Circulatory System and Disorders

Course 4

Cardiac Cycle

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The Heart

- The heart consists of **two pumps** in series:
  - One pump propels blood through the lungs for exchange of O_2 and CO_2 (the **pulmonary circulation**)
  - The other pump propels blood to all other tissues of the body (the **systemic circulation**).
- **Systole:** ventricular contraction
- **Diastole:** venticular relaxation

Circulatory Circuit

- The heart consists of four chambers:
  - Right and left atrium
  - Right and left ventricle

- The right atrium receives blood from the **superior** and **infrerior vena cava** (systemic circulation). Blood flows from the right atrium into the right ventricle. The outflow tract of the right ventricle is the **pulmonary artery.**

- Blood returns to the heart from the lungs via four **pulmonary veins** that enter the **left atrium.** Blood flows from the left atrium into the left ventricle. The left ventricle ejects blood into the **aorta**.

Cardiac Valves

- The orientation of the cardiac valves is responsible for the unidirectional flow of blood through the heart. There are two types of valves in the heart:

1. **Atrioventricular valves:**
   – Tricuspid Valve
   – Mitral Valve
2. **Semilunar valves**
   – Aortic Valve
   – Pulmonary Valve

- There is no valve in the enterance of the atria.

Atrioventricular Valves

- The **tricuspid valve**, located between the right atrium and the right ventricle. *(has three cusps)*

- The **mitral valve**, which lies between the left atrium and the left ventricle, (*has two cusps*).

- Valves have fibrous strands (**chordae tendineae**) on their leaflets that attach to **papillary muscles.**

- The papillary muscles contract when the ventricles contract, prevents the valves from bulging back and leaking blood into the atria (i.e., preventing regurgitation).

Semilunar Valves

- The **pulmonic valve** located between the right ventricle and the pulmonary artery.
- The **aortic valve** located between the left ventricle and the aorta.
- These valves consist of three cup-like cusps that are attached to the valve rings.
- The semilunar valves do not have muscular attachments.

The Cardiac Cycle

- The cyclic contraction and relaxation of the myocardium flow into and out of the heart is called **cardiac cycle**.

- A graphical representation of the variations in hemodynamic variables associated with the cardiac cycle is depicted in «**Wiggers diagram**».

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The Cardiac Cycle

- A complete **cardiac cycle** is defined as the cardiac events initiated by the P wave in the electrocardiogram (ECG) and continuing until the next P wave.

- The cardiac cycle is divided into two general categories: systole and diastole:
  - **Systole** refers to events associated with ventricular contraction and ejection.
  - **Diastole** refers to the rest of the cardiac cycle, including ventricular relaxation and filling.

The Cardiac Cycle

- The cardiac cycle is further divided into five phases:

- Ventricular Systole
  1. Isovolumic Contraction
  2. Ejection

- Ventricular Diastole
  1. Isovolumic Relaxation
  2. Rapid Filling Phase
  3. Diastasis
  4. Atrial Systole

Ventricular Systole

W1

1. Isovolemic Contraction:

START: AV-valve closure (the 1st heart sound)

- All exits of ventricle is closed. (Isovolumetric)

- Pressure rises abruptly beacuse of contraction.

- Pressure exceeds the opening pressure of semilunar valves and valves are opened.

END: Semilunar valve opening

Ventricular Systole

W2

2. Ejection

START: Semilunar valve opening

- May be subdivided into an earlier, shorter phase (**rapid ejection**) (70%) and a later, longer phase (**reduced ejection**) (30%).
- Ventricular volume decresases rapidly and then in lower rate.
- Aortic pressure increases then decreases.

END: Aortic valve closure (2^{nd} heart sound)

Ventricular Diastole

W3

1. Isovolumic Relaxation

START: Closure of the aortic valve

- It produces the characteristic **incisura (notch) =(dicrotic notch)** on the descending limb of the aortic pressure curve, also causes the second heart sound.
- The incisura marks the end of ventricular systole.
- Isovolumic relaxation is characterized by a precipitous fall in ventricular pressure without a change in ventricular volume.

END: Opening of the AV valves.

Ventricular Diastole

W4

2. Rapid Filling Phase

START: Opening of the AV Valves

- The major portion of ventricular filling occurs immediately after the AV valves open.
- This period of ventricular filling is called the *rapid filling phase.*
- This pressure reversal opens the mitral valve. The rapid flow of blood from atria to relaxing ventricles produces transient decreases in atrial and ventricular pressures and a sharp increase in ventricular volume.

Ventricular Diastole

W5

3. Diastasis

- The rapid ventricular filling phase is followed by a phase of slow ventricular filling called *diastasis.*
- During diastasis, blood returning from the peripheral veins flows into the right ventricle and blood from the lungs flows into the left ventricle.
- This small, slow addition to ventricular filling is indicated by gradual rises in atrial, ventricular, and venous pressures and in ventricular volume

Ventricular Diastole

W6

4. Atrial Systole

- The onset of atrial systole occurs soon after the beginning of the P wave.
- Atrial contraction completes the period of ventricular filling.
- At slow heart rates, filling practically ceases toward the end of diastasis, and atrial contraction contributes little additional filling.
- During tachycardia, however, diastasis is abbreviated and the atrial contribution can become substantial.

Atrial Fibrillation

- Atrial contraction is **not essential** for ventricular filling, as can be observed in patients with atrial fibrillation or complete heart block.

- In certain disease states, the AV valves may be markedly narrowed (stenotic). In such conditions, atrial contraction plays a much more important role in ventricular filling than it does in a normal heart. Also in exercise.

Jugular Venous Pressure (JVP)

- Three waves are apparent:
  1. When the right atrium contracts, a retrograde pressure pulse wave is sent backward into the jugular vein. This is called the **a wave**.
     - Factors that impede the flow of blood from the atria to the ventricles, such as tricuspid valve stenosis, increase the amplitude of the a wave.

Jugular Venous Pressure (JVP)

- Three waves are apparent:
  2. A second venous pulse wave, called the **c wave**. The upslope of this wave is created by the bulging of the tricuspid valve into the right atrium during ventricular contraction, which sends a wave into the jugular vein.
     - Failure of the tricuspid valve to completely close during ventricular systole results in the propulsion of blood back into the atrium and vena cava and results in a high-amplitude c wave.

Jugular Venous Pressure (JVP)

- Three waves are apparent:
  3. The **v wave** of the venous pulse is seen as a gradual pressure increase during reduce ejection and isovolumic relaxation followed by a pressure decrease during the rapid-filling phase of the cycle.
     - Tricuspid valve stenosis increases resistance to the filling of the right ventricle, which is indicated by an attenuation of the descending phase of the v wave.

Heart Sounds

- Four sounds are usually generated by the heart, but only two are ordinarily audible through a stethoscope.

- With electronic amplification, the less intense sounds can be detected and recorded graphically as a **phonocardiogram**.

Heart Sounds

- The first heart sound is initiated at the onset of ventricular systole.
- The **AV valves** closure is associated with a series of broad low-pitched sounds that are a result of the vibrations of blood and the *chordae tendineae* in the ventricles.
- This is called the **first heart sound.**
- The intensity of the first heart sound is proportional to the strength of myocardial contraction, and its evaluation can be used in clinical diagnosis.

Heart Sounds

- **The second heart sound**, which occurs with abrupt closure of the semilunar valves.
- Higher frequency vibrations (higher pitch) and is of shorter duration and lower intensity than is the first heart sound.
- Intensity is proportional to the intensity of the valve closure.
- Intensity is increased whenever aortic or pulmonary pressure is abnormally high and is taken as a clinical indicator of possible systemic or pulmonary hypertension, respectively

Heart Sounds

- The nature of the second heart sound changes with respiration.
- During expiration, a single heart sound is heard that reflects simultaneous closing of the pulmonic and aortic valves.
- However, during inspiration, closure of the pulmonic valve is delayed, mainly as a result of increased blood flow from an inspiration-induced increase in venous return.
- With this delayed closure of the pulmonic valve, the second heart sound can be heard as two components; this is termed **physiological splitting** of the second heart sound.

Heart Sounds

- **Third heart sound** is sometimes heard in children with thin chest walls or in patients with left ventricular failure. It is not normally heard in healthy people.

- It consists of a few low-intensity, low-frequency vibrations heard best in the region of the cardiac apex.

- The vibrations occur in early diastole and are caused by the abrupt cessation of ventricular distention and by the deceleration of blood entering the ventricles.

Heart Sounds

- A **fourth**, or **atria**l **sound** consists of a few low-frequency oscillations.

- It is not normally heard in healthy people.

- It is caused by the oscillation of blood and cardiac chambers as a result of atrial contraction.

Pressure-Volume Relationship

- Left ventricular pressure-volume (PV) loops are derived from pressure and volume information found in the **cardiac cycle diagram** (Wiggers).

- To generate a PV loop for the left ventricle, the left ventricular pressure is plotted against left ventricular volume during a complete cardiac cycle.

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PV Loop

PV1

Phase I: Period of filling (A – B)

- Point A:
  - Diastolic filling starts, mitral valve opening.
  - Ventricular volume ≈ 50 ml **(End-Systolic Volume)**
  - Diastolic Pressure ≈ 2-3 mmHg
- Blood flows into ventricle.
- Point B:
  - Volume rises to ≈ 120 ml at point B **(End-Diastolic Volume)**.
  - Diastolic Pressure ≈ 5-7 mmHg

PV Loop

PV2

Phase II: Period of isovolumic contraction (B – C)

- Volume of ventricle does not change. All valves are closed.
- Point C:
  - Ventricle pressure equals to aortic pressure (≈80 mmHg). Aortic valve opens.
  - Apprx. Diastolic arterial pressure

PV Loop

PV3

Phase III: Period of Ejection (C – D)

- Systolic pressure rises even higher.
- Volume of ventricle decreases because blood flows into the aorta.
- **Point D:**
  - Aortic valve closes

PV Loop

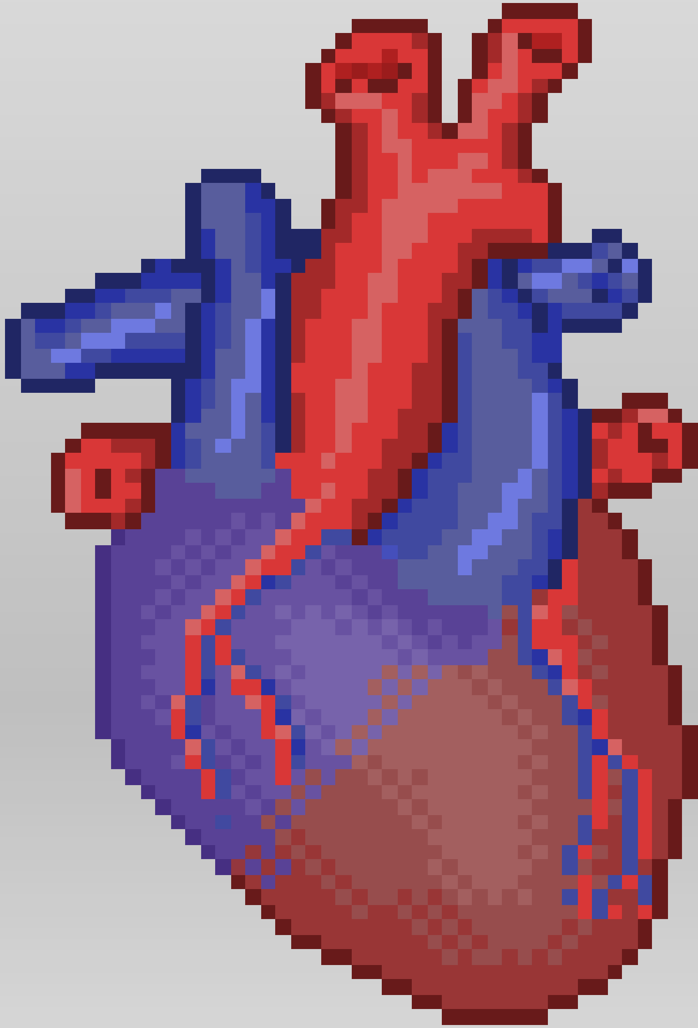
PV4

Phase IV: Period of isovolemic relaxation (D – A)

- Ventricular pressure fall back to the diastolic pressure level.
- Ventricle returns to the starting point.

- **The stroke volume** is then apparent as the "width" of the P-V loop and is calculated as follows:
  Stroke volume = EDV – ESV

- **EW:** Net external work output of the left ventricle during its contraction cycle = cardiac work output



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Thank you for your patience!