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Anatomy and Electrophysiology of the Heart

Fast & Easy ECGs – A Self-Paced Learning Program
Electrocardiogram

• Graphic representation of heart’s electrical activity
  – often referred to as an ECG or EKG
ECG Machine

- Detects heart’s electrical current activity
  - Displays it on a screen or prints it onto graph paper
ECG Machine

- Identifies irregularities in heart rhythm
- Reveals injury, death or other physical changes in heart muscle
- Used as an assessment and diagnostic tool
- Can continuously monitor heart’s electrical activity
What the ECG Won’t Do

• Does not tell how well heart is pumping
  – Patient must be properly assessed to ensure heart is functioning mechanically
The Heart

• The pump of the circulatory system
  – Contraction pushes blood throughout the body to deliver needed oxygen and nutrients to tissues and remove waste products
  – Depending on body’s requirements, heart rate can either be increased or decreased
The Heart

- Shaped like an inverted blunt cone
  - Base is the larger, flat part
  - Apex is the inferior end which tapers to a blunt, rounded point
The Heart

- Located between the two lungs in mediastinum behind the sternum
The Heart

• Anterior-posterior orientation in the chest
  – RV closer to front of left chest
  – LV closer to side of left chest
The Heart

- Surrounded by pericardial sac (a double-walled closed sac)
  - fibrous pericardium
  - serous pericardium
Heart Wall

• Made up of three layers
  – Epicardium (outermost)
  – Myocardium (middle)
  – Endocardium (innermost)
Heart Cells

- **Myocardial cells (working cells)**
  - Contract to propel blood out of heart’s chambers
- **Electrical conduction system cells**
  - Initiate and carry impulses throughout heart
Myocardial Cells

• Cylindrical and branching at their ends
  - Intercalated disks and gap junctions allow rapid movement of electrical impulses from one cell to another
  - Desmosomes hold cells together when heart muscle contracts
Working Cells

- **Myocytes**
  - Enclosed in sarcolemma
  - Composed of two protein filaments
    - Actin (thin)
    - Myosin (thick)
Internal Heart

• Heart consists of four chambers
  – 2 atria collect blood and deliver to ventricles
  – 2 ventricles pump blood to pulmonary and systemic circulation
• Septum separates heart into two functional units
Heart Valves

- Permit blood to flow through heart in only one direction
  - Mitral and bicuspid valves (AV valves) located between atria and ventricles
  - Aortic and pulmonic valves (semilunar valves) located at base of aorta and pulmonary artery
Skeleton of Heart

- Forms fibrous rings around AV and semilunar valves
- Provides firm support for valves and separates atria from ventricles
Cardiac Muscles

- Attached to fibrous connective tissue
- Contract ventricles in a wringing motion
Coronary Arteries

• Provide heart with most of its blood supply
• Originate from base of ascending aorta
  – Immediately above leaflets or cusps of aortic valve
Blood Flow

- **Pulmonary circulation**
  - Pulmonary arteries carry deoxygenated blood to lungs
  - Pulmonary veins carry oxygenated blood back to heart
- **Systemic circulation**
  - Arteries carry oxygenated blood
  - Veins carry deoxygenated blood
Cardiac Cycle

• **Diastole**
  - Relaxation and filling of atria and ventricles
Cardiac Cycle

• Systole
  – Contraction of atria and ventricles
Cardiac Output

• Amount of blood pumped from the heart in one minute
  – Expressed in LPM
Blood Pressure

• The force that blood exerts against walls of arteries as it passes through them
• Equals cardiac output times peripheral vascular resistance

CO \times PVR = BP
Influences on Heart

- Receptors in blood vessels, kidneys, brain, and heart constantly monitor changes
  - **Baroreceptors** identify changes in pressure
  - **Chemoreceptors** sense changes in chemical composition of blood
Baroreceptors and Chemoreceptors
Autonomic Nervous System

• Helps regulate rate and strength of myocardial contractions
  – Divided into sympathetic and parasympathetic nervous systems
Autonomic Nervous System
Sympathetic Stimulation

Sympathetic system
Activates beta receptors

Cardioaccelerator effects
- Rate of pacemaker firing
- Speed of impulse conduction through heart
- Force of contraction
- Coronary vasodilation
Parasympathetic Stimulation

Cardioinhibitor effects
- Rate of SA node pacing
- Speed of AV conduction

Parasympathetic system
Activates cholinergic receptors

Stimulates

Vagus nerve

Inhibits
Key Properties of Myocardial Cells

• **Automaticity**
  – Can produce electrical activity without outside nerve stimulation

• **Excitability**
  – Ability to respond to an electrical stimulus

• **Conductivity**
  – Ability to transmit an electrical stimulus from cell to cell throughout myocardium

• **Contractility**
  – Ability of myocardial cell to contract when stimulated by an electrical impulse
Heart’s Conduction System

• Grouping of specialized tissues that carry wave of depolarization throughout heart
Pacemaker Sites

- SA node is primary pacemaker site of heart
- Other cardiac cells lower in conduction pathway play a back-up role
Polarized State

- Inside of myocardial cells more negatively charged in relationship to outside where it is more positively charged
Depolarization

- Occurs when positively charged ions move inside cells causing interior to become positively charged
  - Change in electrical charge over time referred to as cell’s action potential
Repolarization

- Follows depolarization and occurs when:
  - Potassium leaves cell causing positive charge to lower
  - Sodium and calcium are removed by special transport systems
Refractory Period

• Absolute refractory period
  – No stimulus no matter how strong will depolarize cell
• Refractory period
  – A sufficiently strong stimulus will depolarize myocardium
Putting it All Together

- Cardiac cycle begins with RA and LA receiving blood from systemic and pulmonary circulations
  - Rising pressure within atria forces tricuspid and mitral valves open
Putting it All Together

• Heartbeat initiated by an electrical impulse that arises from SA node
• Impulse travels through atria
  – generates a positive waveform on ECG and contraction of atria
Putting it All Together

- Impulse slows as it passes through AV node from atria to ventricles
  - Allows atria time to finish filling ventricles
Putting it All Together

- Impulse then rapidly travels through His-Purkinje system
  - Seen as a flat line following P wave
Putting it All Together

• Depolarization of septum and ventricular walls generates QRS complex and contraction of ventricles
Putting it All Together

• Repolarization of ventricles is represented on ECG by ST segment and T wave
Summary

- Electrocardiogram detects electrical activity occurring in heart.
- Nerve impulses stimulate cardiac muscles to contract.
- Heart consists of two upper chambers, the atria and two lower chambers, the ventricles.
- Heart is separated into right and left sides by the septum.
- Coronary arteries perfuse myocardium during diastole.
Summary

• Cardiac output is amount of blood pumped through circulatory system in one minute.

• Rate and strength of myocardial contractions can be influenced by autonomic nervous system.
  – Two divisions are the sympathetic and parasympathetic nervous systems.
Summary

• Sodium, calcium and potassium are key electrolytes responsible for initiating electrical charges.

• Depolarization of cells occurs when positive electrolytes move from outside to inside cell causing it to become more positively charged.

• Depolarization of myocardial cells causes calcium to be released and come into close proximity with actin and myosin filaments of muscle fibers leading to myocardial contraction.
Summary

- Myocardial depolarization progresses from atria to ventricles in an orderly fashion.
  - Electrical stimulus causes heart muscle to contract.

- Electrical impulse that initiates heartbeat arises from SA node.

- From there it travels through atria generating a positive waveform on ECG and contraction of atria.

- Impulse is slowed as it passes from atria to ventricles through AV node.
Summary

• On ECG impulse traveling through His-Purkinje system is seen as a flat line following the P wave.

• QRS complex is generated and ventricles contract as a result of electrical impulse stimulating ventricles.

• ST segment and T wave represents repolarization of ventricles.
  – Atrial repolarization occurs but is hidden by QRS complex.

• Other sites in heart can assume control by discharging impulses faster than SA node or stepping in when SA node fails.