Cardiovascular Physiology

Gems of Wisdom

Objectives

- Review the basic anatomy and physiology of the cardiovascular system.
- Describe the electrical and mechanical events involved in the cardiac cycle.

Objectives

- Discuss the factors that alter or impact the electrical and mechanical events of the cardiac cycle.
- Explain the physiology of circulation and perfusion, including the following components:
  - Cardiac output
  - Blood pressure
  - Feedback loops
  - Capillary sphincters

Cardiovascular System Review

Anatomy Review

- Right atrium
  - Incoming blood supply
- Tricuspid valve
  - Chordae tendineae and papillary muscles
- Right Ventricle
  - Pulmonary artery

Review of Cardiovascular Anatomy and Physiology: The Heart
Anatomy Review

- Left atrium
  - Receives supply from the pulmonary vein
- Left ventricle
- Bicuspid valve
  - Also known as the mitral valve
- Aorta

Anatomy Review

- Heart wall
  - Endocardium
  - Myocardium
  - Epicardium
    - Splits into another outside layer – the pericardium

The Pericardium

- Fixates the heart to the thoracic cavity
- Relatively inflexible tissue
- Holds 30-50mL of serous fluid between the pericardium and epicardium
- Pericardial sac
  - Prevents friction during contraction

Coronary Artery Supplies

- Right C.A.
  - Right atrium and ventricle
  - Inferior portion of the left ventricle
  - Interventricular septum
  - Conduction system

- Left C.A.
  - Left atrium
  - Nearly all of the left ventricle
  - AV node in half of the population
Review of Cardiovascular Physiology

Physiology of the Heart
Electrical components
Electrophysiology
The Cardiac Cycle
Mechanical Events of the Cardiac Cycle
Influences of Electrical and Mechanical Heart Function

Electrical Conduction System

Cardiac Cell Types
- Electrical cells
  - Generate and conduct impulses rapidly
  - SA and AV nodes
  - Nodal pathways
  - Interventricular septum
  - No contractile properties
- Muscle (myocardial) cells
  - Main function is contraction
  - Atrial muscle
  - Ventricular muscle
  - Able to conduct electrical impulses
  - May generate its own impulses with certain types of stimuli

Unique Properties of Cardiac Cells
- Automaticity
  - SA and AV nodes
- Excitability
  - All cells
  - Points of stimulation
    - Nervous system
    - Physical cell damage
    - Ischemia
    - Electrolytes
- Conductivity
  - All cells
  - Points of stimulation
    - Nervous system
    - Electrolytes
  - Slowing of conductivity
    - Ischemia
  - Calcification of nodal pathways
- Contraction
  - Muscle cells

Electrophysiology of the Heart
Review of nerve transmission

- Path of travel
  Stimulation of the nerve
  Travel of stimulus down the axon
- "Wave effect" of stimulus down the axon is caused by the rapid movement of ions across the cell membrane of the axon
  Impulse moves across synapse to another nerve or to a target organ

Nerve impulse Terminology

- Resting state
  The relative electrical charges found on each side of the membrane at rest
  - Net positive charge on the outside
  - Net negative charge on the inside
- Action Potential
  Change in the electrical charge caused by stimulation of a neuron

Action Potential Terminology

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Action Potential Terms

- Depolarization
  The sudden reversal of electrical charges across the neuron membrane, causing the transmission of an impulse
  - Minimum voltage must be met in order to do this
- Repolarization
  Return of electrical charges to their original resting state

Action Potential - Resting State

- Sodium stays outside of the cell
  The pores in the membrane are too small for them to pass through
- Potassium mostly stays inside
- Massively negative charges never leave the cell

Action Potential - Depolarization

- The stimulus hits the cell
- Sodium channels open up and sodium pours in
- The charges reverse
  - Positive inside
  - Negative outside

Action Potential - Repolarization

- Sodium channels close
- Potassium channels open
  - Potassium pours out
  - Allows for a quick return to a resting state
- Sodium is kicked out of the cell
  - Active transport
  - Sodium-potassium pump
The Action Potential in Skeletal Muscle

- The electrical events occurring at the cell will always preclude the actual muscle contraction.
- The action potential is quick to allow for a faster contraction of the muscle.

The Action Potential in Cardiac Muscle: Step 1

- The conduction cells stimulate the myocardial cells.
- Similar events of depolarization:
  - Sodium dumps inward
  - Potassium rushes out
  - Sharp spike of the initial action potential.

The Action Potential in Cardiac Muscle: Step 2

- The sodium channels close.
- Calcium channels open slowly:
  - Calcium trickles into the cell, allowing for a stronger contraction.
  - Allows all of the ventricular cells to contract together.
- Potassium movement is minimal.

The Action Potential in Cardiac Muscle: Step 3

- The calcium channels close up.
- Potassium channels widen:
  - Rush of potassium back into the cell.
  - Slower return to a complete resting state.
  - Allows for contraction to finish and to get the ventricular chambers to start filling with blood.

Action Potential Term: Refractory Period

- Absolute:
  - A period of time where the action potential is resistant to any additional stimuli.
  - Steps 1, 2 and the early part of step 3.
- Relative:
  - A period of time where the action potential moderately resists a stimulus.
  - Highlighted area.

Electrical and Mechanical Connections:

- Peak of ventricular contraction.
Mechanical Function of the Heart

The Cardiac Cycle

- 2 components
  - Diastole
    - Filling of the chamber
  - Systole
    - Contraction of the chamber and ejection of blood

Cardiac Output

- The amount of blood ejected from the ventricle in one minute
- Elements of cardiac output
  - Stroke volume
    - Amount of blood ejected from the ventricle in one contraction
  - Heart rate
    - The # of cardiac cycles in one minute

Calculating Cardiac Output

- Cardiac Output (CO) = Stroke Volume (SV) x Heart Rate (HR)

Determination of Stroke Volume

- Preload
  - Amount of blood delivered to the chamber
  - Depend upon venous return to the heart
  - Also dependent upon the amount of blood delivered to the ventricle by the atrium
- Contractility
  - The efficiency and strength of contraction
  - Frank Starling’s Law
- Afterload
  - Resistance to forward blood flow by the vessel walls

Another way to look at cardiac output

Factors Affecting the Cardiac Cycle
Cardiac Feedback Loops

- Master controller: the medulla
  - Incoming input
    - Chemoreceptors
      - Sense changes in pH, PaCO₂, and PaO₂
    - Baroreceptors
      - Sense changes in arterial pressure
  - Response of the medulla
    - Stimulate the autonomic nervous system

Autonomic Nervous System

- Sympathetic Nervous System
  - Extensively innervates the SA node and ventricular cells
  - Increase in heart rate
  - Increase in conduction and contractility in the ventricles
- Parasympathetic Nervous System
  - Innervates the SA and AV nodes
  - Decreases heart rate
  - Decreases conduction times through the AV node

Chemical Factors

- Hormones
  - Epinephrine
    - Stimulation of beta receptors in the myocardium
    - Increase in contractility of the ventricles
    - Increase in conduction throughout the ventricles

- Electrolyte Concentrations
  - Calcium
    - Impacts the strength of contractions
    - High calcium may cause irritability of electrical cells

Chemical Factors

- Potassium
  - Impacts the rates of firing and recovery of the cardiac cells
  - High potassium
    - Irregular firing of cardiac cells
    - Dysrhythmias and ventricular fibrillation potentials
  - Low potassium
    - Longer delays in the firing of cardiac cells
    - May be caused by diuretic use
    - Bradycardia
    - Hypotension (systemic complication)
    - Poor cardiac output results

The pieces will fit together soon....