Cardiovascular Physiology

Objectives

- List the components of the conduction system of the heart
- Explain the different components of a normal ECG
- Define the term "cardiac cycle"
- Describe the events of each of the phases of the cardiac cycle
- Relate the phases of the cardiac cycle with the action of the conduction system that causes the events of the cardiac cycle
- Define auscultation and describe what causes the heart sounds
- Correlate the parts of the ECG, the sounds heard during auscultation, and the phases of the cardiac cycle
- Define the components of blood pressure
- Describe how blood pressure is measured, and how the measurement technique relates to the sounds that are heard during the measurement
- Explain what causes a pulse, and identify the common anatomical locations for measuring a pulse
- Describe how the components of the baroreceptor reflex regulate the heart's pace and rhythm

Cardiac Conduction System

(Section 19.2.2: Conduction System of the Heart)

(Figure 19.18: Conduction System of the Heart)

(Figure 19.19: Cardiac Conduction)

The heart beats originate within the heart itself.
How the CCS works:

- initiates the signal for contraction
- provides a pathway for conducting the signal to all cardiac muscle fibers

1. initiates the signal for contraction

- **Polarization**: allows for the initiation of an electrical impulse across the cell membrane, polarization is a state in which there is a charge difference across a membrane
- **polarized** – the outside of the cell has more positive ions than does the inside
- **depolarized** – a change in the charge across the cell membrane, the inside of the cell is temporarily more positive than the outside

- SA Node Action Potential
  - Depolarization
    - Na^+ first enters slowly (i_f)
    - Ca^{2+} enters next
  - Repolarization

- K^+ leaves

2. provides a pathway for conducting the signal to all cardiac muscle fibers
- sinoatrial (SA) node
  - aka = the pacemaker
  - located in the wall of the right atrium just below the superior vena cava
  - initiates the electrical impulse in the heart
  - causes the atria to contract
- atrioventricular (AV) node
  - located in the lower interatrial septum
  - receives the electrical impulse from the atria muscle fibers
  - causes a 0.1 second delay
  - allows atria to contract prior to ventricular firing
- AV bundle (bundle of HIS)
  - located in a septum between the atria and ventricles
  - the electrical connection between the atria and ventricles
  - receives signals from the AV node
  - sends signals to the bundle branches
- bundle branches
  - located in the interventricular septum
  - sends signals to the Purkinje fibers
  - right and left bundle branches
- Purkinje fibers
  - located in the apex of the myocardium and the lateral walls of the right and left ventricles
  - sends signals to the ventricular cardiac muscle *starting from the apex and spreading upward*
  - ventricles contract

Electrocardiography

During each cardiac cycle, a sequence of electrical impulses from pacemaker cells and nerves causes the heart muscle to produce electrical currents that result in contraction of heart chambers
These impulses can be detected at the body surface with electrodes
A recording of the impulses is called an *Electrocardiogram* (ECG). It's also called an EKG because it was named in Germany, where cardiogram is spelled with a "K"

ECG Components

(Section 19.2.3: Electrocardiogram)

(Figure 19.23: Electrocardiogram)

(Figure 19.24: ECG Tracing Correlated to the Cardiac Cycle)

- P wave
  - First Event
  - Represents atrial depolarization

    - Arises from SA node just before atrial contraction
- P-R Segment
    - Represents the time for an impulse to travel from the AV node to the ventricles
- P-R Interval (AKA P-Q Interval)
    - Occurs between the start of the P wave and the start of the QRS Complex
    - Equals P-wave + P-R Segment
    - It represents the time required for an impulse to travel from the SA node to the ventricular muscle
- QRS Complex
    - Ventricular depolarization
    - Atrial repolarization occurs at this time, but the electrical event is masked by the QRS complex
- S-T Segment
    - Measures the delay between ventricular depolarization and repolarization
- T wave
    - Represents ventricular repolarization
    - just before the ventricles relax
- Q-T Interval
    - The cycle of ventricular depolarization and repolarization

ECGs can detect abnormalities

- *Tachycardia*: heart rate above 100 beats/min
- *Bradycardia*: heart rate below 60 beats/min
- *Fibrillation*: prolonged tachycardia; rapid uncoordinated contraction; no blood is pumped

The Cardiac Cycle

(Section 19.3: Cardiac Cycle)

(Section 19.3.1: Pressures and Flow)

(Figure 19.27: Overview of the Cardiac Cycle)

One complete heart cycle is called a **cardiac cycle**, lasts about 0.8 sec and is commonly called a heart beat
It is marked by changes in blood pressure and volume in the heart
During the cycle, each atrium and ventricle contract once and relax once
The contraction phase - *Systole*
The relaxation phase - *Diastole*
The human heart averages 75 cardiac cycles/minute

Phases of the Cardiac Cycle

(Section 19.3.2: Phases of the Cardiac Cycle)

(Figure 19.27: Overview of the Cardiac Cycle)

(Figure 19.28: Relationship between the Cardiac Cycle and ECG)

A cycle begins with Atrial Systole - 0.1s
Fills relaxed ventricles (30% of ventricular blood volume enters as a result of atrial systole)
Next, Ventricular Systole - 0.3s
Pump blood out of heart
Last, Atrial/Ventricular Diastole - 0.4s
Most blood (70%) enters the ventricles during this resting period
Decreases time spent in this phase as heart rate increases

Listening to Heart Sounds

(Section 19.3.3: Heart Sounds)

(Figure 19.29: Heart Sounds and the Cardiac Cycle)

(Figure 19.30: Stethoscope Placement for Auscultation)

- Called **auscultation**
- A stethoscope amplifies the sounds to an audible level
- Auscultation of the heart is used to diagnose and evaluate valve function
- Four sounds are produced by the heart during a cardiac cycle

The first two sounds are easily heard and are called S_1 and S_2 (also known as *Lubb* and *Dupp*)

- **S_1** (Lubb) - caused by closure of the AV valves as ventricles begin to contract
- **S_2** (Dupp) - occurs as the SL valves close at the beginning of ventricular diastole
- For a demonstration of the sounds, as well as the location for auscultating each of the heart's valves, visit: https://en.wikipedia.org/wiki/Heart_sounds

The third (S_3) and fourth (S_4) sounds are difficult to hear

- **S_3** – "SLOSHing in" (S1-S2-S3): Too much fluid volume results in blood oscillating between the walls of the ventricles when blood rushes in from the atria; normal in people younger than 40; Otherwise, due to acute heart failure
- **S_4** – "a STIFF wall" (S4-S1-S2): Ventricular hypertrophy; Makes sound during atrial contraction due to higher pressure; can be found in healthy children and athletes; Otherwise, due to long-standing hypertension or heart attack

Abnormal heart sounds are **murmurs** and usually mean there is a problem with the valves. Often, a "swishing" sound is heard because of regurgitation of blood or a high pitched screeching because of constricted valves

- For a sample of all the possible murmurs, and what they sound like, visit: http://www.easyauscultation.com/heart-murmur-sounds

Blood Pressure

(Section 20.2.1.1: Components of Arterial Blood Pressure, Systolic and Diastolic Pressures)

(Section 20.2.3: Measurement of Blood Pressure)

(Figure 20.12: Blood Pressure Measurement)

BP is a measure of the force the blood exerts on the walls of the systemic arteries

- *Systolic Pressure* - LV contracts and pumps blood into the Aorta thereby increasing arterial pressure
- *Diastolic Pressure* - LV relaxes, less blood flows into Aorta, arterial pressure decreases

Average Blood Pressure is 120/80 (male), 110/70 (female)

Arterial blood pressure is affected most importantly by:

1. **Cardiac Output** (CO ml/min): the volume of blood discharged from the left ventricle into the aorta each minute at rest
    a. Know this equation:
    b. CO (Cardiac Output ml/min) = HR (heart beats/min) x (SV) (stroke volume ml)
    c. Stroke volume is the amt of blood pushed from the L ventricle in a single contraction. CO is approx. 5L/min
2. **Blood Volume** (BV): the body's total volume of blood (typically 5-6 L in an adult)
3. **Peripheral Resistance**: the friction caused by blood flow against the vessels walls. Dependent on hormone levels, activity levels, weight, age, and kidney function.

Systolic Pressure: Korotkoff sound first heard, begins to grow louder then softer until…
Diastolic Pressure: absence of Korotkoff sounds
A **sphygmomanometer** is inflated to block blood flow in the brachial artery

- Upon gradually venting the pressure, the blood pressure will exceed the pressure of the cuff
- Blood will spurt through the artery back into the forearm and the turbulent flow produces a *pulsatile sound* - **Korotkoff's sounds**. The pressure at which this pulse-like sound is first heard is recorded as the systolic pressure.
- The pressure at which the Korotkoff's sounds first become inaudible is the diastolic pressure. This is because the artery is no longer compressed and the cuff pressure is equal to the arterial pressure.

Problems with blood pressure

Hypertension

- chronic resting BP > 140/90
- can weaken small arteries and cause aneurysms

Hypotension

- chronic low resting BP
- causes: blood loss, dehydration, anemia

Measuring the Pulse

(Section 20.2.2: Pulse) *(Figure 20.11: Pulse Sites)*

Heart rate is determined by measuring the *Pulse* or *pressure wave* in an artery Ventricular Systole - blood pressure increases and stretches the walls of arteries Ventricular Diastole - blood pressure decreases and arterial walls rebound
The change in vessel diameter is felt as a throb or pulse at various pressure points on the body
Most common places to feel a person's pulse are the carotid artery and the radial artery. DO NOT push on carotids simultaneously- they supply blood to your brain.

Baroreceptor Reflex

(Section 20.4.1.1: Baroreceptor Reflexes)

(Figure 20.18: Baroreceptor Reflexes for Maintaining Vascular Homeostasis)

Baroreceptors in the carotid sinus and arch of the aorta respond to an increase in blood pressure.
Increased blood pressure stretches carotid arteries and aorta Baroreceptors
increase action potential generation
Action potentials are conducted to medulla oblongata (by way of glossopharyngeal and vagus nerves)
Parasympathetic stimulation to the heart increases, therefore decreasing heart rate. Decreased sympathetic stimulation to the heart decreases heart rate and stroke volume Decreased sympathetic stimulation to the blood vessels causes vasodilation Vasodilation, as well as a decreased heart rate and stroke volume, work together to bring elevated blood pressure back to normal.

Lab 4: Blood Pressure and Pulse

Activities

Measurement of Pulse Rate in Beats per Minute (BPM)
Measurement of Arterial Blood Pressure
Effects of Various Stimuli on Blood Pressure and Heart Rate (below)

Learning Objectives

- To define the following
    - Systole
    - Diastole
    - Cardiac cycle
- To use a stethoscope to auscultate heart sounds, and to relate heart sounds to events in the cardiac cycle
- To determine a subject's apical and radial pulses
- To accurately determine a subject's blood pressure with a sphygmomanometer, and to relate systolic and diastolic pressures to events of the cardiac cycle
- To investigate the effects of exercise on blood pressure, pulse and cardiovascular fitness

Effects of Various Stimuli on Blood Pressure and Heart Rate

Activity 1 – Effect of position on BP and heart rate (measured as pulse)

Activity 2 - Effects of exercise on BP and heart rate (measured as pulse)

Activity 3 – Effect of a cold stimulus on HR and BP