

TOPIC 15: CARDIOVASCULAR SYSTEM: CARDIAC CYCLE & CONTROL

(All cd references refer to Interactive Physiology cd, Cardiovascular menu)

I. Mechanical Events in the Cardiac Cycle (Figs 13.18 to 13.21; cd cardiac cycle 5 to 17)

- A. Introduction**
 - 1. **Systole:** Contraction and emptying of the chambers
 - 2. **Diastole:** Relaxation and filling of the chambers
 - 3. Atria and Ventricles go through *separate* cycle of systole and diastole
- B. TP interval: Ventricular diastole**
 - 1. Atria and ventricles are in diastole (i.e., relaxed).
 - 2. Blood flows from veins into atria
 - 3. Atrial pressure > ventricular pressure = AV valve open
 - 4. Blood flows from atria directly into ventricles.
- C. P wave and PQ interval: Late ventricular diastole**
 - 1. SA node reaches threshold and fires.
 - 2. Atrial depolarization occurs.
 - 3. Atria contract = atrial systole
 - 4. Atrial Pressure > Ventricular Pressure = AV valves open.
 - 5. Blood squeezed by atrial contraction from atria into ventricles.
- D. QR Interval: End of ventricular diastole**
 - 1. Atrial Pressure > Ventricular Pressure = AV valves open.
 - 2. Blood squeezed from atria into ventricles.
 - 3. Electrical impulse enters ventricles from the AV node.
 - 4. Ventricles begin to depolarize.
 - 5. R peak is end of ventricular diastole and start of ventricular systole.
- E. RS interval: Early ventricular systole**
 - 1. Ventricles begin to contract.
 - 2. Atrial Pressure < Ventricle Pressure = AV valves close
 - 3. Atrial contraction and ventricular filling are completed.
 - 4. Ventricular pressure still not high enough to open aortic valve
 - 5. Volume of blood in ventricles is called end-diastolic volume (EDV) which \approx 135 ml/ventricle
 - 6. Atria repolarize.
- F. ST segment: Ventricular systole**
 - 1. Ventricular pressure > aortic pressure = aortic valve opens
 - 2. Blood ejected into aorta from ventricles.
 - 3. Atria in diastole and filling with blood.
- G. Start of T wave: Late ventricular systole.**
 - 1. Repolarization of the ventricles begins.
- H. T wave peak and start of TP interval: Early ventricular diastole.**
 - 1. Peak of T wave = end of systole and start of diastole.
 - 2. Ventricles begin to relax
 - 3. Ventricular pressure < aortic pressure = aortic valve closes.
 - 4. No more blood can leave ventricles.

5. The remaining volume of blood is called the **End-Systolic Volume (ESV)**. Typically, about half of the end diastolic volume remains in the ventricles (about 65 ml/ventricle).
 6. Atria in diastole and filling with blood.
 - I. **The stroke volume (SV) is equal to $EDV - ESV$** = volume of blood pumped by one ventricle per heart beat. This averages 70 ml/beat when at rest.
 - J. Normal high heart rate (e.g., during exercise)
 1. Much of ventricular filling occurs early in ventricular diastole.
 2. During times of rapid heart rate, length of ventricular diastole is reduced much more than length of systole.
 3. However, because most of ventricular filling takes place in early diastole, filling is not seriously impaired during rapid heart rate.
 - K. Sounds
 1. Classic heart sound description: lub-dub.
 - a) first sound is turbulent rushing of blood as AV valves close
 - b) second sound is turbulent rushing of blood as aortic and pulmonary valves close.
- II. Cardiac Output and its Control (cd cardiac output 3 to 8)
- A. Cardiac output
 1. Cardiac Output (CO) is volume of blood pumped by each ventricle/minute (**not** volume of blood pumped by whole heart)
 2. cardiac output (CO) = heart rate (HR) multiplied by stroke volume (SV)
 3. ***Control of cardiac output is accomplished by controlling heart rate and stroke volume!!!!***
 4. At rest for average individual
 - a) HR = 70 beats/min
 - b) SV = 70 ml/beat (see above)
 - c) CO = 70 beats/min x 70 ml/beat = 4900 ml/min
 - d) Because total blood volume in a person is 5 to 5.5 liters, each ½ of the heart pumps nearly the whole blood volume each minute at rest
 - B. Control of ***Heart Rate*** (Fig 13.23)
 1. Review: SA node sets baseline heart rate at ~ 70 beats per minute
 2. Parasympathetic can modify baseline rate.
 - a) Vagus nerve is primary parasympathetic nerve to heart, supplies the atrium, especially the SA and AV nodes, but has little effect on ventricles
 - b) Decreases heart rate by:
 - (1) decreasing rate of depolarization in SA node
 - (2) increasing AV node delay
 3. Sympathetic can modify baseline rate.
 - a) Sympathetic cardiac nerves supply the atria, including the SA and AV nodes, and also the ventricles
 - b) Increases heart rate by
 - (1) increasing rate of depolarization in SA node
 - (2) reducing AV node delay

- (3) speeding up spread of AP through Bundles of His and Purkinje fibers

C. Control of *Stroke Volume*

1. Varying length of heart muscle fibers
 - a) longer the fiber at start of contraction, the stronger the contraction
 - b) more blood that is in chamber, the longer the fiber (i.e. they are stretched) so the stronger the contraction
 - c) **Bottom line:** when venous return of blood to heart is increased (by many factors to be discussed later) the blood volume in heart is increased, which increases fiber length, which increases strength of contraction, which allows pumping of larger volume
2. Parasympathetic
 - a) shortens action potentials in atrial contractile cells, which results in weaker contractions
3. Sympathetic
 - a) increases contractile strength of atrial and ventricle cells by increasing Ca^{++} permeability of contractile cells

D. Summary of Control of Cardiac Output

1. Figs 13.30 & 13.31

III. Nourishing the Heart Muscle

A. Heart muscle does *not* extract nutrients from blood in chambers

1. Endocardial lining prevents exchange
2. Even if exchange could occur, heart walls too thick for effective exchange

B. Coronary circulation

1. Coronary arteries branch from aorta just beyond aortic valve
2. Heart muscle receives most (70%) of nutrient blood supply during diastole because coronary arteries compressed during systole, and entries to these arteries partially blocked during systole