Cardiac Cycle

By

Dr. Viral I. Champaneri, MD

Assistant Professor

Department of Physiology

Learning Objectives

1. Definition
2. Cardiodynamics
3. Calculation of duration of cardiac cycle
4. Phases of cardiac cycle
5. Atrial cycle
6. Ventricular cycle
7. Pressure changes during cardiac cycle
8. Volume changes during cardiac cycle

Cardiac cycle ➔ Definition

- Includes both
- Electrical and mechanical events
- That occur from
- Beginning of the one heart beat
- To the beginning of the next

Cardiodynamics

- Is the study of
- The mechanical events
- Associated with
- The Contraction and Relaxation of the heart

Cardiodynamics

- **These include..**

1. **Pressure changes in the ventricles**
2. **Pressure changes in the atria**
3. **Volume changes in the ventricles**
4. **Valvular events**

- **I.e. Production of the heart sounds**

Duration of cardiac cycle

- **Duration of each cardiac cycle**
- **At a Normal *mean* heart rate of ➔ 72 beats/minute**
- **Is ➔ 60 seconds / 72 beats = 0.8 sec**

Phases of cardiac cycle

- During each cardiac cycle both
- Atria ➔
- Contract (Atrial Systole) and
- Relax (Atrial Diastole)
- Ventricles ➔
- Contract (Ventricular Systole) and
- Relax (Ventricular Diastole)

Atrial Cycle (0.8 sec)

- **Atrial Systole or Contraction Phase (0.1 sec)**
- **Atrial Diastole or Relaxation Phase (0.7 sec)**

Ventricular Cycle (0.8sec)

- Ventricular systole (0.3 sec) consisting of

1. Isovolumic (Isometric) Contarction Phase (0.05 sec)
2. Phase of ventricular ejection (0.25 sec)
   a. Rapid ejection phase (0.1 sec)
   b. Slow ejection phase (0.15 sec)

Ventricular Cycle (0.8sec)

Ventricular diastole (0.5 sec) consisting of

1. **Protodiastole (0.04 sec)**
2. **Isovolumic (Isometric) relaxation phase (0.06 sec)**
3. **Rapid passive filling phase (0.11 sec)**
4. **Reduced filling phase or Diastasis (0.19 sec)**
5. **Last rapid filling phase which coincide with atrial systole (0.1s)**

Atrial Cycle (0.8 sec)

- **Atrial Systole or Contraction Phase (0.1 sec)**
- **Atrial Diastole or Relaxation Phase (0.7 sec)**

Atrial Cycle (0.8 sec)

- Atrial Systole (0.1sec)
- Atrial contraction phase
- Lasts for 0.1 sec and
- Coincide with the last rapid filling phase of ventricular diastole.

Atrial systole (0.1sec)

- Before beginning of
- The atrial systole
- The Ventricles are relaxing ➔Ventricles Diastole

Atrial systole (0.1sec)

- AV valves are open & blood is flowing
- From ➔The Great veins in to Atria and
- From ➔The Atria in to Ventricles
- Thus
- Atria and Ventricles are forming a continues cavity

Atrial systole (0.1sec)

- When the Atrial contraction begins
- About 75 % of the blood already flown
- In to the ventricles

Atrial systole (0.1sec)

- **Thus atrial contraction usually causes**
- **An additional 25 % filling of the ventricles**

Atrial systole (0.1sec)

- **Therefore,**
- **Even if the atria fail to function**
- **It is unlikely to be noticed ➔**
- **Unless a person exercise**

Pressure Changes during Atrial Systole

Contraction of the atria causes...

- **Increase in → Intra Atrial Pressure**
- **By 4-6 mmHg in →Right atria**
- **And 7-8 mmHg in →Left atria**

Pressure rise in Right Atrium ➔JVP

- The pressure rise in ➔ Right atrium (4-6 mmHg)
- Is reflected into ➔ The veins and
- Is recorded as “a” wave from the Jugular vein

Atrial systole ➔Increase Intraventricular Pressure

- **Increase in the ventricular pressure**
- **Occurs slightly**
- **Due to ➔Pumping of blood in the ventricles**

Contraction of the atria causes…

- **Narrowing of origin of the great veins**
- **Inferior vena cavae & superior vena cavae opening**
- **IVC & SVC ➔ In Right atrium**
- **Pulmonary vein opening ➔ in the Left atrium**

Contraction of the atria causes

- Some regurgitation of the blood
- Occurs into the great veins
- As ➔No valves ➔ Present between them
- SVC, IVC, Pulmonary vein and atria

Atrial Diastole (0.7 sec)

- After the Atrial systole
- There occurs ➔ Atrial diastole (0.7 sec)

Atrial Diastole (0.7 sec)

- Coincide with
- The Ventricular systole
- And
- Most of the Ventricular diastole

Atrial Diastole (0.7 sec)

- During atrial diastole, Atrial muscles ➔Relax
- Gradual filling of the atria ➔
- Occurs due to ➔ Continuous venous return ➔
- SVC, IVC ➔ Right Atria
- Pulmonary vein ➔ Left atria

Pressure Changes during Atrial Diastole

Atrial Diastole (0.7sec)

- **Pressure gradually increase**
- **To**
- **Drop down to zero ➔**
- **With the opening of the AV valves.**

Atrial Diastole (0.7sec)

- The pressure again rises
- Follows the ➔ Ventricular pressure
- During the rest of the atrial diastole

Ventricular Cycle (0.8 sec)

- After the atrial contraction is over,
- The ventricles starts contracting
- The ventricles get excited by the impulse travelling along the conduction system

Ventricular Systole (0.3 sec)

- Consisting of

1. Isovolumic (Isometric) Contarction Phase (0.05 sec)
2. Phase of ventricular ejection (0.25 sec)
   a. Rapid ejection phase (0.1 sec)
   b. Slow ejection phase (0.15 sec)

Pressure Changes during Ventricular Systole

Phase of Isovolumic Contraction(0.05 sec)

- With the beginning of the ventricular contraction,
- Ventricular pressure exceeds the Atrial pressure very rapidly
- Causing ➔ Closer of the AV Valves

Phase of Isovolumic Contraction(0.05 sec)

- This event
- Is responsible for the production of the
- First Heart Sound (Closure of AV valves)
- Beginning of Isovolumic contraction phase

Phase of Isovolumic Contraction(0.05 sec)

- Since AV Valves are ➔ Closed and
- Semilunar Valves have ➔ Not opened
- So the ventricles contract as a closed chamber
- The pressure inside the ventricles rises rapidly to the high level.

Phase of Isovolumic Contraction(0.05 sec)

- As the ventricles contract and
- The volume of the blood in the ventricle does not change, so this phase is also called
- Isovolumic Contraction Phase.

Phase of Isovolumic Contraction(0.05 sec)

- During this phase
- Due to sharp rise in the ventricular pressure
- There occurs Bulging of the AV valves in the atria
- Producing a small but sharp rise
- In the Intra Atrial Pressure Curve called C-wave

Phase of Isovolumic Contraction (0.05sec)

- This phase lasts for 0.05 sec,
- Until the Pressure in the Left ventricle
- Exceed the pressure in the Aorta (80 mmHg)
- Results ➔ Aoric valve ➔ Open

Phase of Isovolumic Contraction (0.05sec)

- This phase lasts for 0.05 sec,
- Until the pressure in the Right ventricle
- Exceed the pressure
- In the Pulmonary artery (10 mmHg)
- Results ➔Pulmonary valves ➔ Open

Phase of ventricular ejection(0.25 sec)

- Begins with the opening of
- The Semilunar valves
- Aortic and Pulmonary Valves
- Lasts for the about 0.25 sec

Phase of ventricular ejection(0.25 sec)

- **Further divided in to the two phases:**

1. **Rapid ejection phase (0.1sec)**
2. **Slow ejection phase (0.15sec)**

- **(0.1 + 0.15 = 0.25 sec)**

Rapid Ejection Phase (0.1sec)

- As soon as the semilunar valves open
- The blood is rapidly ejected out for about 0.1 sec
- Two third (2/3rd) of the stroke volume (SV)
- Is ejected in this phase

Pressure ➔Rapid Ejection Phase (0.1sec)

- Pressure rises to about
- 120 mmHg in the ➔ Left ventricle
- And to
- 25 mmHg in the ➔ Right ventricle

Right Ventricular Ejection Phase (0.1 sec)

- **Begins ….**
- **Before the Left ventricle**
- **Continued**
- **Even after ➔ Left ventricular ejection is complete**

Velocity of Ejection in Right ventricle

- Less than that of the left ventricle

Slow Ejection Phase (0.15 sec)

- Later 2/3 rd of the systole (0.15 sec)
- Rate of ejection ➔Declines ➔ Slow ejection phase
- About 1/3rd of the stroke volume is ➔ Ejected
- During this phase

Volume Changes during Ventricular Cycle

Volume Changes in Ventricle

1. **Stroke Volume (SV)**
2. **End-systolic Volume (ESV)**
3. **End-diastolic volume (EDV)**

End-Diastolic Volume➔130mL

- At the end of each diastole
- Ventricular Relaxation
- The ventricular volume is about ➔ 130 mL
- Called ➔End-diastolic Volume (EDV)

Stroke Volume ➔ 80mL

- About 80 mL of the blood is ejected out
- By each ventricle
- During each systole
- Called ➔Stroke Volume

End-Systolic Volume ➔ 130 – 80 mL

- About 50 ml of the blood
- Is left in the each ventricle
- At the end of each systole
- Called ➔End-systolic Volume

Ventricular Diastole (0.5 sec)

Ventricular diastole (0.5 sec) consisting of

1. **Protodiastole ➔0.04 sec**
2. **Isovolumic (Isometric) relaxation phase ➔0.06 sec**
3. **Rapid passive filling phase ➔0.11 sec**
4. **Reduced filling phase or Diastasis ➔0.19 sec**
5. **Last rapid filling phase which coincide with atrial systole: 0.1sec**

Protodiastole (0.04 sec)

- When the ventricular systole ends,
- The ventricles ➔ Start relaxing
- Protodiastole phase lasts for the ➔0.04 sec

Pressure Changes during Ventricular Diastole

Protodiastole (0.04 sec)

- **Intra Ventricular Pressure**
- **Falls rapidly**

Protodiastole (0.04 sec)

- During this phase Elevated pressure in the distended arteries (Aorta And Pulmonary)
- Immediately pushes the blood back towards ventricles
- Which snaps the Semilunar Valves to Close

During Protodiastole2nd Heart Sound

- **Closure of Semilunar valves**
- **Aortic valve & Pulmonary valve**
- **Produces ➔ Second (2nd) Heart Sound**

Closure of Aortic Valve

- It also causes
- Dicrotic Notch
- In the down slope of the Aortic Pressure
- Called Incisura

Isovolumic Relaxation phase(0.06sec)

- This phase begins ➔
- With the ➔ Closure of the semilunar valves
- And lasts for about 0.06 sec.

Isovolumic relaxation phase (0.06sec)

- Since Semilunar valves (Aortic & Pulmonary) closed
- And the AV valves are not yet opened ➔ So the
- Ventricles continue to relax as the closed chambers
- In this phase

Isovolumic relaxation phase (0.06sec)

- The ventricular volume ➔
- Remains same and constant
- So this phase is called the
- Isometric (Isovolumic) relaxation phase

Isovolumic relaxation phase (0.06sec)

- This phase Ends ➔ with the AV valves open
- As indicated ➔
- By the peak of the
- V wave on the Atrial pressure tracing

Rapid passive filling phase(0.11 sec)

- During ventricular systole,
- The atria are in diastole and
- Venous return ➔ Continues in Atria ➔ So that are

A –V Valves ➔ Open

- **Rapid passive filling Phase (0.06 seconds) ➔**
- **Atrial pressure is high than Ventricular➔**
- **When the AV valves open**

Rapid passive filling phase(0.11 sec)

- **The high atrial pressure causes**
- **Rapid, initial flow of the blood in to ventricles**
- **And**
- **Produces ➔ Third (3^{rd}) heart sound**

3rd Heart sound

- Rapid passive filling phase (0.11 seconds)
- Rapid, initial flow of the blood in to ventricles

Reduce Filling Phase/Diastasis (0.19 sec)

- In this phase,
- The Pressure in the Atria and Ventricles reduces slowly
- And ➔ Remains ➔Little above zero (0)

Reduce Filling Phase/ Diastasis (0.19 sec)

- This decreases the rate of blood flow
- From atria to ventricle causing
- A very slow filling or virtually
- Cessation of ventricular filling called ➔ Diastasis

Last rapid filling phase(0.1sec)

- 75% of the blood passes
- From the atria to ventricles
- During the *Rapid* filling phase and
- *Reduced* filling phase of ventricular diastole

Last rapid filling phase(0.1sec)

- Coincide with the atrial systole and
- Pushes additional 25% of the filling of the blood in the ventricles
- With this phase ➔The ventricular systole ends