Anatomy and Physiology Focus: Cardiovascular System Part 1, Heart and Great Vessels

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Session Objectives

• Review the structure and function of the heart and great vessels
• Describe diseases and disease processes and how they affect the heart and great vessels
Heart and Great Vessels

- Heart: Weighs 250–300 grams, about size of fist
- Lies in middle of thorax with largest part slightly offset to left, beneath sternum, in mediastinum
- Apex is pointed bottom portion, base is opposite apex

Great vessels: Aorta, vena cava (systemic circuit), pulmonary trunk, arteries and veins (pulmonary circuit)
Structure and Function of Heart

Specialized tissues

• Simple squamous epithelium, smooth layer; filtration and absorption
• Elastic connective tissue, branching elastic fibers; stretching
• Cardiac muscle tissue, involuntary; rhythmic contraction and relaxation in response to electrical impulses within heart
• Smooth muscle tissue, involuntary, blood and lymph vessels; relaxation and contraction in wave-like fashion to spread impulses in organized manner
**Pericardium:** sac enclosing heart

- External fibrous layer, upper aspect attaches to great vessels, lower aspect attaches heart to diaphragm, anterior aspect binds heart to sternum

- Internal aspect serous membrane, 2 layers; secretes lubricating fluid, pericardial fluid, to help heart move without friction, cushion

- Parietal layer lines inside of sac, visceral layer adheres to outside of heart, epicardium

**Heart wall:**

- Epicardium, outermost layer

- Myocardium, thickest layer, forms bulk of heart; contraction and pumping, cardiac muscle

- Endocardium, covers inside of myocardium; lines chambers, covers heart valves, continuous with endothelium of great vessels
Heart Chambers

4 chambers separated by septum; right and left atrium, right and left ventricle

- Atria receive blood from veins; thin-walled, separated by interatrial septum
- Ventricles, thick-walled, pump blood out of heart; left ventricle larger and stronger; interventricular septum
Heart Valves

4 valves keep blood flowing in the right direction
• Atrioventricular (A-V), between atria and ventricles
  – Tricuspid, right
  – Bicuspid (mitral), left
• Semilunar, open as blood exits ventricles
  – Pulmonic (pulmonary), right
  – Aortic, left
• As heart contracts, pressure differences cause valves to open or close, allowing or preventing flow of blood; heart sounds are generated by opening/closing; murmurs from heart valve dysfunction, stenosis, insufficiency
Cardiac Cycle, Pumping Function

Superior Vena Cava

Inferior Vena Cava

Diastole
(filling)

Systole
(pumping)
Diastole, Resting/Filling Phase

- **Right**: blood flows into right atrium from inferior and superior vena cava, tricuspid valve is closed; pressure changes cause tricuspid valve to open, allowing flow into right ventricle, atrium contracts briefly, pressure in right ventricle forces tricuspid valve to close
- **Left**: oxygenated blood flows into left atrium from pulmonary veins, mitral valve is closed; pressure changes cause blood to flow into ventricle through open mitral valve, left atrium contracts briefly, pressure in left ventricle forces mitral valve to close

At end of diastole, both atria contract, small amount of additional blood actively pumped into ventricles; tricuspid and mitral valves are closed
Systole, Pumping/Ejection Phase

- **Right**: right ventricle fills, pressure forces tricuspid valve to close; ventricle contracts, ejects blood through pulmonic valve through pulmonary arteries to lungs, pulmonic valve then closes

- **Left**: left ventricle fills, pressure forces mitral valve to close; ventricle contracts, pumps blood out aortic valve to aorta, coronary arteries, systemic circulation; aortic valve then closes

After systole, small amount of blood remains in ventricle(s), waiting for next contraction; amount pumped out per beat is "ejection fraction"; <55% indicates ineffective pumping; usually refers to left ventricular function
Cardiac Conduction

Physiological properties of heart muscle tissue:

- **Automaticity**: impulse generated without stimulation from other source
- **Conductivity**: ability to transfer impulse
- **Contractility**: allows shortening of muscle when stimulated
- **Excitability**: responsiveness of cell to stimulus

Heart function regulated by internal conduction system to maintain constant, rhythmic resting heartbeat; rate modified in response to stimulation from cardiac center in brain, sympathetic/parasympathetic nervous system; physical activity, emotional changes, ion concentration (Na+, K+), changes in body temperature
Cardiac Conduction

- Internal conduction system of heart is regulated by sinoatrial (SA) node, “pacemaker of the heart”
- Action potentials arise in SA node, cause atria to contract
- Action potential travels to atrioventricular (AV) node and on to AV bundle or Bundle of His in ventricular septum
- Divides into right and left bundle branch for each ventricle
- Moves on to Purkinje fibers and endocardium at apex of heart
- Finally to the ventricular myocardium, causing contraction of heart muscle
QRS complex

- Spread of electrical activity through ventricular myocardium produces QRS complex on EKG

ST segment

- Indicates amount of time from end of contraction of ventricles (systole) to beginning of rest period before ventricles begin to contract for next beat (diastole); repolarization

Injured heart tissue conducts electrical impulses more slowly than normal heart tissue; most often left ventricle
Coronary Blood Supply

- Heart is working muscle requiring continuous supply of O2; right and left coronary arteries branch from aorta, fan out over myocardium; veins drain into coronary sinus (behind right atrium), then directly into right atrium.
Great Vessels

Systemic circuit

- **Aorta** (6): divides into three short sections: ascending aorta, aortic arch, descending aorta
- **Vena cava**: deoxygenated blood from body is returned to right atrium by superior vena cava (4) draining head, neck, arms, upper thorax, and inferior vena cava (5), returning deoxygenated blood from legs, abdomen, lower thorax

Pulmonary circuit

- **Pulmonary trunk** (arteries) (7): right ventricle fills with blood and contracts, blood is pumped into pulmonary trunk and its branches, pulmonary arteries, to lungs to be oxygenated
- **Pulmonary veins** (8): reoxygenated blood from lungs is returned to left atrium via 4 pulmonary veins
Diseases, Disorders, Injuries, Other Conditions of Heart and Great Vessels

Atherosclerosis of Coronary Arteries

- “(athero) paste, (sclerosis) hard”
- Buildup of plaque in arteries
- Plaque composed of fatty substances, cholesterol, cellular waste, calcium
- Narrows diameter of artery, reduces blood flow, can rupture releasing clots into smaller arteries, obstructing blood flow
- 90% of myocardial infarctions result from acute thrombus obstructing atherosclerotic coronary artery
Risk Factors for Coronary Artery Disease

Nonmodifiable:
- Age
- Family or personal history of cardiovascular disease

Modifiable/lifestyle:
- Tobacco smoking
- Obesity
- Excessive alcohol consumption
- Abuse of drugs such as cocaine and methamphetamine
- Chronic high stress levels
- Diet
- Inactivity

Associated medical conditions:
- Dyslipidemia
- Diabetes
- Hypertension
- Chronic kidney disease
- Heart failure
Acute Coronary Syndrome/Myocardial Infarction

- Leading cause of death for men and women worldwide
- Irreversible death of heart muscle secondary to prolonged ischemia
- Occlusive (plaque/thrombosis)
- Vasospasm (Prinzmetal’s variant angina)
- May lead to arrhythmias and other complications
- Severity determined by extent of tissue death
- “Silent MI” (25%)
- Anterior, posterior, inferior, lateral, septal
- Initial or subsequent
Angina Pectoris

- Inadequate blood/oxygen supply to heart muscle
- Episodes of pain
  - fullness, squeezing, pressure in chest, under sternum
  - may radiate to left arm, jaw
  - often confused with indigestion/heartburn
  - may present differently in women
- Stable angina
  - predictable response to exertion/stress
  - improves when activity stopped
  - relieved by nitroglycerin (NTG)
- Unstable angina (pre-infarction angina)
  - unpredictable; change from previous pattern of angina
  - unusually severe or long (>15-20 min), may occur at rest, may awaken from sleep
  - If not relieved by 3 NTG 5 min apart, call 911  WHEN IN DOUBT, CHECK IT OUT!!!
  - warning sign that heart attack may happen soon
  - sign of more severe heart disease
Evaluation for ACS

TIME IS CRITICAL!!

• Serial EKGs, 12 lead
• Labs: cardiac enzymes/markers, CBC, metabolic panel
• Portable CXR
• Vital signs monitored, IV access, administration of O₂, aspirin, nitroglycerin to improve coronary circulation
• Medical stabilization is priority, then decisions made re: treatment options
  – tPA (tissue plasminogen activator)
    • “clot buster,” thrombolytic therapy administered within the first 6–12 hours (especially first hour) may abort MI, dramatically reduce mortality; risk of bleeding
  – Cardiac catheterization to determine extent of blockage, damage
  – Angioplasty (PCTA), with or without stent
  – CABG (coronary artery bypass graft)
STEMI vs. NSTEMI

ST-segment elevation myocardial infarction (STEMI)

- Complete blockage of coronary artery, necrosis of heart muscle being supplied by that artery
- ST elevation on EKG, elevated cardiac enzymes (troponin, CK-MB)
- Location: anterior, posterior, inferior, lateral or septal
  - Transmural: extends through whole thickness of heart muscle, usually result of complete blockage
  - Subendocardial: involving small area in subendocardium

Non–ST-segment elevation myocardial infarction (NSTEMI)

- Coronary artery partially blocked, ischemia
- No ST elevation on EKG; elevated enzymes
- Main difference between NSTEMI and unstable angina is that in NSTEMI, severity of ischemia is sufficient to cause cardiac enzyme elevation
- Continued elevation of cardiac markers, need for intervention
Angioplasty (PTCA)

- PTCA, “balloon angioplasty”; opening of narrowed coronary artery; stent may be placed at site of blockage; risk of post-op bleeding
- Catheter with small, inflatable, balloon at tip is inserted via femoral artery; under x-ray visualization
- Tip positioned at mouth of affected coronary artery, dye injected to visualize blockage
- Guide wire advanced, deflated balloon threaded over guide wire to area of blockage; balloon is inflated, compressing coronary blockage
- Stent, if used, is threaded over catheter and placed within lumen of artery; bare metal or drug-eluting stent impregnated with medication to maintain patency
- Risk of clot formation initially, patient on Plavix or similar drug until risk is gone, 4–6 weeks when natural tissue has covered stent
Coronary Artery Bypass Graft (CABG)

• CABG: new route around narrowed/blockaded arteries, allowing sufficient blood flow to deliver oxygen and nutrients to heart muscle
• Autologous vein graft, autograft: sewing graft vessel to coronary artery beyond narrowing or blockage; other end attached to aorta
• Harvested from other area of body; saphenous vein, radial artery; often used on right coronary artery
• Left internal mammary artery (LIMA), rerouted to coronary artery beyond narrowing or blockage; branches from left subclavian artery, repositioned from chest wall
• Used primarily for left coronary artery
• Arterial graft has better patency rates (95% at 10 years)
• No need for additional invasive procedure to obtain graft vessel

Other graft types
• **Human cadaver graft**: patency not good, rejection from use of tissue from another human
• **Synthetic graft**: Dacron, other material; usually in larger vessels (aorta, legs); not routinely used, limited success

Terms *single bypass*, *double bypass*, *triple bypass*, *quadruple bypass* and *quintuple bypass* refer to number of coronary arteries bypassed
Cardiopulmonary Bypass

- Heart stopped during procedure, blood circulated (cardio) and oxygenated (pulmonary) mechanically
- Off-pump bypass, heart beating, no need for c-p bypass
- MIDCAB (minimally invasive direct coronary artery bypass), good success with LAD; robotic-assisted through small incisions between ribs; good for patients with increased risks; shorter length of stay and shorter recovery time
Neoplasms

Primary malignancies of heart/great vessels: rare; angiosarcoma, fibrosarcoma, rhabdomyosarcoma, liposarcoma

- Secondary: metastases from lungs, breast, melanomas, lymphoma

- Benign: myxoma, rhabdomyoma, fibroma, lipoma, pericardial teratoma, pericardial cyst
  - Benign tumors can be lethal due to direct extension into conduction system of heart, interference with structural function of heart or valves, or emboli that may have lethal sequelae

BENIGN DOES NOT NECESSARILY MEAN NOT DANGEROUS!
Infectious Diseases

- **Pericarditis**: inflammation of pericardium, usually complication of viral infection, flu, HIV; may be bacterial, fungal; usually acute, but can last for several months, along with pericardial effusion, fluid between layers of sac; noninfectious causes: lupus, kidney failure, cancer, thyroid disease

- **Myocarditis**: inflammation of middle layer of heart, cardiac muscle tissue; caused by infection, usually viral, toxins, autoimmune disease

- **Endocarditis**: inflammation of inner lining of heart, usually bacterial; SBE, subacute bacterial endocarditis generally begins at another site, travels via bloodstream to heart; bacteria attach to valves, vegetation grows, can damage heart valves with serious complications; increased risk with artificial heart valves, congenital heart defects, damaged heart valves, IV drug use, artificial joints; SBE prophylaxis with dental and other procedures controversial
Pulmonary Heart Disease; Diseases of Pulmonary Circulation

- **Cor pulmonale**: enlargement of right ventricle due to increased resistance or high pressure in pulmonary artery; lungs cause heart to fail; lung disease (emphysema, COPD) causes small blood vessels to become rigid, right ventricle no longer able to push blood into lungs and eventually fails; blood backs up into systemic venous system; chronic or acute; “right sided-heart failure”

Pulmonary hypertension:
- **Primary (PPH)**: elevated pressure in pulmonary arteries, narrowing of lumen, thickening of walls
- **Secondary**: constriction of pulmonary arteries due to hypoxemia, changes in pulmonary vasculature from emphysema, lung disease, pulmonary embolus; increased viscosity of blood, polycythemia, sickle cell disease

- **Pulmonary embolism**: complication of venous thrombosis, DVT; clot breaks free, travels to pulmonary vessels, obstructs blood flow; ventilation/perfusion defect interferes with perfusion of gases in lungs; potentially fatal
Other Heart Diseases

Heart valve disorders: Can affect any or all heart valves; congenital or acquired; murmurs; valve replacements

• Stenosis: narrowing of valve opening stiffening of leaflets, decreases flow; mild to severe; calcification, infectious, vegetative endocarditis, rheumatic, associated with rheumatoid arthritis, lupus

• Insufficiency: incompetence of valve, regurgitation; allows backflow of blood; complication of MI damage to tissue around valve, connective tissue diseases

• Prolapse: mitral most common; “floppy” valve, degeneration of leaflets in valve, leaflets sink back into atrium, can cause regurgitation, backflow of blood; mild to severe

Rheumatic heart disease:

• Rheumatic fever: complication of untreated group A beta hemolytic strep throat; develops 2–3 weeks after strep infection; acute infection, can lead to pericarditis, myocarditis, endocarditis; after acute phase, chronic rheumatic heart disease can result in damage to valves, especially mitral and aortic
Hypertensive heart disease

- Untreated HTN can lead to left ventricular hypertrophy (LVH) due to increased workload on heart; muscle thickens; may lead to heart failure, coronary artery disease, arrhythmias; LVH not disease but marker for heart disease, may be picked up on routine EKG or CXR

Pericardial effusion

- Accumulation of fluid in pericardium; may occur in absence of disease or with trauma, following surgical procedure; infectious, bacterial, viral; autoimmune disease, HIV, thyroid; drugs

Heart failure

- Inability of heart to pump effectively; develops over time; right, inefficient pumping to lungs; left, inefficient pumping to rest of body; can affect both sides; SOB, fatigue, fluid in lower extremities with right; pulmonary edema with left
  - **Systolic**: contraction phase; weakness of heart muscle, especially ventricles
  - **Diastolic**: resting and expansion phase, rigidity of muscle, prevents filling resulting in pulmonary congestion or edema
Cardiomyopathy

Deterioration of myocardium; primary, not due to other disease; secondary, can be linked to specific cause, HTN, valvular or artery disease; all can progress to heart failure; reduced ejection fraction

- **Dilated**: most common; enlarged heart cavity, primarily left ventricle; muscle weak, ineffective pumping; causes: chronic alcohol use, thyroid disease, stimulant use, chronic uncontrolled tachycardia; progresses to heart failure; medical treatment, transplant if not effective

- **Hypertrophic**: thickening, primarily ventricles and septum; can obstruct flow of blood, affect ability of muscle to relax and contract; conduction delays

- **Restrictive**: least common; rigidity of ventricles, inability to fill, ineffective pumping
Conduction Disorders and Arrhythmias

Named for portion of system affected, SA, AV, bundle branch, intraventricular blocks; can stem from malfunction of any part when electrical conduction is interrupted, causing abnormal heartbeat; arrhythmia = no rhythm, dysrhythmia = abnormal rhythm; implanted pacemakers to regulate rhythm, defibrillate

• **Atrial fibrillation**: irregular, rapid contraction of atria; atria quiver rather than contract; pumping action decreases, blood remains in chamber with systole, risk of clots forming in pooled blood; 7x risk of stroke; medical treatment, anti-coagulation, cardioversion; atrial flutter, precursor to AF, may be asymptomatic for yrs, progress to Afib; anticoagulation, Coumadin, Pradaxa

• **Premature beats**: premature ventricular contractions (PVC’s); common, usually not health risk; number and site, associated symptoms; Holter monitor
**Bradycardia**: slow heart rate (<60, usually no symptoms until <50); reduced blood flow; fatigue, dizziness, fainting; hypothyroidism, drug abuse, electrolyte imbalance; athletes, low resting rate

**Tachycardia**: rapid heart rate, >100 in adults; exceeds normal resting rate; sinus, increased heart rate in response to changes in blood flow/pressure; fever, hyperventilation, hyperthyroidism, position change

**Ventricular tachycardia**: rapid beat originating in ventricles; supraventricular tachycardia (SVT) originates above ventricles, may progress to v-fib; ventricular fibrillation (v-fib), life-threatening, progresses to asystole, death; cardioversion, defibrillation, ablation
Injuries (initial, subsequent, sequela)

- Laceration of heart with or without penetration of heart chambers or open wound into thorax
- Traumatic transection of blood vessel, open or closed; result of fracture, Gustilo open fracture classification IIIc, major arterial injury
- Traumatic rupture of blood vessel, open, closed, blunt force trauma
- Hemopericardium, blood in pericardial sac
- Contusion of heart with or without open wound to thorax
- Crush injuries, usually associated with other injuries
Other Conditions of Heart and Great Vessels

Poisonings: drugs, chemicals or other substances (therapeutic or non); toxic and adverse effects, overdosing/underdosing (new); identify substance and specific cardiac manifestations associated with poisoning

Traumatic air or fat embolism

- Air embolism, introduction of air into circulatory system; usually complication of medical or surgical procedure or trauma
- Fat embolism, composed of fat droplets, complication of trauma, fractures; following orthopedic surgery, joint replacement
Signs, Symptoms, Abnormal Findings

Signs, symptoms

- **Chest pain**: cardiac: angina, MI, coronary spasm; noncardiac: atypical, musculoskeletal, GI, respiratory
- **Syncope**: arrhythmia, pulmonary embolism, hypoxia
- **Cardiogenic shock**: decreased pumping ability of heart leads to shock; decreased tissue perfusion, cell death, cardiac arrest, death

Abnormal findings

- Abnormal EKG, Holter monitor
- Abnormal imaging, x-rays, nuclear scans
- Abnormal echocardiogram
- Abnormal stress test, exercise, nuclear
- Abnormal labs, cardiac enzymes, electrolytes, tox screens, therapeutic blood levels
References/Resources

• Advanced Anatomy and Physiology for ICD-10-CM/PCS. Contexo Media. 2010
• Comprehensive Anatomy and Physiology for ICD-10-CM Coding. Optum. 2012

Internet Resources

• Kulick, Daniel Lee, MD. Coronary Balloon Angioplasty and Stents (Percutaneous Coronary Intervention, PCI). http://www.medicinenet.com/coronary_angioplasty/article.htm
There is a TON of information on the internet, all just a keystroke away!
Great Website!

HCPro, good resource for all things HIM and more.


Marketplace has extensive list of free newsletters on many topics. ICD-10 trainer is excellent. Daily email presenting cases related to specific diagnosis and coding.
Questions? Comments?
Thank You.

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