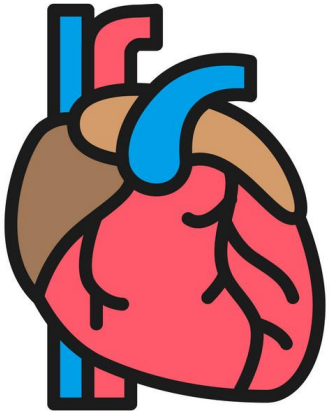
Revised & Reviewed by Abdulaziz & Bahammam Faye & Wael Sindi



MED441
KING SAUD UNIVERSITY

Cardiac cycle 1&2

Color Index:

- Main text
- Important
- Girls Slides
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Editing File

Objectives

- Enumerate the phases of cardiac cycle
- Explain the effect of heart rate on duration of systole and diastole
- Recognize the pressure, electrical, sound and volume changes during cardiac cycle
- Correlate different phases of cardiac cycle with various changes in events.
- Compare and contrast left and right ventricular pressures and volumes during the normal cardiac cycle.
- Describe atrial pressure waves & their relationship to cardiac cycle
- Describe the use of the pressure-volume loop in describing the phases of the cardiac cycle

Some facts to remember

❖ Our heart has its own electrical impulse, it can continue to beat even when separated from the body, as long as it has an adequate supply of oxygen.

❖ Heart is a double pump (right & left) that work together

❖ It has two circulations: systemic & pulmonary circulation which work together.

Recommended videos

Cardiac cycle - ninja nerd

Cardiac cycle - Dr naji

Definitions

Definitions and values are very important

End Diastolic Volume: Volume of blood in each ventricle at the end of diastole.
It is about 110 – 130 ml.

End Systolic Volume: Volume of blood in each ventricle at the end of Systole.
It is about 40 to 60 ml

Stroke Volume: It is a volume of blood pumped out by each ventricle per beat.
It is about 70 ml. Stroke volume (SV) = EDV – ESV

EJECTION FRACTION

(EF) is the percentage of ventricular end diastolic volume (EDV) which is ejected with each stroke ***(60-65%).***

$$EF = \frac{SV \text{ or } EDV\text{-}ESV}{EDV} \times 100$$

EF = (75 /120*100=62.5%)

CARDIAC CYCLE

Definition : Cardiac Cycle is the time duration comprising all the events from beginning of one heart contraction to the beginning of next heart contraction.

At heart rate of 75 beats per minute duration of one Cardiac cycle is 0.8 second.

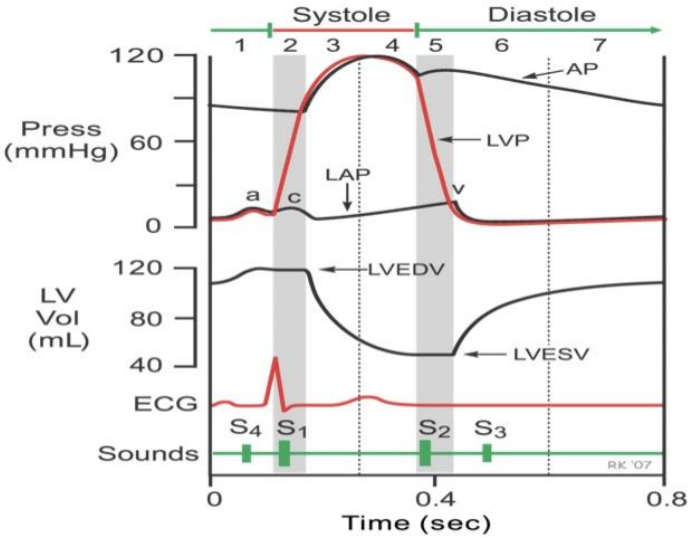
What are the Events?

➢***Mechanical Events:***

1. Pressure changes during cardiac cycle
2. Volume changes during cardiac cycle
3. Heart sounds

➢ ***Electrical Events:***

Electrocardiogram (ECG)



Phases of the Cardiac cycle 0.8s

ATRIAL DIASTOLE 0.7 SECONDS		ATRIAL SYSTOLE 0.1 SEC	*Arterial event*
Ventricular systole 0.3 seconds	Ventricular diastole 0.5		*Ventricular event*
CARDIAC CYCLE 0.8 SECONDS (when HR = 75 beats/min)			

Importance of longer ventricular diastole?

- *Coronary blood flow*
- *Ventricular filling*

Diastole = انبساط
Systole= انقباض

I EXTRA SLIDE

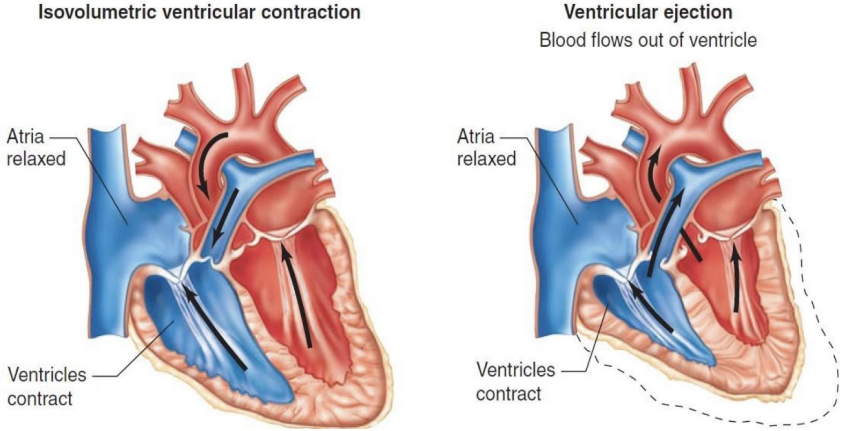
Cardiac Cycle Duration/Time

- ★ *Cardiac cycle starts by systole of both atria (0.1 sec), then systole of both ventricles (0.3 sec), then diastole of whole heart*
- ★ *Diastole of whole heart is 0.4 sec (when ventricles and atria are in diastole at the same time; IVR+Rapid Filling+Half of Reduced Filling)*
- ★ *Normally, diastole is longer than systole*

The 7 Phases of the Cardiac cycle 0.8s

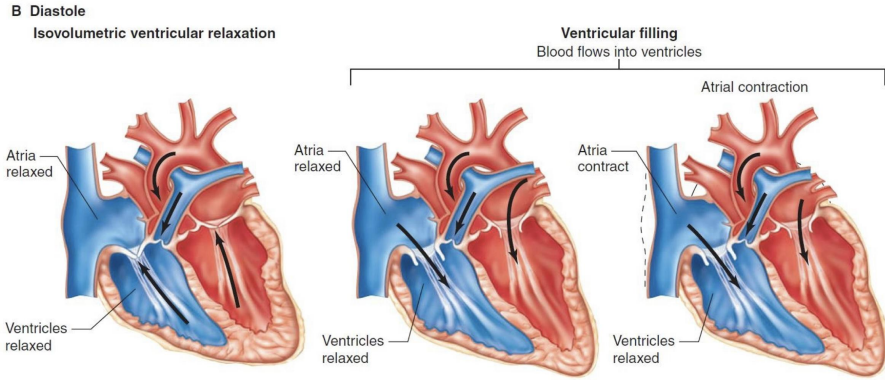
VENTRICULAR SYSTOLE **0.30 sec** (Peak of R wave of QRS complex to the end of T wave)
1.ISO-VOLUMETRIC CONTRACTION **0.05 sec**
2.MAXIMUM EJECTION [Duration 1/3] (2/3 or 70% blood is ejected) **0.10 sec**
3.REDUCED EJECTION [Duration 2/3] (1/3 or 30% blood is ejected) **0.15 sec**
VENTRICULAR DIASTOLE **0.50 sec** (End of T wave to the peak of R wave of QRS complex)
PROTODIASTOLE (the short period in the cardiac cycle between the end of systole and the closure of the aortic valve marking the start of diastole) **0.04 sec**
4.ISO-VOLUMETRIC RELAXATION **0.06 sec**
5.RAPID INFLOW/RAPID FILLING **0.11 sec**
6.SLOW INFLOW/SLOW FILLING / DIASTASIS **0.22 sec**
7.ATRIAL SYSTOLE (after P wave) **0.11 sec**
7 phase of CARDIAC CYCLE 0.8 sec

Systole



AV valves:	Closed	Closed
Aortic and pulmonary valve:	Closed	Open

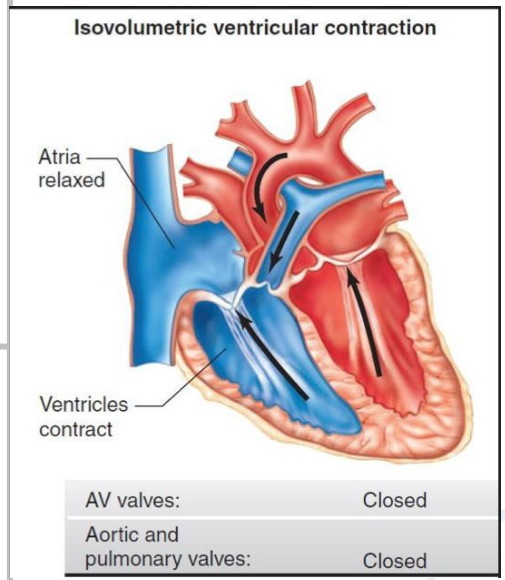
Diastole



AV valves:	Closed	Open	Open
Aortic and pulmonary valve:	Closed	Closed	Closed

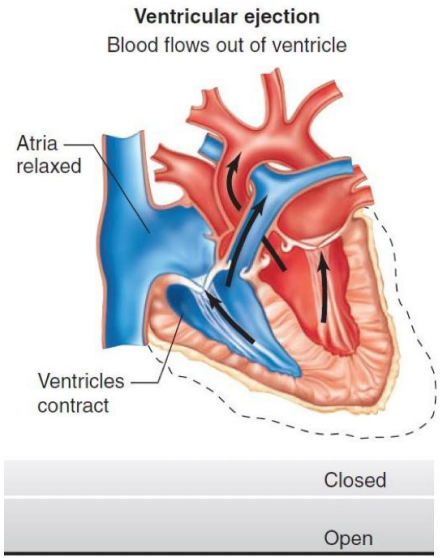
ISOVOLUMETRIC CONTRACTION

Mechanical Events	Increase in ventricular pressure when Ventricular pressure > atrial pressure → AV valves close **After 0.06s**, **semilunar valves open** Period between AV valve closure and semilunar valve opening→heart prepares for contraction without shortening→ occurs without emptying *(No change in size→hence the isovolumetric→ No emptying)*
Heart sounds	• 1st heart sound (S1) heard due to • 1- Sudden closure of A-V valves contraction, • 2- Vibration of chordae tendinae of papillary muscles.
Ventricular volume	• Tension develops without change in muscle length (Isometric/Isovolumetric)



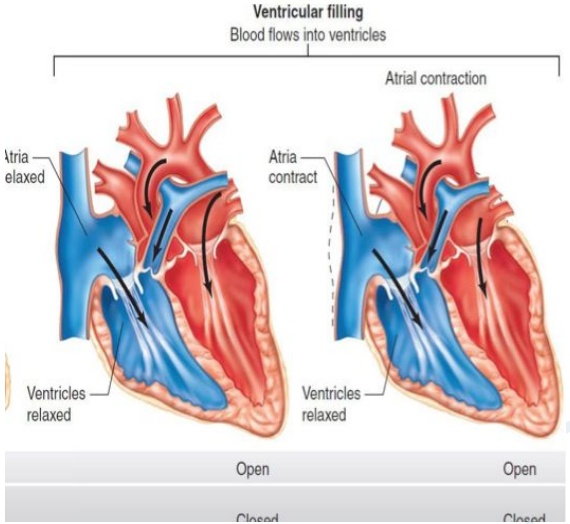
Ejection Phase

Mechanical Events	When Left ventricle pressure > 80 mm Hg Right ventricle pressure> 8 mm Hg, The semilunar valves open. **Rapid Ejection : 70% emptying in first 1/3 duration** **Slow Ejection: 30% in last 2/3 time** The pressure in the ventricle keeps decreasing until it becomes lower than that of the great vessels
Heart sounds	• No sound
Ventricular volume	• ↓ sharply due to shortening of ventricular wall and ejection of blood.



VENTRICULAR FILLING

Mechanical Events	▪ Begins with the opening of AV valves ▪ ***Rapid filling*** – first 1/3 of diastole (60-70% blood flows) ▪ ***Reduced filling (Diastasis)*** – middle 1/3 of diastole (<5% blood flows) ▪ **Atrial contraction** last 1/3 of diastole (25 %blood)
Heart sounds	-
Ventricular volume	As the atrial pressures fall, the AV valves close and left ventricular ***volume is now maximum → EDV (120 ml in LV)***



atrial pressure changing during cardiac cycle (THE JUGULAR VENOUS PRESSURE)

"A" wave (Atrial systole)	• atrial pressure during atrial contraction
"C" wave (ventricular systole)	• Positive as a result of bulging of AV valve into the atria during **'isovolumetric contraction phase'.** • Negative as a result of pulling of the atrial muscle & AV cusps down during **'rapid ejection phase'**, resulting in ↓ atrial pressure
"V" wave (Atrial diastole)	• Positive : atrial pressure ↑ **gradually** due to continuous VR • Negative: as a result of ↓ atrial pressure during **'rapid filling phase'**
"X" descent	• Downward displacement of AV valves during **'reduced ejection phase'**
"Y" descent	• ↓ atrial pressure during **'reduced filling phase'**

Abnormalities of "a" waves

1. **Elevated a wave (**Tricuspid stenosis**)**

   Decreased ventricular compliance (ventricular failure, pulmonic valve stenosis, or pulmonary hypertension)

2. **Cannon "a" wave**

   - Atrial-ventricular asynchrony (atria contract against a closed tricuspid valve)
   - complete heart block, following premature ventricular contraction, during ventricular tachycardia, with ventricular pacemaker

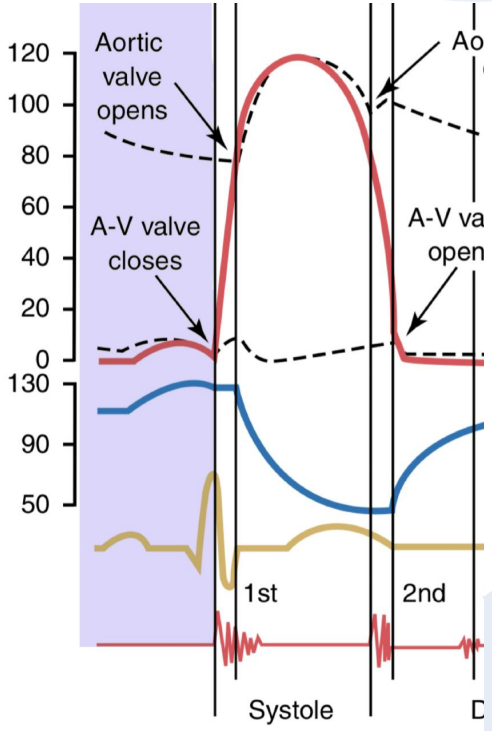
3. **Absent a wave**

   Atrial fibrillation or atrial standstill (Atrial flutter)

ATRIAL SYSTOLE

- Phase of atrial contraction at end of diastole (JVP – 'a' wave) [≈ 0.11 sec]
- Preceded by atrial depolarization

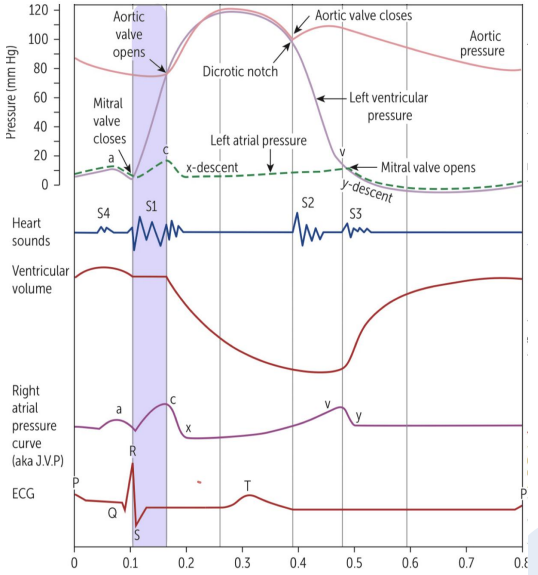
Valves	A-V valves open (semilunar valves closed). blood goes from atria to ventricles.
Ventricular volume	up to 130 ml (EDV) .
Ventricular pressure	First slightly ↑ due to entry of blood from atria. Then ↓ due to dilatation of ventricles. In both cases, it is less than atrial Pressure
Atrial pressure	First ↑ due to systole of atria. Then ↓ due to blood passage into ventricles.
heart sound	4th (S4) Heart sound heard (Vibration of the vent wall during atrial contraction).
ECG	P-wave



ISOVOLUMETRIC CONTRACTION

▪Start of ventricular systole [≈ 0.04 sec] & with closure of A-V valves.

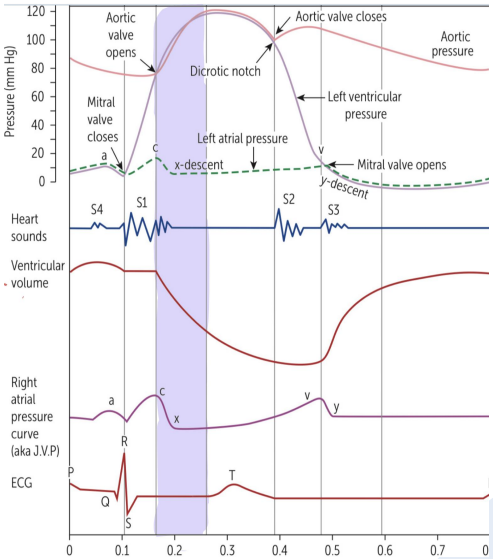
Valves	Still closed Aortic valve opens at the end of this phase, when LV exceeds 80mmHg.
Ventricular volume	***EDV (120 ml)*** Ventricle contracts with no changes in volume (isometrically, no shortening)
Ventricular pressure	↑ suddenly
Atrial pressure	↑ due to doming of cusps of closed A-V valves into atria
heart sound	You will hear first sound S1
ECG	End of QRS complex
JVP	'c'wave ⟶ due to the bulging of the Tricuspid valve into RA



Rapid ejection phase

- The ventricles contract isotonically (with shortening) **ejecting 75% of stroke volume.**
- Duration:≈0.10sec.

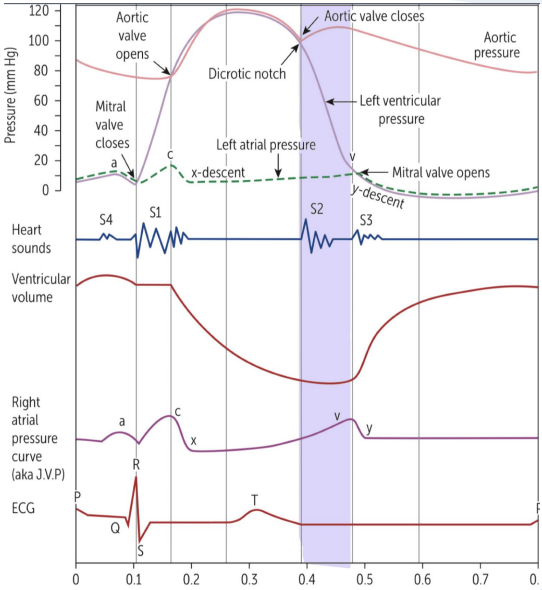
Valves	**Semilunar Valves** Open At Beginning Of This phase when ***LV pressure exceeds 80 mmHg.*** **AV valves** :Still closed.
Ventricular volume	Decrease
Ventricular pressure	Increase (reaches 120 mmHg in left Ventricle.)
Atrial pressure	First increases because when ventricles contract, they pull fibrous AV ring with AV valves downward
Aortic pressure	**Increase**
heart sound	NONE !
ECG	T wave



Slow Ejection

- The ventricles contract with lesser force and less blood is ejected (end of systole).
- Almost 25% of Stroke Volume is ejected.
- Duration: ≈ 0.15 sec.

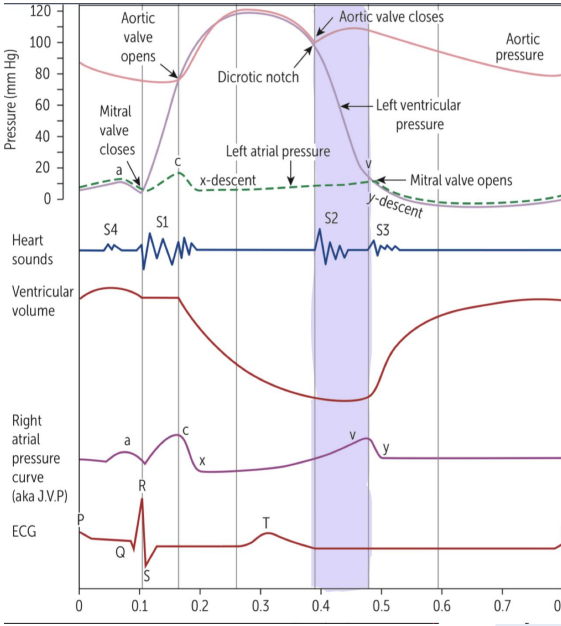
Valves	**AV valves:** Still closed. **Semilunar valves:** Still opened.
Ventricular volume	Continue to fall
Ventricular pressure	decreases
Atrial pressure	Still Gradually increase due to venous return.
Aortic pressure	decreases Even at the end of systole pressure in the aorta is maintained at 80-90 mm Hg
heart sound	None.
ECG	T-wave



ISOVOLUMETRIC RELAXATION

- The ventricles relax at the start of diastole.
- It lasts for ≈ 0.06 sec.

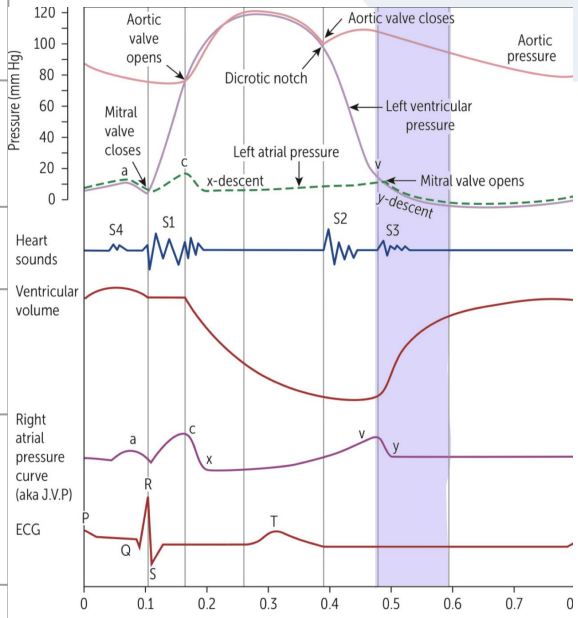
Valves	**Semilunar valves:** close at the beginning of the phase **AV valves:** Still closed.
Ventricular volume	is constant at the ESV (60 ml).
Ventricular pressure	decrease rapidly
Atrial pressure	Still ↑ gradually due to accumulation of venous blood.
Aortic pressure curve	INCISURA : backflow of blood coming across a closed aortic valve
heart sound	S2, closure of the semilunar valves
ECG	T wave
JVP	**v wave**, due to accumulation of venous blood.



VENTRICULAR FILLING (Rapid filing)

- About 60-70% of blood passes passively to the ventricles **[≈ 0.11sec].**

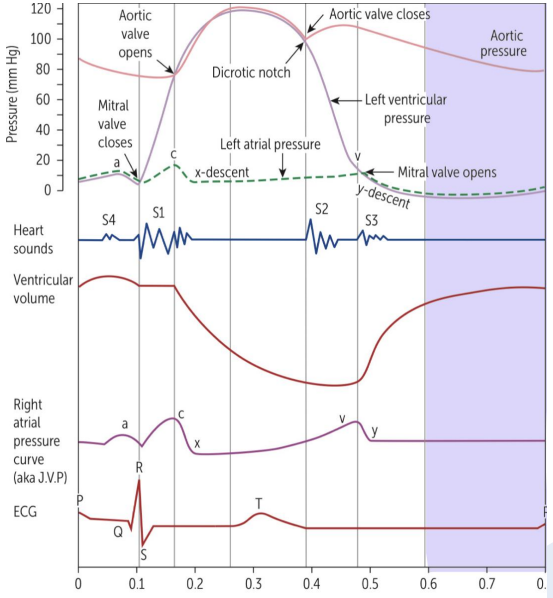
Valves	**A-V valves:** still open **Semilunar valves:** Still closed
Ventricular volume	↑because it is being filled with blood.
Ventricular pressure	Slightly ↑but < atrial pressure
Atrial pressure	First sudden ↓ due to rush of blood from atria to ventricles. Then gradually ↑due to entry of venous blood.
heart sound	[S3] due to rush of blood into ventricles and vibration in ventricular wall.



VENTRICULAR FILLING (Reduced filling)

Remaining atrial blood flows slowly into ventricles by pressure gradient <5%. [≈ 0.22 sec]

Valves	**A-V valves:** still open. **Semilunar valves:** Still closed.
Ventricular volume	Still ↑
Ventricular pressure	Slightly ↑gradually
Atrial pressure	Still ↑
ECG	P wave before atrial systole
JPV	'y' descent in first 2/3 & 'a' wave in last 1/3



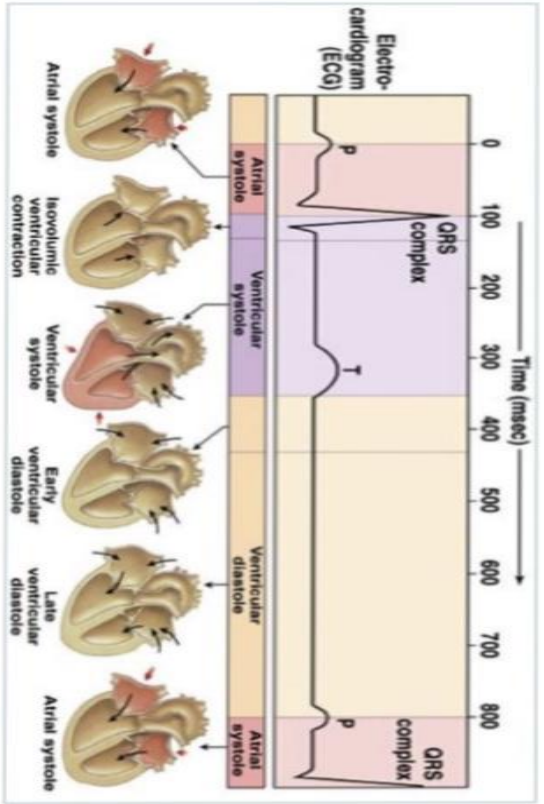
Phase	Ventricular Pressure	Cause	Ventricular Volume
1-Atrial systole	First slightly ↑ Then	Entry of blood from atria dilatation of ventricles	↑(EDV 130ml)
2-Isovolumetric Contraction	↑ Suddenly (80 mmHg)	All valves are closed and contraction is isovolumetric	Constant
3-Maximum Ejection	↑ Sharply (120 mmHg)	Shortening of the ventricular wall and ejection of blood	↓ Rapidly
4-Reduced Ejection	↓ Gradually (80 mmHg))	Volume of blood leaving ventricles > the decrease in ventricular volume	↓ Slowly (ESV 60ml)
5-Isovolumic Relaxation	↓Rapidly	All valves are closed and relaxation is isovolumetric	Constant
6-Rapid Filling	Slightly ↑ but <atrial pressure	Entry of blood from atria	↑ Rapidly
7-Reduced filling	Slightly/gradually ↑	Entry of blood from atria	↑ Gradually

HEART SOUNDS & CARDIAC CYCLE

Phase	Heart sound	Cause
1-Atrial systole	4th heart sound	1-contraction of atria 2-blood rush from atria to ventricles
2-Isovolumetric Contraction	1st heart sound	1-sudden closure A-V valves 2-vibration of chordae tendinae of papillary muscles
3-Maximum Ejection	1st heart sound continues	1-contraction of ventricles 2-vibration of walls of aorta & pulmonary artery
4-Reduced Ejection	No sound	
5-Isovolumic Relaxation	2nd heart sound	Sudden closure of semilunar valves
6-Rapid Filling	3rd heart sound	Rush of blood into ventricles and vibration in ventricular wall
7-Reduced filling	No sound	

ECG CHANGES IN CARDIAC CYCLE

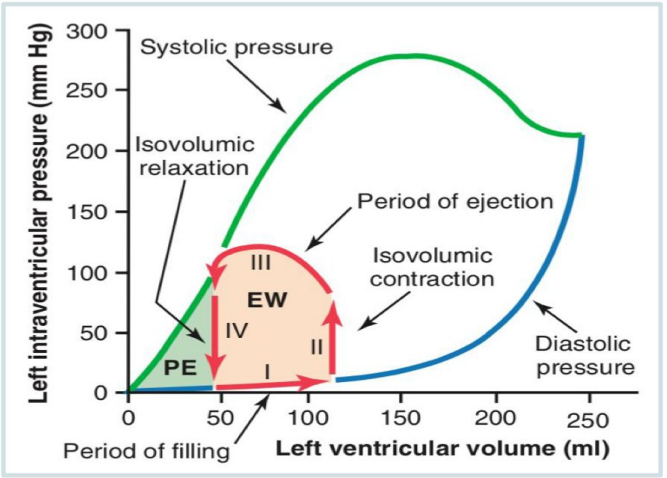
Phase	ECG changes
1-Atrial systole	P-wave starts 0.02sec. before atrial systole Q-wave occurs at the end of this phase
2-Isovolumetric Contraction	Q-wave starts 0.02 sec. before this phase. R & S- waves occur during it
3-Maximum Ejection	T- wave starts at the last part of it.
4-Reduced Ejection	T-wave continues
5-Isovolumic Relaxation	T- wave ends
6-Rapid Filling	T-P segment
7-Reduced filling	P- wave of the next cycle starts at the end of this phase



Left Ventricular Pressure - Volume Diagram (loop)

THANKS TO TEAM439

- ★ The “volume-pressure diagram” demonstrate the relationship between changes in intraventricular volume and pressure during the normal cardiac cycle (diastole and systole).
- ★ Can be used to determine EW = net external work and PE = potential energy
- ★ Plots LV pressure against LV volume through one complete cardiac cycle
- ★ It is divided into four phases discussed in the next slide



Left Ventricular Pressure - Volume Diagram (loop)

Phase 1 (filling phase) (Late diastole):

- Begins at point A where: Ventricular volume is about **70 ml** (the amount of blood that remains in the ventricle, the (ESV) Diastolic pressure is **2 to 3 mm Hg**

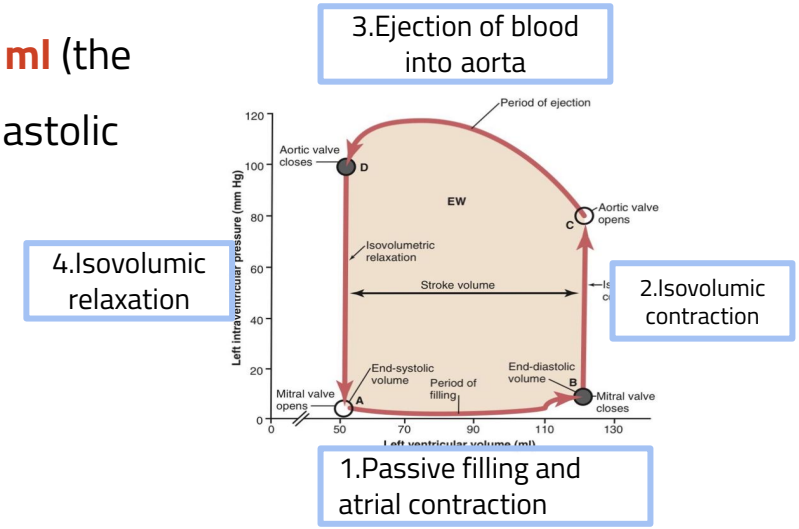
- Ends at point B where the ventricular volume normally increases to **140 milliliters** (EDV)

-Stroke volume=EDV-ESV (B-A)

Phase 2 (isovolumic contraction phase):

- The volume of the ventricle does not change.

- Ventricular pressure rises to about 80 mm Hg (point pressure level.C).



THANKS TO TEAM439

Left Ventricular Pressure - Volume Diagram (loop)

Phase 3 (Ejection phase):

- Systolic pressure rises **(from 80 to 120 mmHg)**. *Maximum pressure is reached during this phase*

- The volume of the ventricle decreases because blood flows out of the ventricle into the aorta.

Phase 4 (isovolumic relaxation phase):

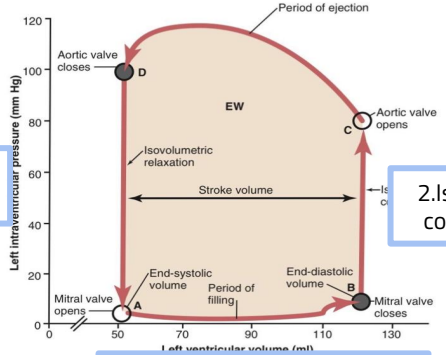
-at the end of ejection period (point D), the aortic valves closes

-Ventricular pressure falls back to the diastolic pressure level

-the ventricles return to its starting point (point A)

(all valves closed)

3.Ejection of blood into aorta



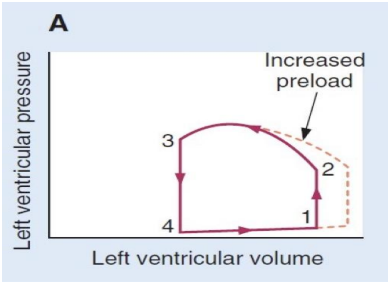
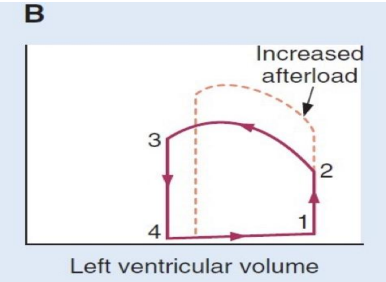
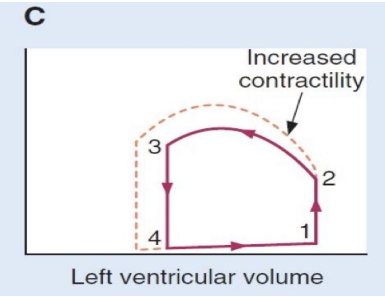
4.Isovolumic relaxation

2.Isovolumic contraction

1.Passive filling and atrial contraction

THANKS TO TEAM439

VENTRICULAR PRESSURE - VOLUME LOOP

Increased preload	Increased afterload	Increased contractility
↑venous return → increase in SV based on the Frank–Starling relationship it is reflected in increased width of the PV loop.	due to an increase in aortic pressure → decrease in stroke volume it is reflected in decreased width of the PV loop.	increased width & height of the PV loop.
		

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physiology 441

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