Learning Objectives (1 of 2)

- Basic anatomy and physiology
- Causes, effects, and treatment
  - Congenital heart disease
  - Valvular heart disease
- Pathogenesis, risk factors, clinical manifestations, complications, and treatment:
  - Coronary heart disease (CHD)
  - Myocardial infarction (MI)
- Principles of diagnosis and treatment
  - Coronary heart disease (CHD)
  - Myocardial Infarction (MI)

Learning Objectives (2 of 2)

- Dietary effects on coronary heart disease
  - “Good” and “bad” cholesterol
  - Transport of cholesterol by lipoproteins
- Adverse effects, pathogenesis, clinical manifestations, and treatment
  - Hypertension
  - Acute and chronic heart failure
  - Arteriosclerotic and dissecting aneurysms of aorta
  - Diseases affecting veins
Anatomy and Physiology (1 of 6)

- Function: muscular pump; propels blood through the lungs → tissues
- Heart disease: disturbance of function
- Location: within mediastinum; extends obliquely about 5 inches from second rib to fifth intercostal space; rests on the diaphragm; anterior to vertebral column and posterior to sternum
  - 2/3 of heart mass lies left of midsternal line
  - Apex of heart points downward toward the left hip

Anatomy and Physiology (2 of 6)

- Heart coverings
  - Pericardium (double-walled sac, outer layer of tough connective tissue)
  - Epicardium (visceral layer of pericardium covering myocardium)
- Layers of the heart wall
  - Epicardium: outer layer of connective tissue, coronary arteries
  - Myocardium: middle layer, muscular, thickest layer, workhorse of the heart
  - Endocardium: innermost layer, smooth membrane, heart valves part of endocardium

Anatomy and Physiology (3 of 6)

- Chambers: no direct communication between right and left halves
  - Right half (right atrium, RA, and right ventricle, RV)
    - Pulmonary pump, circulates blood into pulmonary artery, lungs
  - Left half (left atrium, LA, and left ventricle, LV)
    - Systemic pump, circulates blood into aorta, organs and tissues
Anatomy and Physiology (4 of 6)

- Atria (singular: atrium) = receiving chambers, thin-walled
- Blood enters RA via three veins:
  - Superior vena cava (from body regions above diaphragm)
  - Inferior vena cava (from body areas below diaphragm)
  - Coronary sinus (collects blood that drains from myocardium)
- Blood enters LA via four pulmonary veins

Anatomy and Physiology (5 of 6)

- Cardiac valves permit flow of blood in only one direction
- Atrioventricular or AV valves: flap-like valves between atria and ventricles; prevent back flow of blood into atria when ventricles contract
  - Tricuspid valve: three flexible flaps; directs blood flow from RA to RV, prevents backflow to RA when RV contracts
  - Bicuspid valve or mitral valve: directs blood flow from LA to LV; prevents backflow to LA when LV contracts

Anatomy and Physiology (6 of 6)

- Semilunar valves
  - Cup-shaped
  - Surround orifices of aorta and pulmonary artery
  - Free margins of valves face upward
  - Prevent backflow of blood into ventricles during diastole
- Pulmonary valve: from RV to pulmonary trunk
- Aortic valve: from LV to aorta
Pulmonary-Systemic Circulation

- Blood returns to the heart low in oxygen and high in carbon dioxide
- Pulmonary circulation
  - Oxygen-poor blood enters RA → RV through tricuspid valve → pulmonary artery → lungs
- Systemic circulation
  - Freshly oxygenated blood leave lungs through pulmonary veins → LA → LV through mitral valve → aorta → rest of the body

Coronary Circulation (1 of 3)

- Main blood supply of the heart
- Shortest circulation in the body
- Myocardium is too thick for the diffusion of nutrients
- Aorta branches to right and left coronary arteries that carry arterial blood to the heart when relaxed
- Blood passes through capillary beds of myocardium
- Venous blood collected by cardiac veins
- Cardiac veins join together and form the coronary sinus that empties blood into the RA
Coronary Circulation (2 of 3)

- Blood supply to the heart
  - Right coronary artery, RCA
    - Supplies posterior wall and posterior part of interventricular septum
  - Left coronary artery, LCA, and branches
    - Left anterior descending artery, LADA
    - Supplies anterior wall, anterior part of interventricular septum
    - Left circumflex artery, LCA; supplies lateral wall
- Adult cardiac muscle does not proliferate to replace damaged or destroyed muscle fibers
- Most areas of cell death repaired with non-contractile scar tissue

Distribution of Coronary Arteries

Coronary Circulation (3 of 3)

- Angina pectoris
  - Chest pain from temporary reduction in blood flow to cardiac muscles despite increased oxygen demand
  - Causes:
    - Narrowed coronary arteries from arteriosclerosis
    - Stress-induced spasm of coronary arteries
- Prolonged coronary artery blockage can lead to myocardial infarction (MI)
Conduction System

• A group of specialized muscle cells that initiate electrical impulses
• Impulses are initiated in the SA (sinoatrial node) in RA near opening of the superior vena cava
• Ability of cardiac muscle to depolarize and contract is intrinsic; does not depend on the nervous system

Cardiac Cycle

• Consists of all events associated with blood flow through the heart during one complete heart beat
• Atrial systole → atrial diastole → ventricular systole → ventricular diastole
  – Systole: contraction period
  – Diastole: relaxation period
• Cardiac output: typically 5 liters/minute pumped out by each ventricle
Blood Pressure

- Blood flow in the arteries results from the force of ventricular contraction
- Pressure is highest when ventricles contract (systolic pressure)
- Pressure is lowest when ventricles relax (diastolic pressure)

Electrocardiogram, ECG

- Measures electrical activity of heart; diagnostic tool
  - P wave: atrial depolarization, atrial systole
  - QRS complex: ventricular depolarization, ventricular systole
  - T wave: ventricular diastole
  - PR interval: time for depolarization to pass from atria to ventricles via AV bundle
- Detects disturbances in rate, rhythm, conduction, muscle injury, extent of muscle damage

Cardiac Arrhythmias

- Disturbances in heart rate or rhythm
- Atrial fibrillation, AF
  - Atria quiver versus contracting normally
  - Ventricles beat irregularly and fast shortening diastole (pulse deficit)
- Ventricular fibrillation, VF
  - Ventricles unable to contract normally, incompatible with life
- Heart block (complete or incomplete)
  - Delay or interruption of impulse transmission from atria to ventricles, from arteriosclerosis
Heart Disease—A Disturbance of Pump Function

<table>
<thead>
<tr>
<th>Mechanical Pump Abnormality</th>
<th>Comparable Heart Diseases</th>
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Congenital Heart Disease
- Causes: German measles, Down syndrome, drugs, genetic factors, undetermined causes
- Presentation
  - Fetal bypass channels fail to close normally
    - Patent ductus arteriosus; patent foramen ovale
  - Atrial, ventricular, or combined septal defects
  - Abnormalities obstructing flow: Pulmonary stenosis, aortic stenosis, coarctation of the aorta
  - Abnormal formation of aorta and pulmonary artery or abnormal connection of vessels: tetralogy of Fallot, transposition of great vessels
- Prevention: protect developing fetus from intrauterine injury

Valvular Heart Disease (1 of 9)
- Rheumatic fever and rheumatic heart disease
- Non-rheumatic aortic stenosis
- Mitral valve prolapse
- Serotonin-related heart valve damage
- Infective endocarditis
Valvular Heart Disease (2 of 9)

• Rheumatic fever
  – Commonly encountered in children
  – NOT a bacterial infection but an immunologic reaction that develops weeks after initial streptococcal infection
  – Complication of group A beta hemolytic streptococcal infection (sore throat and scarlet fever)
  – Fever and inflammation of connective tissue throughout the body, especially heart and joints
  – Acute arthritis (multiple joints) and inflammation of heart

Valvular Heart Disease (3 of 9)

• Rheumatic fever
  – Anti-streptococcal antibodies against strep antigens cross react with similar antigens in tissues
  – Antigen-antibody reaction injures connective tissue and causes fever
  – Clinical outcomes
    • Healing with scarring of tissues (heart valves)
    • Death from severe inflammation and acute heart failure
    • Can recur if another streptococcal infection reactivates hypersensitivity and tissue damage

Valvular Heart Disease (4 of 9)

• Rheumatic heart disease
  – Complication of rheumatic fever
  – Scarring of heart valves following rheumatic inflammation
  – Primarily affects mitral and aortic valves
  – Clinical outcome: valve regurgitation or stenosis → impairs cardiac function, increases strain on heart, eventually leads to heart failure
  – Prevention
    • Treat beta strep infection promptly
    • Prophylactic penicillin throughout childhood and young adulthood to prevent strep infections and reduce risk of recurrent rheumatic fever and further heart valve damage
Valvular Heart Disease (5 of 9)

- Non-rheumatic aortic stenosis
  - Occurs in 2% of population
  - Aortic stenosis secondary to bicuspid aortic valve
  - Calcific aortic stenosis
  - Aortic stenosis secondary to bicuspid aortic valve
  - Aortic valve has 2 cusps rather than the usual 3 cusps
  - Functions satisfactorily for a time, then becomes thickened, calcified, and rigid from increased strain on valve, leads to heart failure

Valvular Heart Disease (6 of 9)

- Non-rheumatic aortic stenosis
  - Calcific aortic stenosis
  - Normal 3 cusps, common valvular heart disease
  - Leaflets undergo connective tissue degenerative changes → fibrotic, calcified, rigid → restricts valve mobility, stenosis
  - Recent studies: also occurs with deposits of lipids and macrophages as in coronary atherosclerosis
  - Clinical outcomes: ↑ strain → left ventricular hypertrophy → heart failure
  - Prevention: Control risk factors (high cholesterol, diabetes, hypertension)

Mitral Valve Damage

Partial Cusp Fusion

Congenital Bicuspid Aortic Valve

Early scarring

Severe Calcific Aortic Stenosis
Valvular Heart Disease (7 of 9)

- Mitral valve prolapse
  - Common but only few develop problems
  - One or both leaflets enlarge, stretch, and prolapse into LA during ventricular systole
  - Prolapsing leaflets may not fit together tightly → blood leaks back into LA; mitral regurgitation
  - On auscultation: “click” sound on systole followed by a “faint systolic murmur” from reflux of blood in between closed valve leaflets
  - Diagnosis: echocardiography
  - Prolapse with mitral regurgitation → give antibiotic prophylaxis prior to dental or surgical procedure

Valvular Heart Disease (8 of 9)

- Infective endocarditis: affects abnormal or damaged mitral, aortic valves
  - Subacute infective endocarditis
  - Caused by organisms of low virulence
  - Complication of any valvular heart disease
  - Mild symptoms of infection
  - Platelets and fibrin may deposit on abnormal or damaged valves; then serve as sites for bacteria to implant or for thrombi to form followed by emboli and tissue infarct
  - Prophylactic antibiotics given prior to dental or surgical procedures to prevent transient bacteremia and resulting endocarditis
Valvular Heart Disease (9 of 9)

- Infective endocarditis
  - Acute infective endocarditis caused by highly pathogenic organisms, commonly staphylococci
  - Severe symptoms of infection and valve destruction
  - Affects normal heart valves
- At-risk groups:
  - Intravenous drug users; affect tricuspid valve instead of mitral or aortic valves
  - Unsterile materials or contaminants enter right side of heart, form large bacteria-laden vegetations on valve, lodge into lungs cause pulmonary infarct

Bacterial Endocarditis, mitral valve

Severe Bacterial Endocarditis
Staphylococcal infection of normal mitral valve with leaflet destruction and perforation

Coronary Heart Disease (1 of 2)

- Cause: arteriosclerosis of coronary arteries
  - Narrowing of arteries from lipid deposits (neutral fat and cholesterol) by diffusion from bloodstream
- Pathogenesis: Endothelial injury → cells proliferate in intima
  - Cholesterol and lipids accumulate in cytoplasm (unstable plaques)
  - Cholesterol precipitates as crystals, causing cell necrosis
  - Cholesterol crystals, debris, enzymes leak out
  - Secondary fibrosis, calcification, degenerative changes in arterial wall
  - Formation of atheroma (rough, ulcerated surface predisposed to clot formation)
Coronary Heart Disease (2 of 2)

- **Atheroma or atheromatous plaque**
  - Irregular mass of yellow, mushy debris
  - Encroaching on lumen of artery and extending into muscular and elastic tissues of arterial wall

- **Stable plaque**
  - Surrounded by fibrous tissue
  - Causes permanent narrowing of vessel

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*Early atheromatous plaques inside aorta*

*Advanced atherosclerosis of aorta*

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*Several stable atheromatous plaques surrounded by dense connective tissue.*

*Atheromatous deposits reduce lumen of coronary artery*

Without excessive demands on heart, 50% or more arterial narrowing may still supply enough blood to heart, but is inadequate during exertion.
Coronary Heart Disease Risk Factors

- Most important risk factors
  - Elevated blood lipids
  - High blood pressure
  - Cigarette smoking
  - Diabetes
- Likelihood of coronary heart disease and heart attack
  - 1 risk factor = 2x risk
  - 2 risk factors = 4x risk
  - 3 risk factors = 7x risk
- Other risk factors: obesity; Type A personality

Coronary Heart Disease Manifestations (1 of 2)

- Also referred to as ischemic heart disease
- Due to decreased blood supply to heart muscle from narrowing or obstruction of the coronary arteries (myocardial ischemia)
- Clinical manifestations are variable
  - Asymptomatic (free of symptoms)
  - Angina pectoris, "pain of the chest"
  - Bouts of oppressive chest pain that may radiate into neck or arms; caused by myocardial ischemia

Coronary Heart Disease Manifestations (2 of 2)

- Stable angina: midsternal pressure or discomfort on exertion, subsides with rest or intake of nitroglycerine
- Unstable angina: pain lasts longer, occurs more frequently, and is less completely relieved by nitroglycerine
- More severe and prolonged myocardial ischemia may precipitate an acute episode manifested as:
  - Myocardial infarction: actual necrosis of heart muscle
  - Cardiac arrest: cessation of normal cardiac contractions
Small reduction in diameter causes a large drop in flow rate.

Causes and Effects of Severe Myocardial Ischemia

Myocardial Infarction

- Necrosis of heart muscle from severe ischemia
  - Insufficient blood flow through one of the coronary arteries and inadequate collateral flow into ischemic muscle
- Transmural infarct: full-thickness infarct from endocardium to epicardium, usually from clot in major coronary artery
- Subendocardial infarct: only part of wall undergoes necrosis
Myocardial Infarction—Location

• Often involves muscles of left ventricle and septum
  – Thicker walls require rich blood supply; work harder to pump blood into systemic circulation; rarely involves atria or right ventricle
• Depend on location of obstruction and collateral flow
  – Anterior wall: left anterior descending artery distribution
  – Lateral wall: circumflex artery distribution
  – Posterior wall: right coronary artery distribution
  – Massive anterior and lateral wall: main left coronary distribution, frequently fatal

Myocardial Infarction—Mechanisms

• Basic mechanisms that trigger a heart attack
  – Sudden blockage of a coronary artery from a thrombus or atheromatous debris
  – Hemorrhage into an atheromatous plaque
  – Arterial spasm
  – Sudden greatly increased myocardial oxygen requirements (vigorous physical activities)
• Cardiac arrest may result from
  – Arrhythmia from prolonged or severe myocardial ischemia that disrupts ventricular contraction; most common and rapidly fatal is ventricular fibrillation
  – Asystole: complete cessation of cardiac contractions

Myocardial Infarction—Complications

• Arrhythmias from irritability of ischemic heart muscle adjacent to the infarct or from conduction disturbance (heart block)
• Heart failure due to badly damaged ventricles
• Intracardial thrombi: mural thrombus forms on ventricular wall; bits of clot embolize into systemic circulation causing infarct in brain, kidneys, spleen
• Cardiac rupture: blood leaks into pericardial sac from perforation in necrotic muscle, prevents ventricular filling (cardiac tamponade); rupture may occur in ventricular septum or papillary muscle
Mural thrombus adherent to endocardium

Clotted blood around heart compressing heart, preventing ventricular filling

Cardiac rupture through a large transmural infarct

Infarcted Heart Muscle

Myocardial Infarction–Survival

- Factors affecting survival:
  - Size of infarct
  - Age of patient
  - Complications
  - Other diseases
- Mortality rates: 6% for small infarcts without heart failure to ≥ 50% for large infarcts with severe heart failure
- 90% of hospitalized patients survive
- Causes of death following MI: arrhythmia, heart failure, cardiac rupture
Myocardial Infarction—Diagnosis
(1 of 2)

• Medical history: inconclusive
  – Pain of severe angina may be similar to pain of MI
  – Possible mild symptoms subendocardial infarct
• Physical examination: usually not abnormal unless patient exhibits evidence of shock, heart failure, murmur
• Laboratory data
  – Electrocardiogram, ECG or EKG
  – Enzyme tests; enzymes leak out from necrotic cells after an infarct
  – The larger the infarct, the longer for elevated levels to return to normal

Myocardial Infarction—Diagnosis
(2 of 2)

• Enzyme tests
  – Troponin T and troponin I
    • Specific to heart, slight heart damage causes levels to rise
    • Peaks in 24 hours, remains high for 10-14 days
  – Creatine kinase isoenzyme, CK-MB
    • Rises a few hours after MI, peaks in 24 hours

Myocardial Infarction—Treatment
(1 of 2)

• Acute coronary syndromes
  – Severe unstable angina
  – Minor myocardial damage
  – Major myocardial infarction
• Results from complete blockage of major coronary artery from a thrombus
  – Chest pain and EKG suggestive of large infarct and high CK-MB, troponin
Myocardial Infarction– Treatment (2 of 2)

• Thrombolytic therapy
  – Effective but clot may not dissolve completely
  – Better outcome the sooner clot is dissolved
  – May cause bleeding problems
  – Angioplasty favored for restoring coronary blood flow

Myocardial Revascularization Procedures

Bypass Surgery
Uses segment of saphenous vein of internal mammary arteries to bypass obstruction

Coronary Angioplasty
Dilates narrowed coronary arteries rather than bypassing them

Cocaine-Induced Arrhythmias and Infarcts

• Prolongs and intensifies effects of sympathetic nervous system:
  – Increases heart rate: increased oxygen demand
  – Increased muscle irritability; predisposes to arrhythmias
  – Increased peripheral vasoconstriction and coronary artery spasm: high blood pressure
  – Fatal arrhythmias and MI can occur even among those with normal coronary arteries
Blood Lipids and Coronary Artery Disease

- Neutral fat: triglyceride (3 molecules of fatty acid combined with glycerol) from ingested fat, sugar, and carbohydrates
- Trans fat and saturated fat: atherogenic
- Cholesterol: synthesized in body and from diet
- High levels associated with premature atherosclerosis and increased CVD risk; transported by lipoproteins
  - Low density lipoprotein, LDL, “bad cholesterol”
  - High density lipoprotein, HDL, “good cholesterol”
    - Protective; increases with regular exercise, smoking cessation, modest alcohol intake

LDL promotes atherosclerosis by transporting cholesterol into arterial wall; HDL protects by transporting cholesterol to the liver for excretion.

Cardiovascular Risk Factors

- Metabolic syndrome
  - Abdominal obesity, hypertension, abnormal lipids, insulin resistance, impaired glucose tolerance
  - Leads to heart disease and type 2 diabetes
Aspirin and Reduced CVD Risk

• Action: Interferes with platelet function by permanently inactivating thromboxane A2 that causes platelets to aggregate and start clotting process
• Rapidly absorbed from stomach and small intestines
• Inhibits platelet function within 1 hour of ingestion
• 30 mg/day can inactivate thromboxane A2 for the entire 10-day life span of platelets
• Reduces risk of cardiovascular disease and stroke

Hypertension (1 of 2)

• Excessive vasoconstriction of small arterioles resulting in:
  – Increased peripheral resistance; increased diastolic blood pressure
  – Increased force of ventricular contraction
  – Compensatory increase in systolic pressure
• Cardiac effects: increased peripheral resistance → higher workload → heart enlarges → heart failure
• Vascular effects: increased pressure → premature wearing out of vessels; accelerates atherosclerosis; injury to arterioles → rupture and hemorrhage
• Renal effects: narrowed renal arterioles → decreased blood supply to kidneys → injury and degenerative changes in glomeruli and tubules → renal failure

Hypertension (2 of 2)

• Primary or essential hypertension: unknown cause
• Secondary hypertension: from a known disease (chronic kidney disease, pituitary or adrenal tumor, hyperthyroidism)
• Isolated systolic hypertension: mild to moderate rise in systolic pressure but low or normal diastolic pressure
  – Increased rigidity of aorta with age
  – Arteries less able to stretch and absorb force of ejected blood during ventricular contraction
  – Diastolic pressure is normal because of absence of arteriolar vasoconstriction
  – Same harmful effects as primary and secondary hypertension
Heart Failure
- No longer able to pump adequate amount of blood
- May result from any type of heart disease
- Chronic heart failure: develops slowly and insidiously
- Acute heart failure: rapidly failing heart
  - Forward failure: reduced blood flow to tissues → reduced renal blood flow → salt and water retention to increase blood volume and venous pressure → edema
  - Backward failure: blood “back ups” in veins draining to the heart → increased venous pressure, congestion, edema
  - Both types are present to some degree in patients with heart failure

Acute Pulmonary Edema
- Manifestation of acute heart failure from temporary disproportion in output of blood from ventricles
- Temporary reduction in output from left ventricle “right heart” pumps blood into lungs faster than “left heart” can deliver blood to peripheral tissues
- Rapidly engorges lungs with blood causing:
  - Increased pulmonary capillary pressure
  - Leakage of fluid in alveoli
  - Shortness of breath from fluid accumulation in alveoli and impaired oxygenation

Aneurysms
- Dilatation or outpouching of portion of arterial wall
- Cause: arteriosclerosis (most common)
  - Arteriosclerotic aneurysm: arteriosclerosis causes narrowing, thrombosis, and weakening of vessel wall
    - In aorta: most common in distal part of aorta; may rupture leading to massive and fatal hemorrhage
  - Dissecting aneurysm of aorta: splitting of middle layer consisting of elastic and muscle tissues; degenerative changes cause layers to loose cohesiveness and separate; severe chest and back pain
Sites of Aortic Dissection
A: Tear in ascending aorta
B: Tear in descending aorta

Discussion
• What is the difference between angina pectoris and myocardial infarction?
• What are the clinical manifestations of myocardial infarction?
• Patients at risk for coronary heart disease frequently take low-dose aspirin tablets to reduce the risk of heart attacks. What effects does aspirin have? Why is it used?

Case Study
• 74-year-old man admitted to ER for severe oppressive chest pain of about 5 hours duration. Two weeks before admission, had less severe chest pain when walking rapidly, but subsided with rest
  – BP: 190/110; lungs clear, normal heart sounds
  – ECG: acute MI on anterior wall of LV
  – Elevated creatine phosphokinase and lactic dehydrogenase
• Which coronary artery is likely involved?
• Why are cardiac enzymes elevated?
• What conditions may follow this man’s MI?