Introduction to Cardiology
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Topics to be Discussed:

- Cardiovascular Disease
- EMS System Role
- Cardiovascular Anatomy and Physiology
- Cardiovascular Electrophysiology
Cardiovascular Disease

- Single greatest cause of death and disability in the United States. Cardiovascular disease refers to any disease that involves the heart and blood vessels including:
  - Aneurysm
  - Angina
  - Atherosclerosis
  - Cerebrovascular Accident (Stroke)
  - Cerebrovascular Disease
  - Congestive Heart Failure
  - Coronary Artery Disease
  - Myocardial Infarction
  - Peripheral Vascular Disease
2 million people are diagnosed with an Acute Coronary Syndrome (ACS) per year

- 1.5 million will experience an acute MI
  - Of those, 500,000 will die
  - Almost half of these (250,000) will be sudden and within the first hour of onset of symptoms

- 500,000 people will suffer a stroke each year in the US
  - Nearly 125,000 of these will die
Cardiovascular Morbidity

- 6.2 million Americans have significant coronary artery disease (CAD)!
- 5 million years of life are lost EACH YEAR to cardiovascular disease in people under 75.
- Education and lifestyle changes are important to improving cardiovascular health.
Cardiovascular Morbidity

- EMS plays a key role in survivability.
- EARLY reperfusion is the key to decreased morbidity and mortality.
- TIME = MUSCLE
Cardiovascular Disease

Source: National Center for Health Statistics and the American Heart Association.
Cardiovascular Disease

- Atherosclerosis
  - Plaque accumulation within the lumen of the artery resulting in
    - decreased lumen inner diameter
    - increased vascular resistance
    - potential for thrombus or embolus formation

- Associated with:
  - HTN
  - Stroke
  - Angina, Heart Attack
  - Renal Failure
Cardiovascular Disease

- Risk Factors
  - Age
  - Family History
  - Hypertension
  - Hypercholesterolemia
  - Male gender
  - Smoking
  - Diabetes

- Contributing Risk Factors
  - Diet
  - Obesity
  - Oral contraceptives
  - Sedentary living
  - Personality type
  - Psychosocial
EMS System Role

- The original Paramedic idea was based upon the need for rapid response to, identification of, and emergency care for victims of:
  - Sudden Cardiac Death (SCD)
  - Acute Myocardial Infarction (AMI)
- 1963 – Dr. J. Frank Pantridge, Department of Cardiology, Royal Victoria Hospital, Belfast, Northern Ireland.
  - Began using non-physicians for pre-hospital cardiac care.
EMS System Role

- The EMT and Paramedic roles in the treatment of sudden cardiac death has made a difference in survivability.
- Contributions being recognized in acute coronary syndromes with early recognition, treatment, and transport to the appropriate facility.
- The key is a STRONG chain of survival

Operation Heartbeat
EMS System Role

- Survivability based on time to treatment.
Cardiac Anatomy and Physiology
Anatomy Review

- Pulmonary trunk
- Right ventricular outflow track
- Right ventricle
- Anterobasal segment
- Anterior segment
- Apical segment
- Posterobasal segment
- Inferior segment
- Apex of heart
- Left ventricle
Anatomy Review

- Right coronary artery (RCA)
- Left coronary artery (LCA)
- Left circumflex artery (LCX)
- Ramus intermedius
- Left anterior descending art. (LAD)
- Diagonal branch, LAD
- Acute marginal branches, RCA
- Posterior descending artery (PDA)

- Conus arteriosus
- Epicardial fat
- Left atrium
- Right atrium
- Right ventricle
- Left ventricle
- Apex
Anatomy

- **Location**
  - Rests in the mediastinum with 11 cm span on chest x-ray

- **Size**
  - Healthy heart is about the size of a closed fist with approximately a 30° pivot to the left.

- **Shape – acorn shaped**
  - Base - top part
  - Apex - bottom pointed part
Layers of the Heart

- **Layers**
  - Pericardium
    - Parietal
  - Epicardium
    - Visceral
  - Myocardium
  - Endocardium

- **Myocardial muscle:**
  - Highly specialized
  - Striated like skeletal
  - Electrical properties like smooth muscle
Pericardial space contains about 25 mL of serous fluid for lubrication. (By definition: >90 mL constitutes a tamponade.)
Atria - less muscular

- 80% of blood flow from right atrium is passive, remaining 20% provides atrial kick.
- Loss of atrial kick can significantly reduce cardiac output (CO).
  - What cardiac rhythms result in a loss of atrial kick?
Two Pumps

- **Ventricles** - left thicker than right
  - Separated by septum

- **Right side** –
  - Low pressure
  - 1/3 the size of left ventricle
  - Pulmonary circulation

- **Left side** –
  - High pressure
  - Systemic circulation
  - Pumps between 5 – 7 L of blood every minute
Heart Valves

- Prevent backflow
- AV valves
  - Tricuspid
  - Mitral (Bicuspid)
- Semilunar
  - Pulmonic
  - Aortic
- Chordae Tendinae
- Papillary muscles
Heart Valves

- $S_1$ ("lub") or the first heart sound is caused by the closure of the AV valves.

- $S_2$ ("dub") or the second heart sound is caused by the closure of the semilunar valves.
Heart Sounds

- Extra heart sounds include:
  - $S_3$-ventricular gallop (Kentucky). Commonly associated with failure of the left ventricle in CHF.
  - $S_4$-atrial gallop (Tennessee). Can also be associated with LVF or restrictive cardiomyopathy.
Heart Sounds

- Murmurs—caused by turbulent blood flow due to stenosis or regurgitation.
  - Mitral valve regurgitation is most common murmur.
  - Aortic valve stenosis is next most common murmur.
  - Murmurs are graded from 1 – 6
    - 1. Very faint, heard only after listener has "tuned in"; may not be heard in all positions.
    - 2. Quiet, but heard immediately after placing the stethoscope on the chest.
    - 3. Moderately loud with stethoscope on chest.
    - 4. Loud, with palpable thrill (a tremor or vibration felt with palpation)
    - 5. Very loud, with thrill. May be heard when stethoscope is partly off the chest.
    - 6. Very loud, with thrill. May be heard with stethoscope entirely off the chest.
Anatomy

Great Vessels:
- Vena Cava
- Pulmonary Arteries (2)
- Pulmonary Veins (4)
- Aorta
- The Great Vessels are attached to the base of the heart.
Coronary Circulation

- Usually thought of as 3 arteries
  - Left Coronary Artery (LCA)
    - Left circumflex artery (LCX)
    - Left anterior descending artery (LAD)
  - Right Coronary Artery (RCA)
Coronary Circulation

- The LCA bifurcates into the LAD and the LCX.
  - LAD supplies blood to the anterior wall of the left ventricle and the septum.
  - The LCX supplies blood to the lateral and posterior wall of the left ventricle.
- The RCA supplies blood to the right ventricle, the inferior and part of the posterior wall of the left ventricle, the sinoatrial node in 60% of patients and the AV node in >80% of patients.
Coronary Circulation

- **Coronary Sinus**
  - short trunk receiving blood from cardiac veins
  - empties into the right atrium between inferior vena cava and AV orifice

- **Cardiac veins**
  - feed into the coronary sinus
Cardiac Cycle

Diastole

Systole
Cardiac Output

- **Stroke volume x Heart rate**
  - **Stroke volume**
    - Amount of blood ejected with one contraction
    - 60-100 mL (average for the adult is 70 mL)
  - **Heart rate**
    - Measure of the number of beats per minute
    - Average resting heart rate in the adult patient is 70 bpm.
Other factors that influence cardiac output:

- **Contractility**
  - Enhanced by the administration of a positive inotrope.

- **Preload**
  - Volume in ventricle at end of diastole
  - Determined by venous pressure and rate of venous return

- **Afterload**
  - Resistance against which left ventricle must pump
  - Also referred to as end-systolic pressure

- **Frank-Starling’s law**
  - The greater the stretch of the cardiac myofibrils (greater filling of the ventricle), the stronger the contraction.
Vascular System

- Consists of Arteries, Veins, and Capillaries.
  - Largest artery is the Aorta
    - ascending thoracic
    - descending thoracic
    - abdominal
  - Largest veins are the Vena cava
    - superior
    - Inferior
  - Capillary beds is where gas exchange occurs.
Peripheral Vascular System

Major Arteries

- Carotid
- Subclavian
- Innominate
- Axillary
- Aorta
- Brachial
- Iliac
- Radial
- Femoral
- Ulnar
- Dorsal Pedis
- Popliteal
- Posterior Tibial
Peripheral Vascular System

- **Arteries and Veins**
  - Tunica intima
  - Tunica media
  - Tunica externa

- **Flow through a vessel directly proportional to the size of the lumen**
  - atherosclerosis
  - vascular constriction
  - viscosity
Capillaries

- Smooth muscle
- Arteriole
- Precapillary sphincters
- Anastomosis (shunt)
- True capillary with single layer of endothelium
- Metarteriole
- Venule
Peripheral Vascular System

- Blood return to the heart is dependent on:
  - Skeletal muscle pump
    - Muscular contraction squeezes adjacent veins causing a milking action
    - Valves prevent back flow
  - Respiratory Movements
    - Diaphragm contraction exerts pressure in abdomen and decreases pressure in thoracic cavity
    - Blood moves to an area of lower (negative) pressure in thorax
Peripheral Vascular System

- Factors affecting Venous Return
  - Constriction of veins
  - Sympathetic stimulation causes contraction of the smooth muscle walls of veins
    - Venous reservoir. The venous system contains approximately 65% of blood volume at any given time
  - Blood vessel constriction returns 20% or 1 liter of blood to active circulation
- Gravity
Peripheral Vascular System

- Negative Effects on Venous Return
  - Increased intrathoracic pressure
  - PEEP/CPAP/BiPAP
  - Vasodilatation of the inferior vena cava
Peripheral Vascular System

- **Arterial Resistance (afterload)**
  - BP
  - cardiac output $\times$ systemic vascular resistance
    - (stroke volume $\times$ heart rate) $\times$ systemic vascular resistance

- **Systemic vascular resistance**
  - vasoconstriction
    - Sympathetic tone
    - Medications (prescription, non-prescription, recreational)
    - Renin-Angiotensin-Aldosterone mechanisms
  - atherosclerosis
Electrophysiology
Electrical Conduction System

- SA Node
- AV Node
- Interventricular septum
- Right bundle branch
- Purkinje network
- Internodal atrial pathways
- AV Junction
- Bundle of His
- Left bundle branch
- Purkinje fibers
Sinoatrial Node (Sinus Node or SA Node)

- “Normal pacemaker” of the heart
- Located in the wall of the right atrium near the opening of the superior vena cava.
- Fed by the RCA 60% and LCX 40%
Internodal Atrial Pathways

- Bachman’s Bundle
- Anterior, middle, and posterior pathways
- Accessory pathways
Electrical Conduction System

Atrioventricular Junction (AV junction)

- **AV node**
  - “Gatekeeper”
  - Slows conduction to the ventricles allowing time for ventricles to fill
  - May receive impulses as high as 600 bpm, generally will not allow impulses more than 180 bpm to reach ventricles
- Bundle of His
Electrical Conduction System

His-Purkinje System

- Bundle Branches
  - Right bundle branch
  - Left bundle branch
    - left anterior fascicle
    - left posterior fascicle
Figure 1-15: Left anterior fascicle (LAF).

Figure 1-16: Left posterior fascicle (LPF).
Electrical Conduction System

Properties of myocardial cells

- **Automaticity**: cells can depolarize without any impulse from outside source (self-excitation)
- **Excitability**: cells can respond to an electrical stimulus
- **Conductivity**: cells can propagate the electrical impulse from cell to another
- **Contractility**: the specialized ability of the cardiac muscle cells to contract
- **Irritability**: cells can become irritable due to the lack of oxygenated blood and become source of ectopic foci
- **Elasticity**: cells stretch and can increase force of contraction
- **Rhythmicity**: pacemakers tend to fire with a rhythm at their intrinsic rate
- **Refractoriness**: cells may not be able to depolarize if the resting membrane potential has not been restored
Electrical Conduction System

Myocardial Cells

- Three groups of cardiac muscle
  - Atrial
  - Ventricular
  - Excitatory/Conductive Fibers
- Atria contract from superior to inferior
- Ventricles contract from inferior to superior
- Atria and ventricles are separated
- Conduction from atria to the ventricles only through AV bundle
- "All or None" principle of muscle contraction
Electrophysiology

Electrolytes

- Allow for electrical and mechanical function of heart
  - **Sodium**: major extracellular cation, role in depolarization
  - **Potassium**: major intracellular cation, role in repolarization
  - **Calcium**: intracellular cation, role in depolarization and myocardial contraction
  - **Chloride**: extracellular anion
  - **Magnesium**: intracellular cation
Electrophysiology

Depolarization

- Reversal of charges at the cell membrane (opposite charge from resting state)

- Resting Potential
  - more extracellular negatively charged anions than intracellular
  - approximately $-90\,\text{mV}$ in myocardial cell

- Action Potential
  - stimulus to myocardial cell allows sodium to enter cell changing to positive intracellular charge
  - approximately $+20\,\text{mV}$ in myocardial cell
  - slow influx of Calcium follows
Electrophysiology

Fast-Response Action Potential (e.g., ventricular myocyte)

mV

0

-50

1

2

3

4

ERP

\( \text{Na}^+ \text{in} \)

\( \text{K}^+ \text{out} \)

\( \text{Ca}^{++} \text{in} \)

Membrane potential (mV)

50

0

-60

-100

Threshold

P0

P2

P3

P4

Inward Na\(^+\) channels

Inward Ca\(^{++}\) channels

Outward K\(^+\) channels

Lidocaine (lignocaine)

Flecainide

Quinidine

β-Blockers

Amiodarone

Sotalol
Electrophysiology

- **Depolarization**
  - Complete depolarization would normally result in muscle contraction

- **Threshold**
  - The minimal stimulus required to produce excitation of myocardial cells
Electrophysiology

Repolarization

- Process of returning to resting potential state
  - Sodium influx stops and potassium leaves cell
  - Sodium pumped to outside the cell

- Relative refractory period
  - Cell will respond to a second action potential but the action potential must be stronger than usual

- Absolute refractory period
  - Cell will not respond to a repeated action potential regardless of how strong it is
Myocardial cells are POLARIZED. They have more positive charges outside than inside.
Stimulation of cell opens “fast” channels in cell membrane. Na⁺ rapidly enters cell. Now there are more positive charges inside than outside. The cell is **DEPOLARIZED**.
Electrophysiology

- Depolarization causes $\text{Ca}^{++}$ to be released from the cisternae of the sarcoplasmic reticulum in the cell.
- $\text{Ca}^{++}$ release catalyzes a chemical reaction that promotes the sliding of the actin and myosin filaments or muscle contraction.

**Calcium couples the electrical event of depolarization to the mechanical event of contraction.**
Electrophysiology

- The thin actin filaments are made up of two chains of proteins, called tropomyosin and troponin.
- Troponin has a high affinity for calcium ions. As the Ca\(^{++}\) binds to the troponin, the shape of the troponin-tropomyosin complex changes to expose the active sites on the actin filaments.
Cell then REPOLARIZES by pumping out K+ then Na+ to restore normal charge balance.
Finally, the Na\(^+\)-K\(^+\) pump in the cell membrane restores the proper balance of sodium and potassium.
Phase 0 = rapid Na influx
Phase 1 = stop Na influx, K efflux, Cl influx
Phase 2 = Ca influx, K influx
Phase 3 = stop Ca influx, minimal K efflux, Na efflux
Phase 4 = resting membrane potential state

Sarcomere: Fast Sodium Channels
Electrophysiology

Pacemaker sites of the heart and the intrinsic firing rates

- Specialized groups of cells called pacemaker sites
- SA Node -- 60 to 100 bpm
- AV Junction -- 40 to 60 bpm
- Ventricles -- 15 to 40 bpm
Specialized cells in conducting system (pacemaker cells) undergo spontaneous diastolic depolarization. During diastole, calcium leaks into the cell through slow calcium channels.
When a critical amount of calcium has entered the cell, fast channels open, sodium enters, and rapid DEPOLARIZATION begins.
Electrophysiology

- Electrical impulse from depolarizing pacemaker cell spreads to working myocardial cells and stimulates them.
- Depolarization and contraction result.
Electrophysiology

- Communication between myocardial cells allows for contraction to occur.
- Syncytium
Electrophysiology

Ectopic Impulse Formation

- Enhanced Automaticity
  - Pacemaker cells
    - lost function of contractility
    - acquired function of impulse formation
  - May lead to ectopic beats
- Picture to the right shows the Bundle of Kent, an accessory pathway found in WPW.
Electrophysiology

Ectopic Impulse Formation

- Reentry
  - abnormal waveform propagation
  - “electrical loop”
  - accessory pathway
The autonomic nervous system is mainly activated by centers located in the spinal cord, brain stem, and hypothalamus.

Medulla contains the cardioacceleratory and cardioinhibitory centers.

Baroreceptor reflex controls arterial pressure.
Effects of ANS on Electrophysiology

- **Parasympathetic Nervous System**
  - Acetylcholine
    - Activates muscarinic and nicotinic receptors
  - Cholinesterase

- **Sympathetic Nervous System**
  - Adrenergic receptors stimulated by epinephrine and norepinephrine
    - Alpha₁ and alpha₂ receptors
    - Beta₁ and beta₂ receptors
      - Inotropic effect
      - Dromotropic effect
      - Chronotropic effect
Electrophysiology: Results of Depolarization & Repolarization

Atrial Depolarization

Ventricular Depolarization

Ventricular Repolarization
Questions?