent enlargement of the gas-exchange airways accompanied by destruction of alveolar walls without obvious fibrosis
  - Loss of elastic recoil
  - Centriacinar emphysema
  - Panacinar emphysema
• How COPD develops
  • Smoking causes increased mucus production and bronchial inflammation
  • Nicotine paralyzes the mucociliary escalator
    • Mucociliary escalator traps mucus, bacteria, irritants
    • Nicotine blocks protein inhibitors which will eventually dissolve the alveoli
• Pathophysiology
  • Involves all four parts of the respiratory tract
    • Bronchi
    • Bronchioles
    • Alveoli
    • Parenchyma
Specific Pathophysiology

• Increased resistance to airflow
• Loss of elastic recoil
• Decreased expiratory flow rate
• Alveolar walls frequently break because of the increased resistance of air flows
• The hyper inflated lungs flatten the curvature of the diaphragm and enlarge the rib cage
• The altered configuration of the chest cavity places the respiratory muscles, including the diaphragm, at a mechanical disadvantage and impairs their force-generating capacity
• Consequently, the metabolic work of breathing increases, and dyspnea increases
• Two types of COPD
  • Type A – Pink Puffers
    • Have mostly emphysema
    • Need to breathe rapidly to exchange O2 and CO2
    • Have prominent dyspnea, the fast puffing keeps them from becoming cyanotic
    • Most of the lung is perfused with blood exchange is not efficient because of fewer alveoli
- Two types of COPD
  - Type B – Blue Bloaters
    - Have mostly chronic bronchitis with bronchiolar obstruction and non-ventilated alveoli
    - Results in shunting of cyanotic blood away from the area where there is no air in the lungs
    - Results in pulmonary hypertension which leads to heart failure with peripheral swelling
    - Severe dyspnea with any exertion
• Diagnosis
  • Smoker with hacking cough, sputum and dyspnea
  • Type A – thin, dorsal kyphosis, clubbing, pigeon breast (pectus carinatum) or funnel chest (pectus excavatum)
  • Type B – obese, swollen appearance, cyanotic
• X-ray findings
  • Large lung volumes hyperlucent, flat diaphragm, increased AP diameter
• Pulmonary function tests
  • Airway obstruction and decrease, air trapping
• Blood gases
  • Type A – normal blood gases
  • Type B – marked hypoxemia and CO₂ retention
• Treatment of COPD
  • Bronchodilators
  • Antibiotics
  • Corticosteroids
  • Supplemental oxygen therapy
  • Chest physiotherapy to lose secretions
  • Surgery to remove diseased lung tissue
  • Lung transplantation
Pulmonary Disorders

- Respiratory tract infections
  - Tuberculosis
    - *Mycobacterium tuberculosis*
    - Acid-fast bacillus
    - Airborne transmission
    - Tubercle formation
    - Caseous necrosis
    - Positive tuberculin skin test (PPD)
Pulmonary Disorders (cont’d)

• Respiratory tract infections—acute bronchitis
  • Acute infection or inflammation of the airways or bronchi
  • Commonly follows a viral illness
  • Acute bronchitis causes similar symptoms to pneumonia but does not demonstrate pulmonary consolidation and chest infiltrates
Pulmonary Disorders (cont’d)

• Abscess formation and cavitation
  • Abscess
  • Consolidation
  • Cavitation
Pulmonary Disorders (cont’d)

- Pulmonary vascular disorders: Pulmonary embolus
  - Occlusion of a portion of the pulmonary vascular bed by a thrombus, embolus, tissue fragment, lipids, or an air bubble
  - Pulmonary emboli commonly arise from the deep veins in the thigh
- Virchow triad
  - Venous stasis, hypercoagulability, and injuries to the endothelial cells that line the vessels
Pulmonary Embolism

- Occurs when a blood clot is from the deep venous system travels to the lungs
  - Usually involves veins of legs, arms and pelvis (pregnancy)
- Three conditions are put you at risk
  - Increased coagulation of blood
    - Stress, surgery, injury, heart attack, severe illness
  - Stasis or stagnation of blood flow
    - Seen in conditions of immobility such as prolonged bed rest long car rides of plane flights in cramped position
  - Damage to vessel wall or venous valves
    - Stasis-induced phlebitis, soft-tissue injury, bad ankle sprain
• Pathophysiology
  • Pulmonary infarction of distal tissues occurs in a small number of cases
  • Hemorrhage and edema of tissues distal to the clot is more common
  • Vasoconstriction of pulmonary blood vessels occurs
    • This causes a release of serotonin and vasoconstrictive amines which cause more constriction
  • Low blood pH causes even more constriction
  • Right sided heart failure followed by left sided blood flow followed by syncope and sudden death
• S & S
  • Sudden dyspnea
  • Pleuritic chest pain with hemoptysis
  • Can have syncope followed by death

• Diagnosis
  • Normal chest x-ray
  • Perfusion lung scan shows absence of perfusion to involved arteries
  • Pulmonary arteriography – “gold standard”
  • Contrast CT
  • Decreased blood gases and increased pH
• Treatment
  • tPA – tissue plasminogen activator if potentially life threatening embolism
  • Complete bed rest
  • Anticoagulation with heparin in ICU
  • Coumadin anticoagulation for six months
  • Vena caval filter surgery
• PE prophylaxis
  • Most common secondary cause of hospital deaths
  • Lower extremity anti-embolism device with compression during surgery are after heart attack or severe illness
  • Low dose heparin during surgery
  • Graduated compression support hose for patients with deep venous insufficiency
Pulmonary Disorders

• Pulmonary vascular disorders: Pulmonary hypertension
  • Mean pulmonary artery pressure 5 to 10 mm Hg above normal or above 20 mm Hg
  • Primary pulmonary hypertension
    • Idiopathic
  • Diseases of the respiratory system and hypoxemia are more common causes
Pulmonary Disorders (cont’d)

• Pulmonary vascular disorders: Pulmonary hypertension (cont’d)
  • Classifications:
    • Pulmonary arterial hypertension
    • Pulmonary venous hypertension
    • Pulmonary hypertension due to a respiratory disease or hypoxemia
    • Pulmonary hypertension due to thrombotic or embolic disease
    • Pulmonary hypertension due to diseases of the pulmonary vasculature
Pulmonary Disorders

- Pulmonary vascular disorders: Cor pulmonale
  - Pulmonary heart disease
    - Right ventricular enlargement
    - Secondary to pulmonary hypertension
  - Pulmonary hypertension creates chronic pressure overload in the right ventricle
Pulmonary Disorders (cont’d)

- Malignancies of the respiratory tract
  - Lip
    - Most common form—exophytic
  - Stages
  - Laryngeal
    - Forms:
      - Carcinoma of the true vocal cords (most common)
      - Supraglottic
      - Subglottic
Lip Cancer
Laryngeal Cancer
Pulmonary Disorders

• Malignancies of the respiratory tract
  • Lung (bronchogenic)
    • 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
Pulmonary Disorders (cont’d)

• Malignancies of the respiratory tract (cont’d)
  • Lung
    • Types:
      • Non-small cell cancer:
        • Squamous cell carcinoma
        • Adenocarcinoma
        • Large cell carcinoma
      • Small cell cancer—from neuroendocrine tissue so see ectopic hormone secretion (paraneoplastic); large size