Physiology Team 439

Cardiac Cycle I&II

Black: in male / female slides
Red : important
Pink: in female slides only
Blue: in male slides only
Green: notes
Gray: extra information

Helpful video

Editing File

Objectives

1.Enumerate the phases of cardiac cycle

2.Explain the effect of heart rate on duration of systole and diastole

3.Recognize the pressure, electrical, sound and volume changes during cardiac cycle

4.Correlate different phases of cardiac cycle with various changes in events

5.Compare and contrast left and right ventricular pressures and volumes during the normal cardiac cycle

6.Describe atrial pressure waves & their relationship to cardiac cycle

7.Describe the use of the pressure-volume loop in describing the phases of the cardiac cycle

Facts About Our Heart

- Pumping is the main function of the heart.
- It is the size of a fist and weighs about 250 grams.
- In a lifetime, it beats 3 billion times and pumps 110 million gallons of blood (2000 gallons/day.)
- Every day, your heart creates enough energy to drive a truck for 20 miles (32 km.) In a lifetime, that is equivalent to driving to the moon and back.
- 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.

Intracardiac Blood Circulation:

1- Oxygen-poor blood returns to the heart through superior vena cava & inferior vena cava to the right atrium

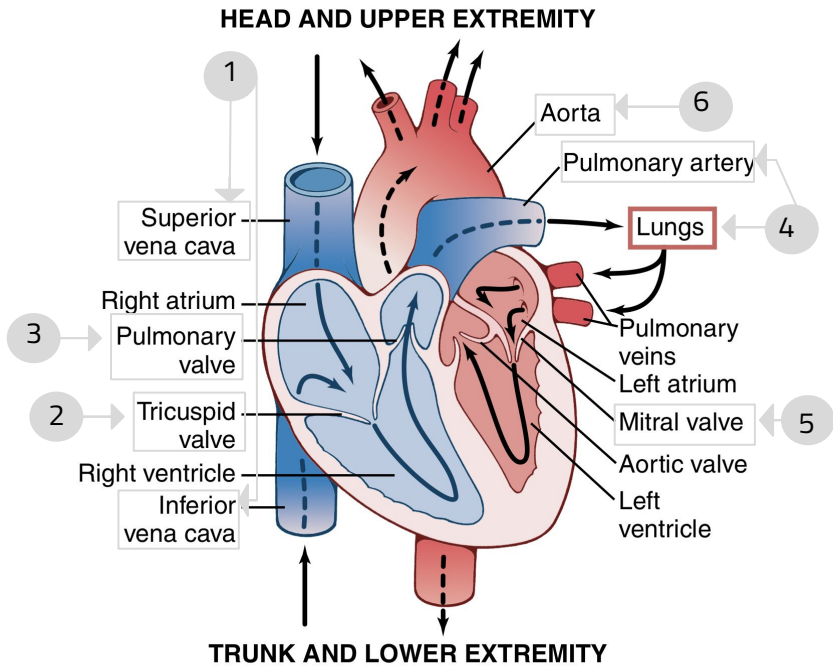
2-Then it flows from right atrium to the right ventricle (tricuspid valve open to allow for that)

3-The oxygen-poor blood pumped through pulmonary artery to the lung (pulmonary valve opened)

4-The lung refresh the blood which come from pulmonary artery with a new supply of oxygen then return it from the lung to the left atrium

5-The oxygen-rich blood now flows from left atrium to the left ventricle (mitral valve open to allow for that)

6-The oxygen-rich blood then pumped through the aorta to supply the tissues body (aortic valve opened)



Valves of The Hearts

Atrioventricular valves:

1. **Tricuspid valve:** between right atrium & right ventricle.
2. **Mitral valve:** between left atrium & left ventricle.

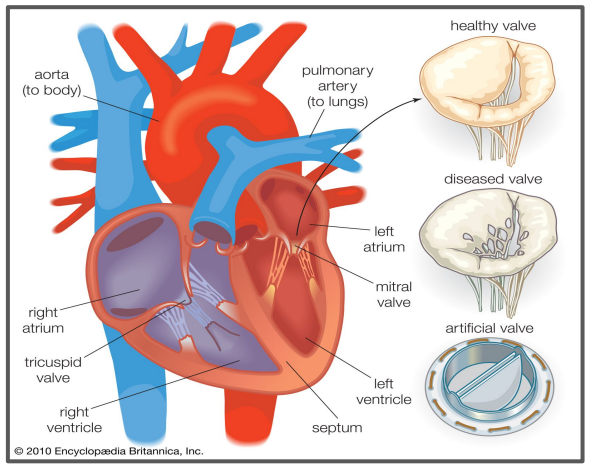
Semilunar valves:

1. **Pulmonary valve:** between right ventricle & pulmonary artery.
2. **Aortic valve:** between left ventricle & aorta.

Functions of The Valves

- Valves allow blood to flow in only ONE direction.
- Opening & closure of valves occur as a result of pressure gradient across the valve. (high pressure against the valve = opening of valve)
- When A-V valves open, semilunar valves close and vice versa. (They can never open at the same time, but can close at the same time like in Isovolumetric phases , This is to prevent backflow of blood from aorta or pulmonary artery to their perspective Ventricle)
- A-V cusps are held by chordae tendineae to muscular projections called "papillary muscles".

This is to limit movements and eversions of the valves during ventricular systole. i.e. To hold it in place/prevent inversion prolapse during systole (يعني لما تسكر ما تفتح من جهة ثانية). Have no role in opening or closing the valves.



Definitions

End-Diastolic volume (EDV):

Volume of blood in each ventricles at the end of diastole = 110-130 mL.

End-Systolic Volume (ESV):

Amount of blood left in each ventricles at the end of systole = 40-60 mL.

Stroke Volume (SV):

Amount of blood ejected from ventricles during systole = 70 mL/beat.

It is Volume Of Blood Pumped out by each ventricle per beat.

$$\mathbf{SV = EDV - ESV}$$

So when SV decreases the ESV increases, because there will be more blood left in the ventricle.

Ejection Fraction (EF):

The percentage of EDV which is ejected with each stroke. It is a good index of ventricular function.

Normal ejection fraction is about 60 – 65 %.

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

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

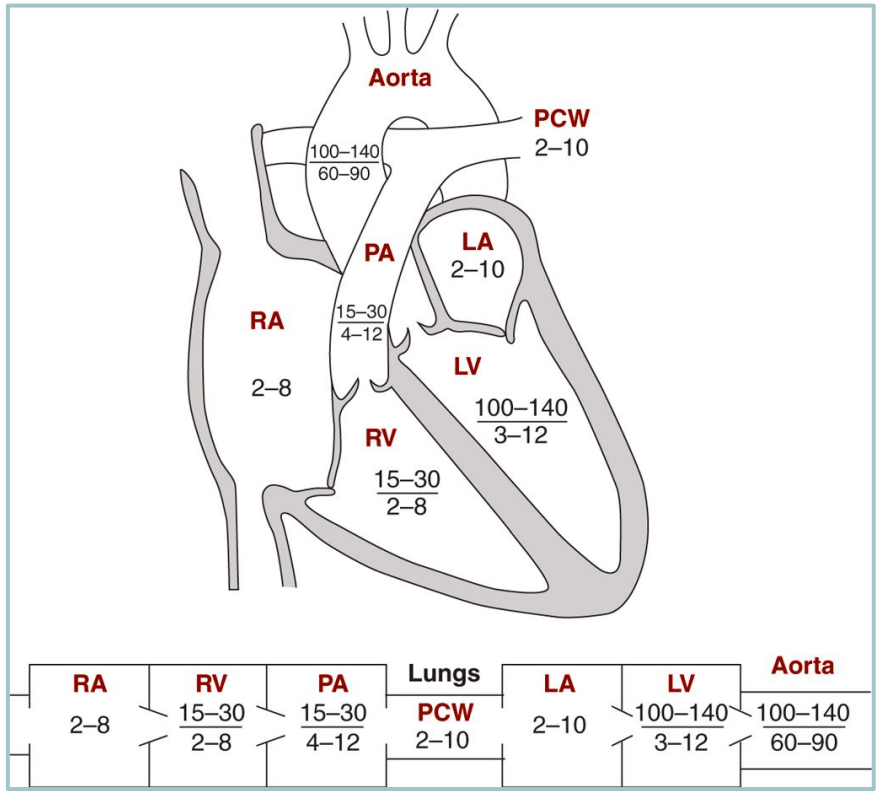
General Principles

- Contraction of the heart generates pressure changes & results in orderly blood movement.
- Blood flows from an area of high pressure to an area of low pressure.
- Events are the same in the right & left sides of the heart, **but with lower pressures in the right** side

  (pressure in the right side (ventricle)= to open pulmonary valve= 4-12mmgh , reaches 25mmhg)
  (pressure in the left side(ventricle) = to open the aortic valve = 80mmhg , reaches 120mmhg)

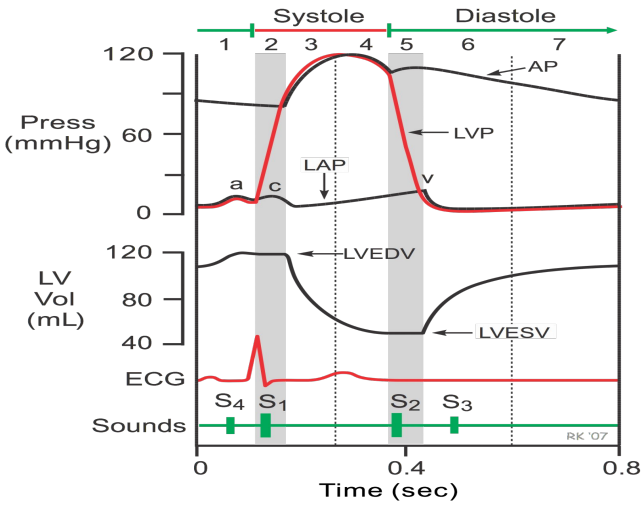
- **Atrial & ventricular systole do not occur at same time**, but their **relaxation occurs at same time** during diastole of whole heart which lasts for 0.4 sec.

- **AV valves open when atrial pressure is higher than ventricular pressure, and it closes when the reverse happens.**
- **Semilunar valves open when ventricular pressure is higher than aortic and pulmonary pressure, and it closes when the reverse happens.**
- **The cycle is initiated with the firing of the SA node**



The Cardiac cycle

- **Cardiac cycle:** the sequence of events that take place in the heart in each beat (from the beginning of one heart beat to beginning of the next one).
- Each cycle is initiated by depolarization of S-A node, followed by contraction of the atria.
- The signal is transmitted to ventricles through A-V node & A-V bundle to cause ventricular contraction.
- **Events of the Cardiac Cycle**
  - Mechanical Events:
    1. Pressure changes during cardiac cycle
    2. Volume changes during cardiac cycle
    3. Heart sounds
  - Electrical Events:
    Electrocardiogram (ECG)



The 7 Phases of the Cardiac cycle

- Considered '8' phases if including 1st phase of diastole

-isovolumetric contraction and relaxation have the shortest duration.

-reduced filling has the longest duration.

Ventricular Systole (0.3 sec)			Ventricular Diastole (0.5 sec)		
***IVC:** IsoVolumetric Contraction			***IVR:** IsoVolumetric Relaxation		
IVC* (0.05 s)	**Rapid/Maximum Ejection** (0.10 sec)	**Reduced Ejection** (0.15 sec)	**IVR*** (0.06 s)	**Rapid Filling** (0.11 sec)	**Reduced Filling** (0.22 sec)

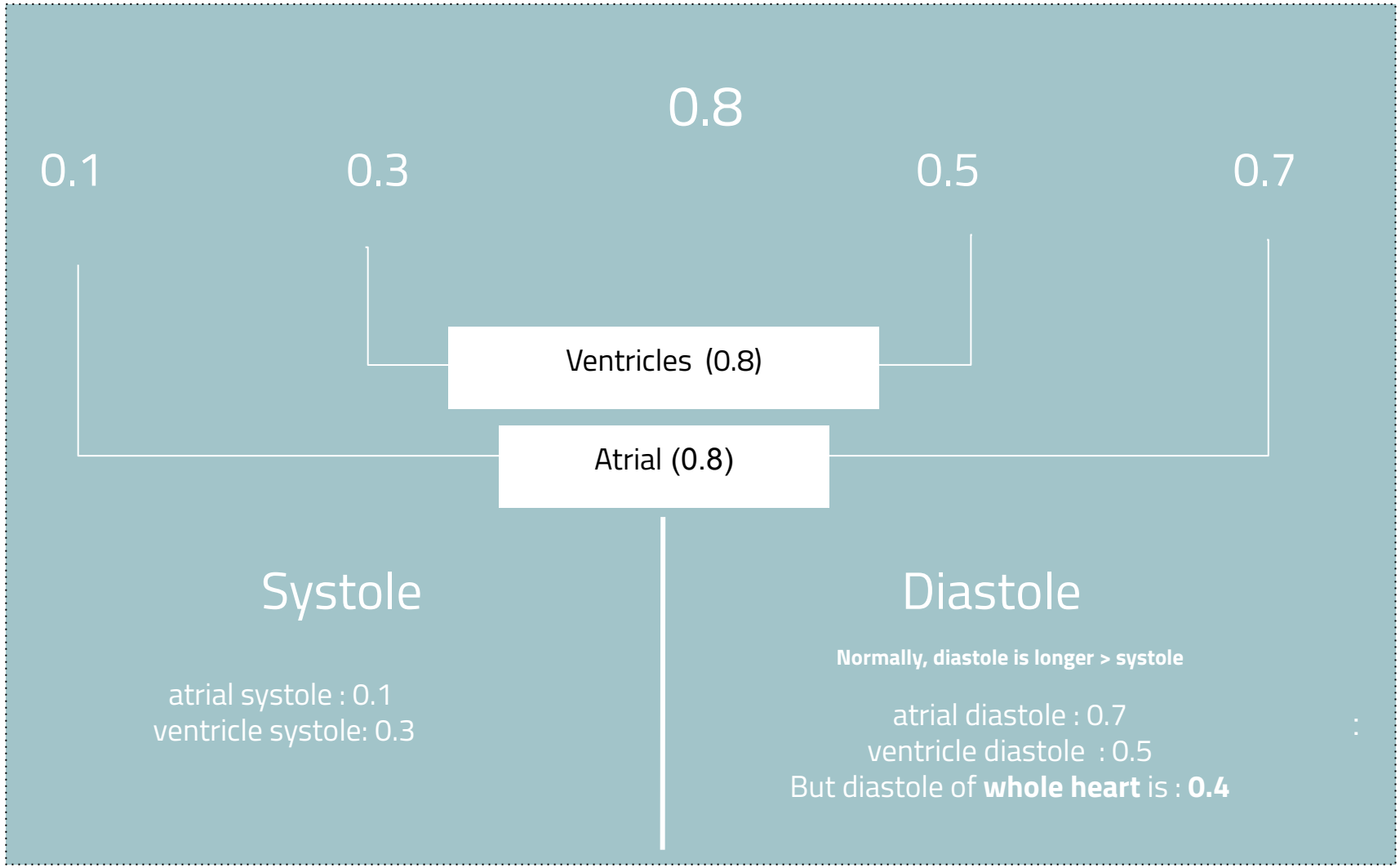
Atrial Diastole (0.7 sec) | **Atrial Systole (0.11 sec)**

ينسحب عليه من ناحية Phases
حتى ECG سحبت عليه
لأنه يصير في نفس وقت آخر مرحلتين

Diastole of whole heart (0.4 sec)

Might help you memorize the values from previous slide

Cardiac Cycle Duration



Cardiac Cycle Duration/Time

- **Cardiac Cycle Duration:** the time required for one complete cardiac cycle.
- When heart rate (HR) is 75 beats/min, the time will be **0.8 Sec**

$$\text{Cardiac Cycle Time} = \frac{\text{Minute}}{\text{HR}} = \frac{60}{75} = 0.8 \text{ sec}$$

Cardiac cycle time and heart rate are **inversely** proportional

Cardiac Cycle 0.8 sec (when HR is 75)

- **Atrial Cycle** (0.8 sec)
  - **Atrial Systole** (0.1 sec) — shortest
  - \+
  - **Atrial Diastole** (0.7 sec) — longest
- **Ventricular Cycle** (0.8 sec)
  - **Ventricular Systole** (0.3 sec)
  - \+
  - **Ventricular Diastole** (0.5 sec)

- 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**

  Importance of long ventricular diastole:

  1-Ventricular filling

  2-Coronary blood flow (**coronary blood flow is the blood supply to the heart;** it is slowed by contraction)

Male slide only

Heart Rate & Cardiac Cycle

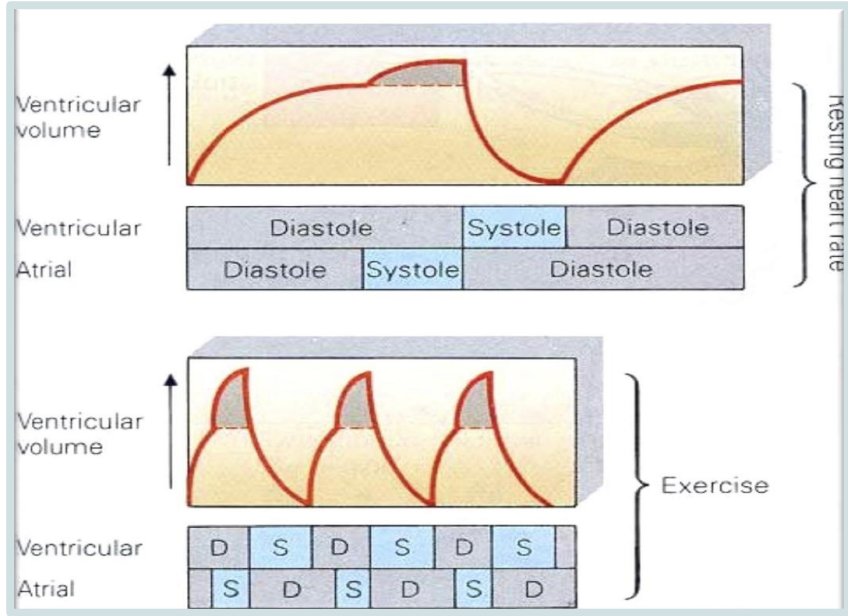
- The higher the heart rate, the lesser is duration of Cardiac cycle. However, the duration of systole is much more fixed than that of diastole.

Physiologic and clinical implications of shortened diastole:

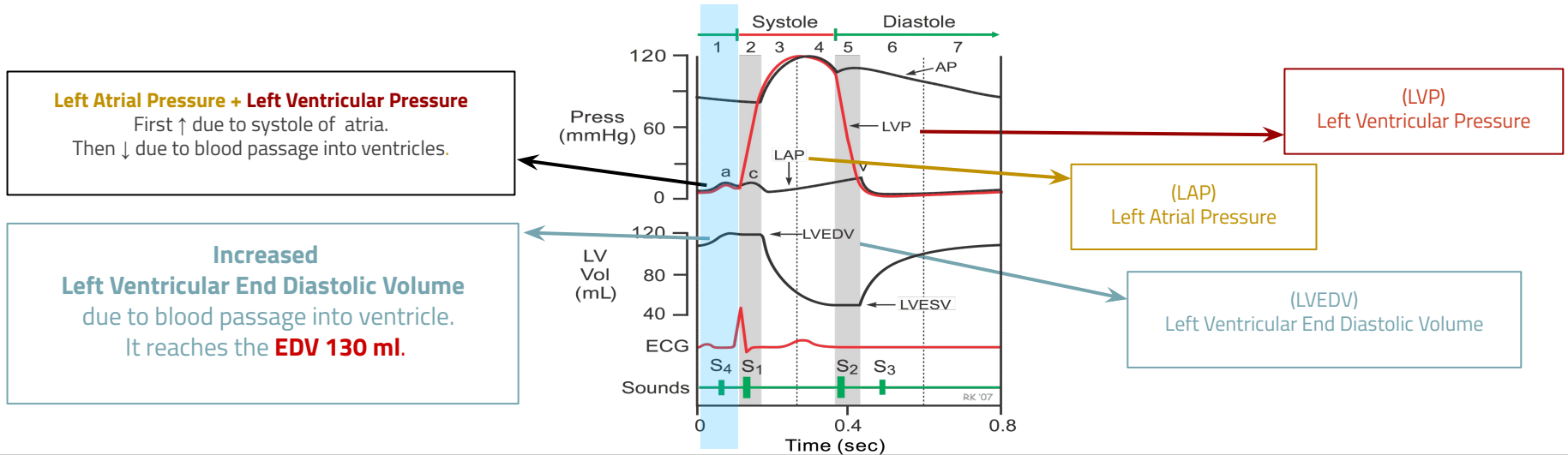
- The heart muscle rests during diastole. Coronary blood flows to the subendocardial portions of the left ventricle only during diastole. Furthermore, most of the ventricular filling occurs in diastole.
- Up to about 180/min, filling is adequate as long as there is enough venous return, and cardiac output per minute is increased by an increase in rate. However, at very high heart rates, filling may be compromised to such a degree that cardiac output per minute falls.

Effect of Atrial Contraction on Ventricular Filling

At rest, atrial contraction adds little extra blood to the ventricles. When the heart rate is high, ventricle filling time is reduced. During exercise, atrial contraction adds a **larger** amount of blood to the ventricles.



1-Atrial Systole (0.11 sec)

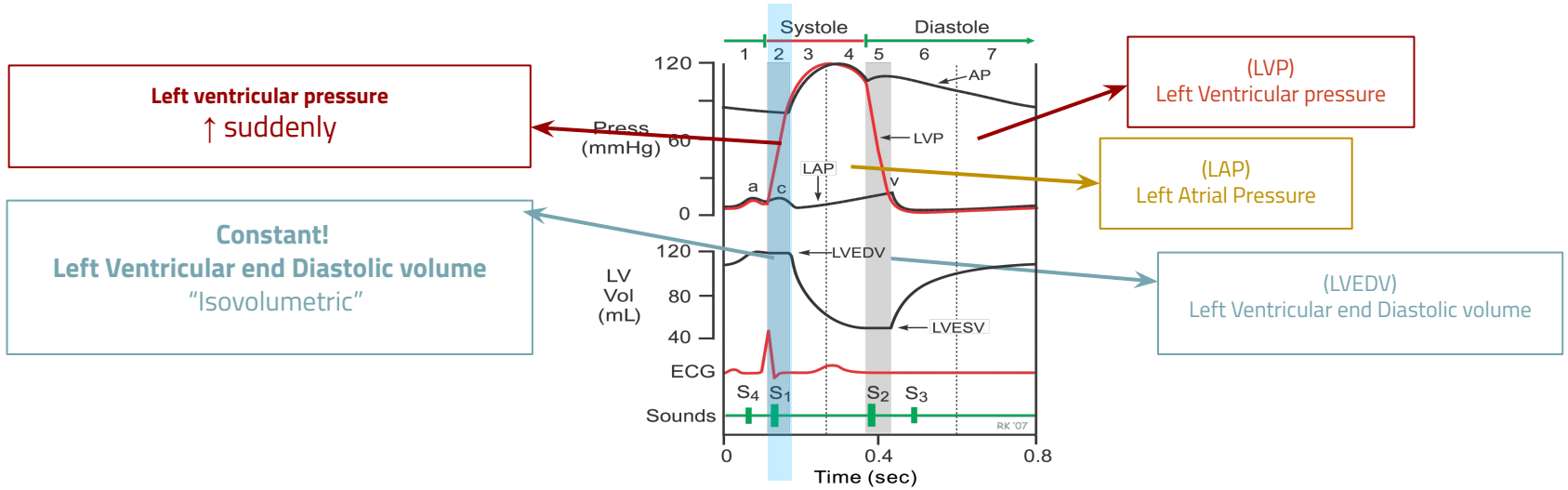
Mechanical Events	It occurs at the end of ventricular diastole (last ⅓ of diastole) 25 % of blood passes to the ventricles. Atria act as primer pumps & increase the ventricular pumping effectiveness as much as 20-25% ليه بس الربع بينتقل؟ Because of the ventricles suction which responsible for 75% of blood movement. **Valves:** **AV** valves still **open** (**semilunar** valves still **closed**) AV valves opened during rapid filling phase of ventricles blood goes from atria to ventricles. لذلك لما يمرض Atrium لأي سبب كان وتأثر انقباضه ما نعتبره Life threatening لأن الفنتريكلز بتأخذ ٧٥٪ من حاجتها بدون انقباضه عادي
Ventricular Volume Changes	↑ due to blood passage into ventricle. It reaches **EDV 130 ml** (remember the ventricle already filled with 75% passively during the ventricle diastole)
Pressure Changes	**Atrial:** First ↑ due to systole of atria. Then ↓ due to blood passage into ventricles As the atrial pressures fall, the AV valves close and left ventricular volume is now maximum → EDV (120 ml in LV) **Ventricular**: First slightly ↑ due to entry of blood from atria. Then ↓ due to dilatation of ventricles (for accommodation) In both cases, it is less than atrial pressure (because once it's higher, AV valve will close)
Heart Sounds	**4th heart sound** heard due to **1-atrial contraction 2-Blood rush from atria to ventricles.**
Before you study this part, check the boxes on the right side.	

Ventricular systole (3 phases)

cardiac cycle ثاني مرحلة من
الأولى من أصل الثلاث مراحل حقت
Ventricular systole

First one: **2- Isovolumetric Contraction Phase** (0.05 sec)

Mechanical Events	It occurs at beginning of ventricular systole. atrial pressure > ventricular pressure = AV OPENS + semilunar CLOSES atrial pressure < ventricular pressure = AV CLOSES + semilunar OPENS Starts with **A-V valve closure** (**Semilunar** valves still **closed**) → Ventricle is a closed chamber. → It contracts isometrically (tension develops without change in muscle length) (no shortening, no emptying) → Ventricular pressure increases, & becomes higher than atrial pressure. This causes the AV valves to close → Aortic valve (semilunar) opens (after 0.6) at the end of this phase when **LV exceeds** 80mmHg **And RV** > 8mmHg .
Ventricular Volume Changes	Volume in ventricle still EDV (both valves closed; constant volume)
Pressure Changes	Team 436: at the end of this phase, aortic (not atrial) pressure reaches its minimum value which is 80 mmHg. **Atrial pressure:** ↑ due to doming/bulging of closed AV cusps into atria. يوم تقفلت القالفز انتفخت على فوق زي البارشوت فقلت مساحة الاتريوم> زاد الضغط **Ventricular pressure** : ↑ suddenly (from 3 to 80 mmHg in LV).
Heart Sounds	**1st heart sound** heard due to **1- Sudden closure of A-V valves contraction**, **2- Vibration of chordae tendinae of papillary muscles.**



Ventricular systole (3 phases)

Second one: **3- Maximum (Rapid) Ejection Phase** (0.10 sec)

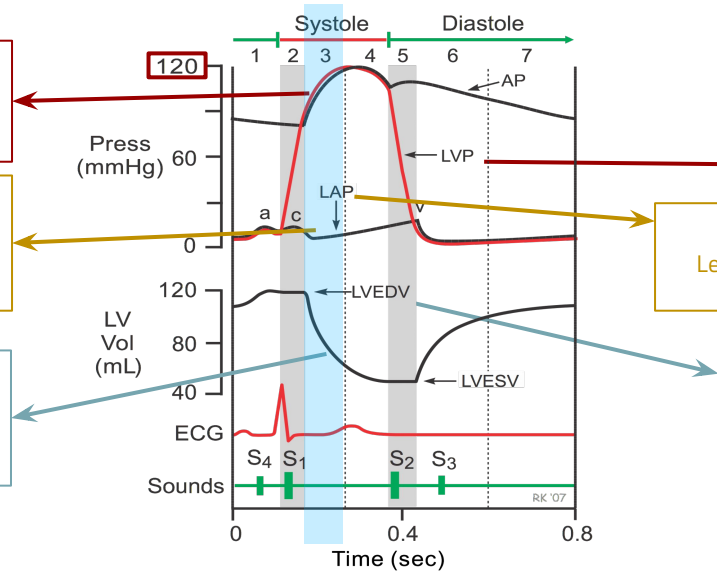
[Duration 1/3] (2/3 or 70% blood is ejected)

Mechanical Events	دائمًا سواء في **Contraction ejection / relaxation filling** صمام مفتوح وصمام مقفل	when LV exceeds 80mmHg (which is the aortic pressure) And RV > 8mmHg . **(AV** valves still **closed)** **Semilunar** valves **open** at beginning of this phase لأن مثل ماقلنا الفنتركلز وصل أعلى من الاتريال The ventricles contract **isotonically** (with shortening) pushing or emptying most of blood **(70%-75% of ventricular blood**) into aorta & pulmonary artery **passively**.
Ventricular Volume Changes		↓ sharply due to shortening of ventricular wall and ejection of blood.
Pressure Changes	**Team 436:** -In this phase aortic (not atrial) pressure reaches its maximum value which is also 120 mmHg (like LV) after aortic valve opens. -IN THIS PHASE BLOOD GOING FROM LV TO AORTA > THAN BLOOD LEAVING AORTA TO TISSUES.	**Atrial pressure:** ↓ because when ventricles contract, they pull fibrous AV ring with AV valves downward thus ↓ atrial P. البارشوت اللي قلنا ارتفع قبل شوي، نزل الحين فانخفض الضغط **Ventricular pressure**: reaches 120 mmHg in left Ventricle.
Heart Sounds		No sound (Any sound occurs in ejection phases it will be pathological conditions)

Left ventricular pressure (LVP)
↑ reaches **120 mmHg in left V**

Left atrial pressure (LAP)
First ↓ because when ventricles contract, they pull fibrous AV ring with AV valves downward thus

↓ sharply due to shortening of ventricular wall and ejection of blood.



(LVP)
Left Ventricular pressure

(LAP)
Left Atrial Pressure

(LVEDV)
Left Ventricular end Diastolic volume

Ventricular systole (3 phases)

Third one: **4- Reduced (slow) Ejection Phase** (0.15 sec)

[Duration 2/3] (1/3 or 30% blood is ejected)

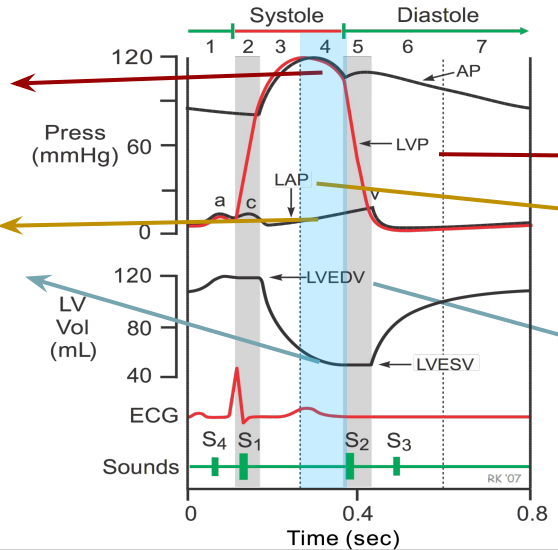
يعني صح وقته اطول بس كمية الدم اللي يضخها أقل

Mechanical Events	The ventricles contract with **less shortening** than the previous phase and **less blood is ejected** (end of systole). Almost (**25% of ventricular blood**) is ejected, **25% of SV.** **(Semilunar** valves still **opened** **AV** valves still **closed)** That means the ejection of **Stroke volume** is: 75% of it ejected during maximum ejection 25% of it ejected during reduced ejection
Ventricular Volume Changes	Continue ↓ gradually till it reaches the **end systolic volume** (ESV=60 ml). الدم قاعد يطلع لبرا فبيقل الضغط تدريجيًا
Pressure Changes	ترا هنا يقصد مرحلة atrial diastole اللي قلنا انسحب عليها **Atrial pressure:** Still ↑ gradually due to accumulation of venous blood. **Ventricular pressure:** ↓ gradually (from 120 to 80 mmHg in LV), as volume of blood leaving ventricles > the decrease in ventricular volume. The pressure in the ventricle keeps decreasing until it becomes lower than that of the great vessels
Heart Sounds	No sound

Left ventricular pressure
↓ gradually, as volume of blood leaving ventricles > the decrease in ventricular volume

Left atrial pressure (LAP)
Still ↑ gradually due to accumulation of venous blood.

Constant!
Left Ventricular end Diastolic volume
"Isovolumetric"



(LVP)
Left Ventricular pressure

(LAP)
Left Atrial Pressure

(LVEDV)
Left Ventricular end Diastolic volume

Before Ventricular Diastole begins there is a phase called**: protodiastole. Once the ventricular muscle is fully contracted, the already falling ventricular pressures drop more rapidly (0.04 Sec)**

Then the ventricular relaxation (diastole) begins (4 phases).

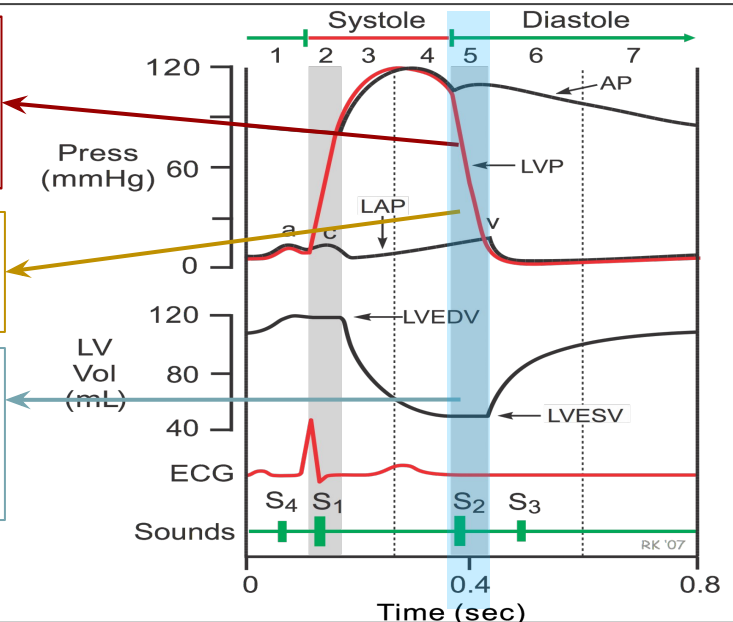
First one: **5-Isovolumetric Relaxation Phase** (0.06 sec)

Mechanical Events	It occurs at the beginning of diastole. **Semilunar** valves **close** at the beginning of phase because When ventricle pressure < arterial pressure→ backflow of blood → forces semilunar valves to close. **(AV** valves still **closed)** For 0.06s The **ventricles relax without changing their volume**. (iso-volumetric) دائمًا سواء في Contraction/ relaxation Isovolumetric كل الصمامات مقفلة وهذا اللي مساعده في حجمه الثابت
Ventricular Volume Changes	Ventricular volume is **constant** at the **ESV (60 ml)**.
Pressure Changes	ترا هنا يقصد مرحلة atrial diastole اللي قلنا انسحب عليها **Atrial pressure:** Still ↑ gradually due to atria fill up because of accumulation and of venous blood. **Ventricular pressure:** ↓ rapidly (from 80 to 3-12 mmHg in LV), because the valves are closed & the relaxation is isometric.
Heart Sounds	**2nd heart sound** due to sudden closure of semilunar valves.

Left ventricular pressure
↓ suddenly
Pressure in ventricle keep falling till it is < atrial pressure

Left Atrial Pressure
Still ↑ gradually due to accumulation of venous blood.

Constant!
Left Ventricular end systolic volume = 60ml
"Isovolumetric"



(LVP)
Left Ventricular pressure

(LAP)
Left Atrial Pressure

(LVEDV)
Left Ventricular end Diastolic volume

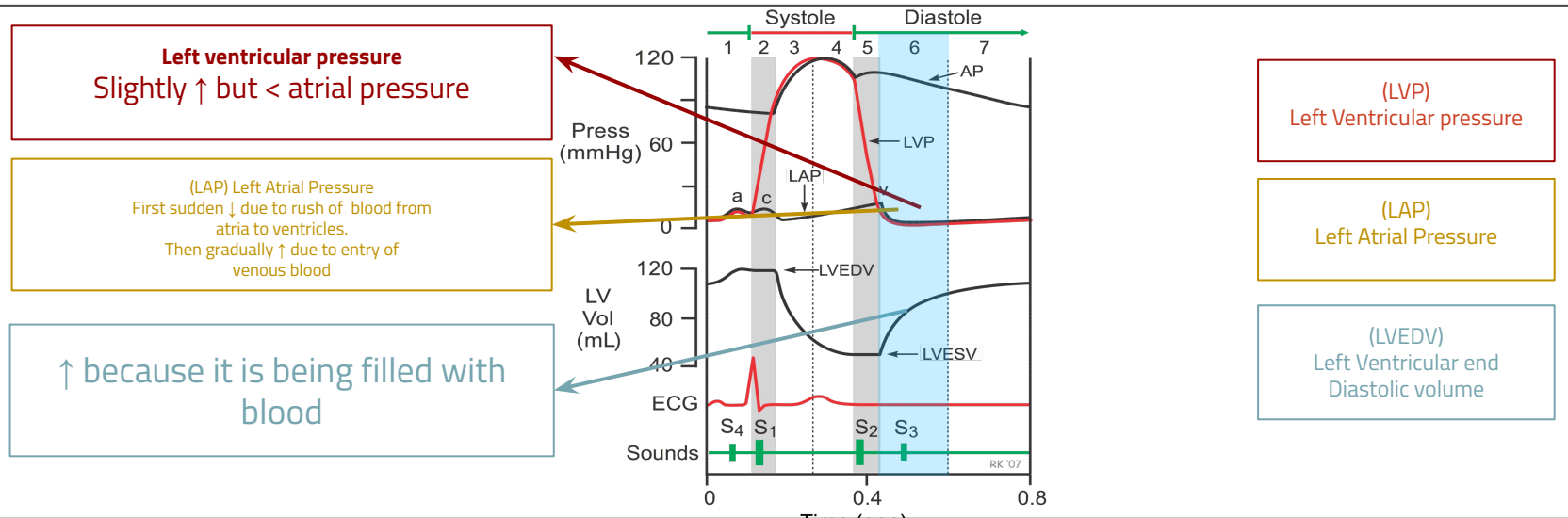
Ventricular relaxation/diastole (3 phases)
Second one: **Maximum (Rapid) Filling Phase**

Mechanical Events	Atrial pressure > ventricular pressure: **AV** valves **open**. **(Semilunar** valves still **closed)** ≈ **60-70%** of blood passes **passively** to the ventricles along pressure gradient. Why passive? Because the Normal suction by ventricles, مثل ماقلنا قبل نعتمد على انقباض الاتريوم بربع الدم او ٢٠٪ هنا فسروا الباقي كيف يجي؟ 60-70% : by maximum filling <5% : by reduced filling (next slide)
Ventricular Volume Changes	↑ because it is being filled with blood (remember AV valve opened!!)
Pressure Changes	**Atrial pressure:** First sudden ↓ due to rush of blood from atria to ventricles. Then gradually ↑ due to entry of venous blood **Ventricular pressure:** Slightly ↑ but < atrial pressure (لو صار اعلى من الاتريوم راح تقفل الفالف)
Heart Sounds	**3rd heart sound heard** due to rush of blood into ventricles and vibration in ventricular wall.

خذوها قاعدة، ماتنفتح AV valves إلا إذا زاد ضغط الاتريوم عن الفنتريكلز يعني بإختصار فتحها وقفلها متحكم فيها ضغط الاتريوم

مثل ماقلنا في Ejection or Filling : واحد مفتوح وواحد مقفل المفتوح في AV < Filling لأن الدم متوجه للفنتركلز Semilunar < Ejection المفتوح في Aorta or pulmonary لأن الدم متوجه لل

تخيلو بلونه فيها فتحتين وحدة كانت مقفلة والثانية فاتحة وقاعده تعبيها بماء فالضغط عالي جوا، اول ما تفتح الفتحة الثانية الماء بيتدفق وبيطلع منها فالضغط بيقل بالأول بس بما ان الفتحة اللي تعبيها ماء لسه مفتوحة بيرجع يرتفع



Ventricular relaxation/diastole (3 phases)

Third One: **Reduced (slow)** Filling Phase **(Diastasis)**

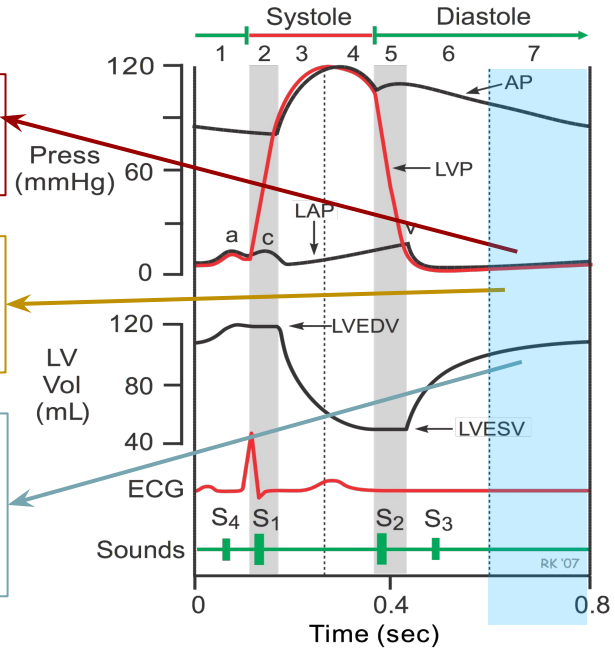
middle 1/3 of diastole

Mechanical Events	Remaining atrial blood (≈ <5%) passes **passively** & **slowly** to the ventricle by pressure gradient. **(A-V** valves still **open** **Semilunar** valves: Still **closed**)
Ventricular Volume Changes	Still ↑ due to entry of blood into ventricles.
Pressure Changes	**Atrial pressure:** Still ↑ gradually due to continuous venous return. **Ventricular pressure:** Slightly ↑ gradually because the increase in volume is less than the entering blood.
Heart Sounds	-

Left ventricular pressure
Slightly ↑ gradually because the increase in volume is less than the entering blood.

(LAP)
Left Atrial Pressure Still ↑ gradually due to continuous venous return.

Constant!
Left Ventricular end Diastolic volume
"Isovolumetric"



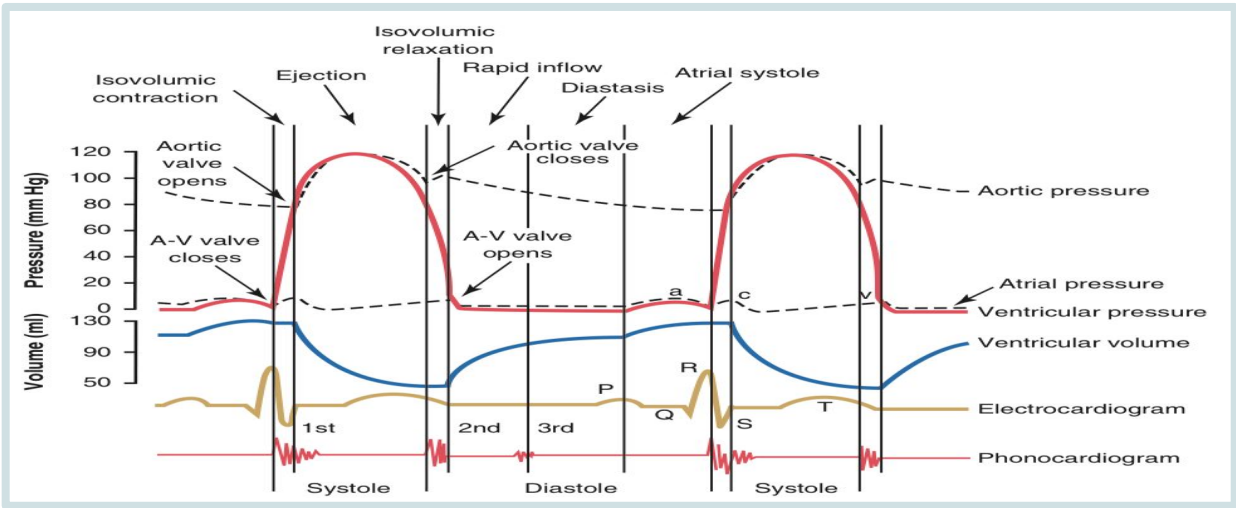
(LVP)
Left Ventricular pressure

(LAP)
Left Atrial Pressure

(LVEDV)
Left Ventricular end Diastolic volume

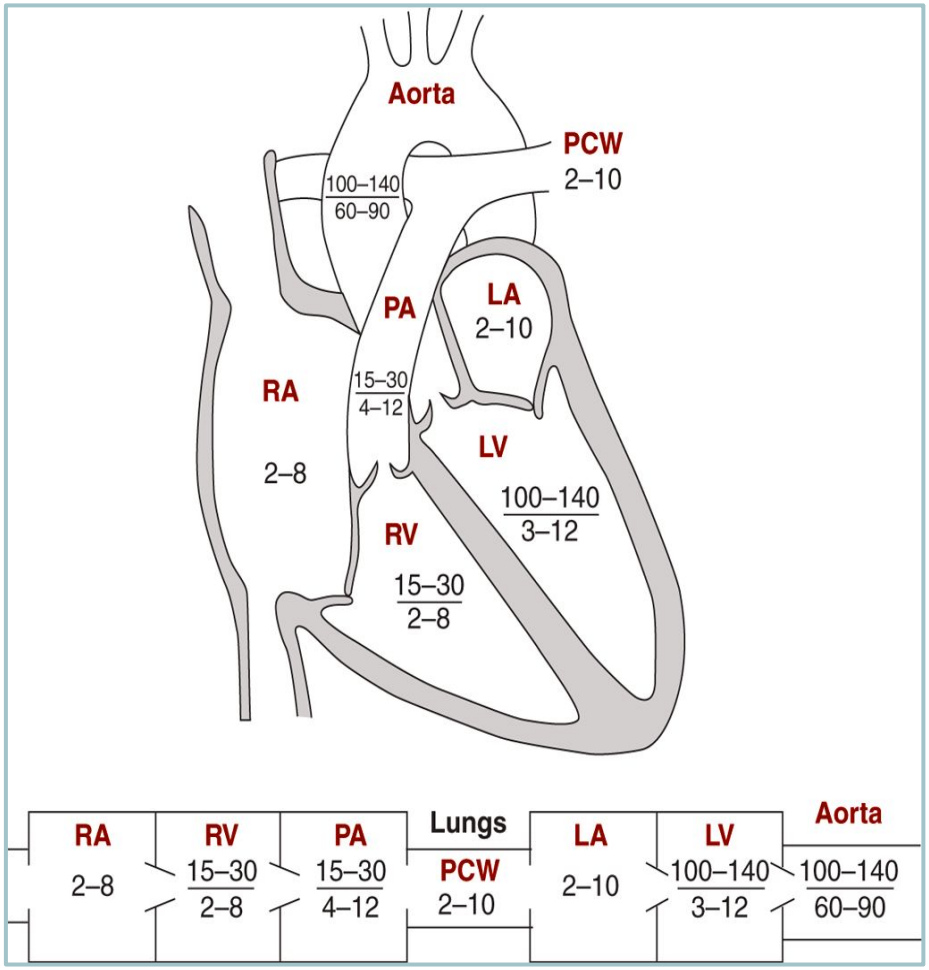
Pressure and Volume Changes During Cardiac Cycle

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 (80mmHg)	All valves are closed and contraction is **isovolumetric**	Constant
3-Maximum Ejection	↑ Sharply (120mmHg)	Shortening of the ventricular wall and ejection of blood	↓ Rapidly
4-Reduced Ejection	↓ Gradually (80mmHg)	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

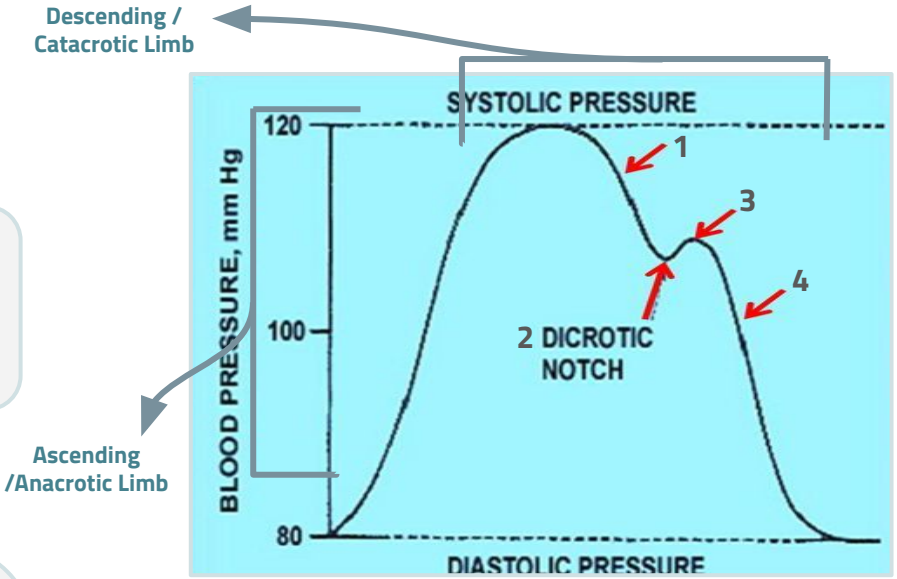


Pressure changes in cardiac cycle

Location	Normal range	
	Systole	Diastole
RT Atrium	2- 8 ,7 mmHg	
LT Atrium	2-10 mmHg	
Pulmonary Artery	25-30 mmHg	4-12 mmHg 10 mmHg
RT Ventricle	25-30 mmHg	2-8 mmHg
LT Ventricle	100-120 mmHg	3 or 2 -12 mmHg
Aorta	120 mmHg	80 mmHg



Aortic Pressure Changes (Curve)



A) Ascending or Anacrotic Limb

With the 'rapid ejection phase'.

Aortic pressure ↑ up to 120 mmHg

(راح يزيد لان الدم اللي قاعد يدخل بسرعة اكثر من اللي ينضخ للجسم في هالوقت)

B) Descending or Catacrotic Limb

Passes in 4 stages:

1. ↓Aortic Pressure

With 'reduced ejection phase'.

Amount of blood amount leaves aorta > enters

2. Dicrotic Notch (Incisura)

Sudden drop in aortic pressure. Due to closure of aortic valve.

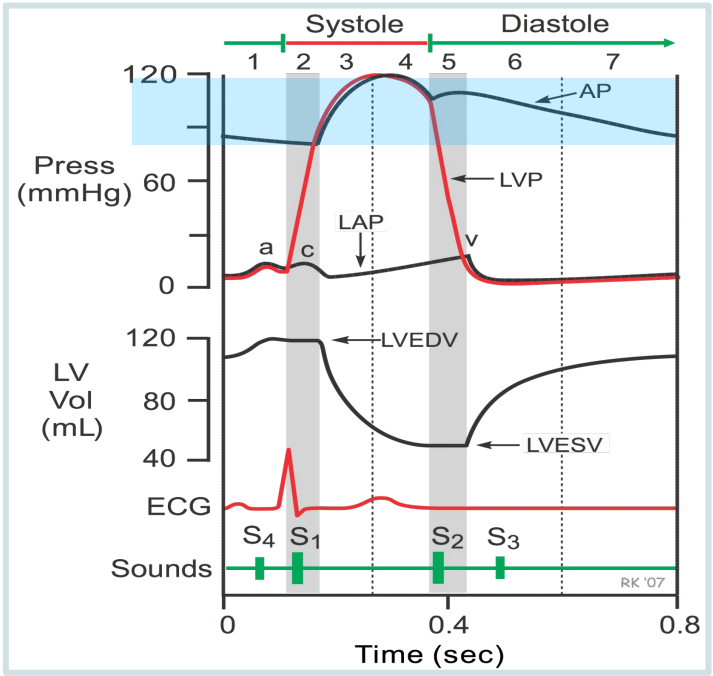
This notch is seen in the aortic pressure curve at end of ventricular systole

3. Dicrotic Wave

Slight ↑ in aortic pressure. Due to elastic recoil of the aorta.

4. Slow ↓ Aortic Pressure

Down to 80 mmHg. Due to continued flow of blood from aorta into systemic circulation



Pulmonary artery pressure changes are similar to the aortic pressure changes [Magnitude 3-4 times Less].
Normal pulmonary artery pressure during the cardiac cycle ≈ 25-30/4-12 mmHg

Why is aortic pressure higher than ventricular pressure during diastole?

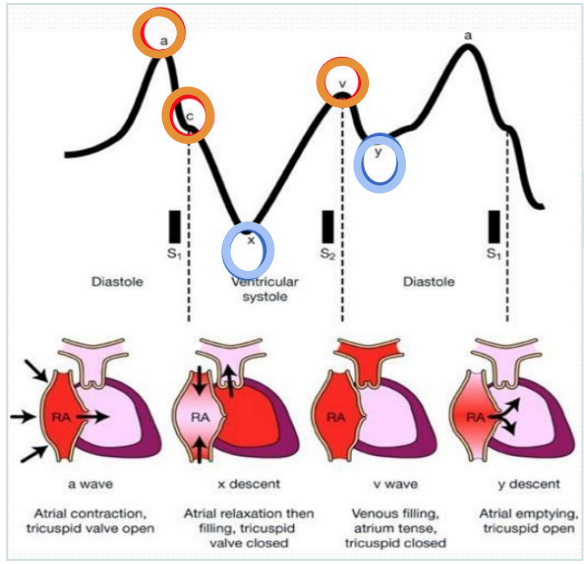
Because during ventricular contraction, the aorta stores energy by stretching (pressure reservoir).
During ventricular diastole, the aorta releases this pressure to maintain blood flow to the body.

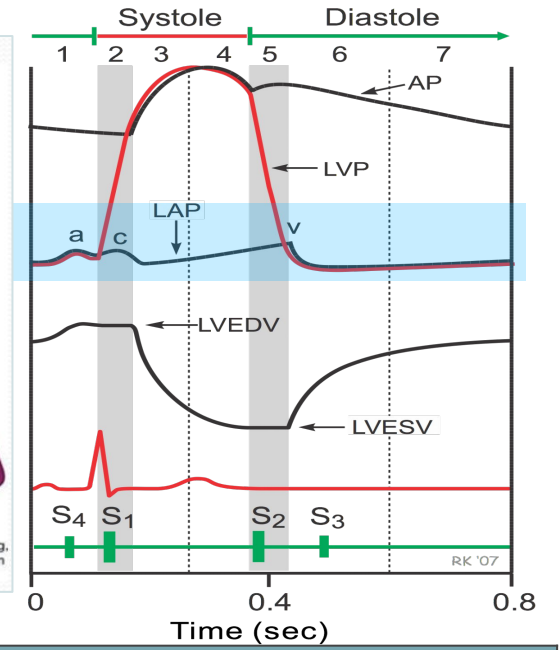
Atrial Pressure Changes In The Cardiac Cycle

Atrial pressure results in:

- **3 Upward Deflections(waves): a, c, & v waves**
  2 components in each wave:
  +ve (↑arterial pressure), -ve (arterial↓ pressure)
- **2 Downward deflections(waves): x & y waves**

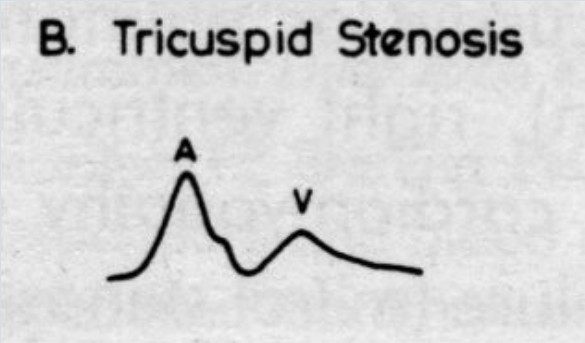
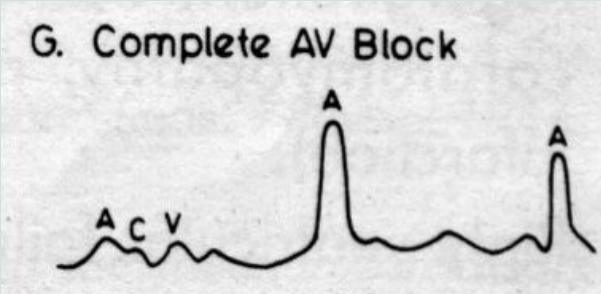
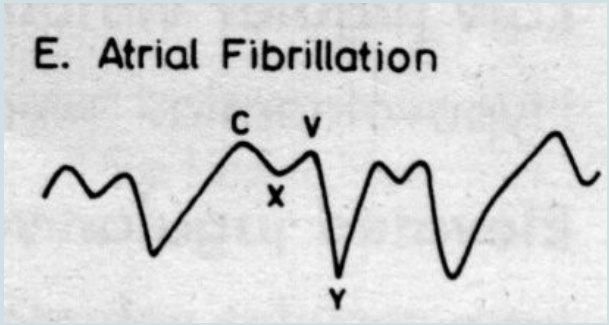
The 3 wave (a, c, & v) are equal to ONE cardiac cycle = 0.8 sec





Atrial Pressure Wave	Cause
a wave **Atrial systole**	**+ve** due to atrial systole **-ve** due to blood passage into ventricles.
c wave (cusp) **Ventricular systole**	**+ve:** as a result of bulging of AV valve into the atria during 'isovolumetric contraction phase' **-ve:** as a result of pulling of the atrial muscle & AV cusps down during 'rapid ejection phase', resulting in ↓ atrial pressure (when ventricles contract, they pull fibrous AV ring with AV valves downward)
'x' descent	Downward displacement of AV valves during 'reduced ejection phase'
v wave (venous return) **Atrial diastole**	**+ve:** due to venous return during atrial diastole. **-ve:** due to entry of blood into ventricles during 'rapid filling phase.'
'y' descent	↓↓ atrial pressure due to entry of blood into ventricles during 'reduced filling phase.'

Abnormalities of a wave

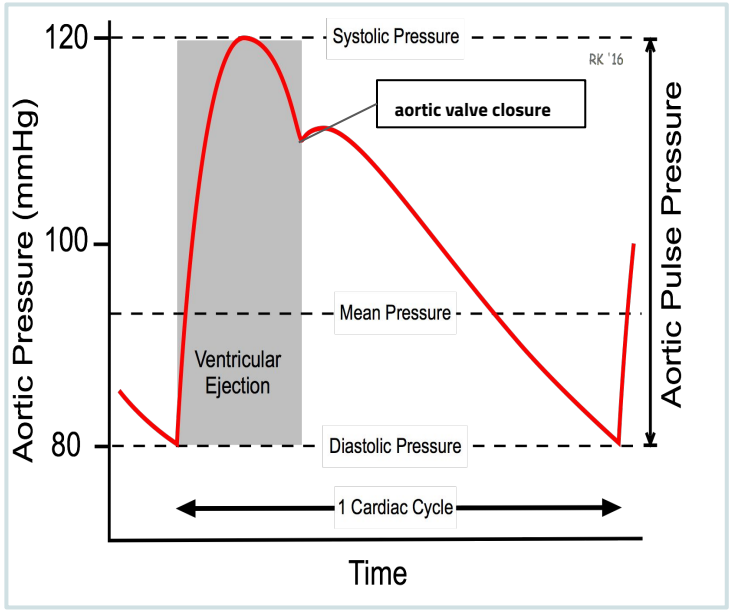
The abnormality	Description
Elevated "a" wave (Tricuspid stenosis) 	**Decreased ventricular compliance:** ❖ ventricular failure ❖ pulmonic valve stenosis ❖ pulmonary hypertension
Cannon "a" wave Atria and the ventricle contract In irregular manner (لدرجة ان انقباضهم ممكن يصير في نفس الوقت) 	**Atrial-ventricular asynchrony (atria contract against a closed tricuspid valve):** ❖ complete heart block ❖ following premature ventricular contraction ❖ during ventricular tachycardia ❖ with ventricular pacemaker
Absent "a" wave 	❖ Atrial fibrillation ❖ Atria flutter

In Girls' slides only

Arterial Pressure Changes

Similar to aortic pressure waves, but sharper.
Reflects a systolic peak pressure of 110-130 mmHg & a diastolic pressure of 70-85 mmHg.

Pulse pressure= systolic P - Diastolic P



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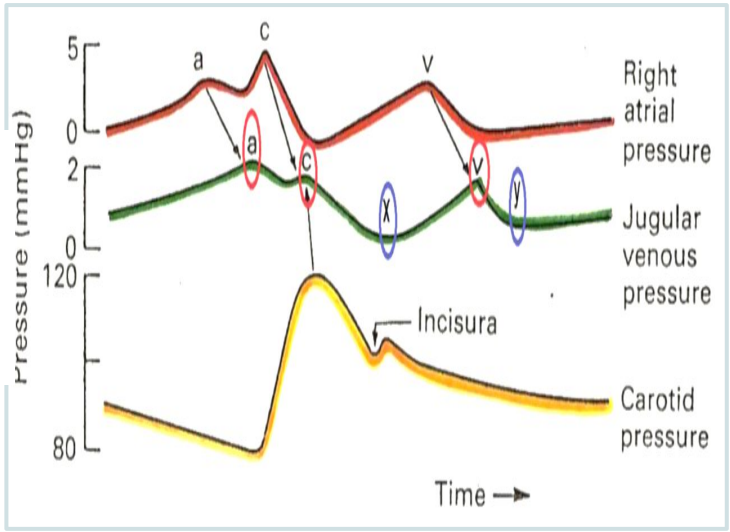
Jugular Vein Pulse Changes

Similar recordings of transmitted delayed atrial waves:

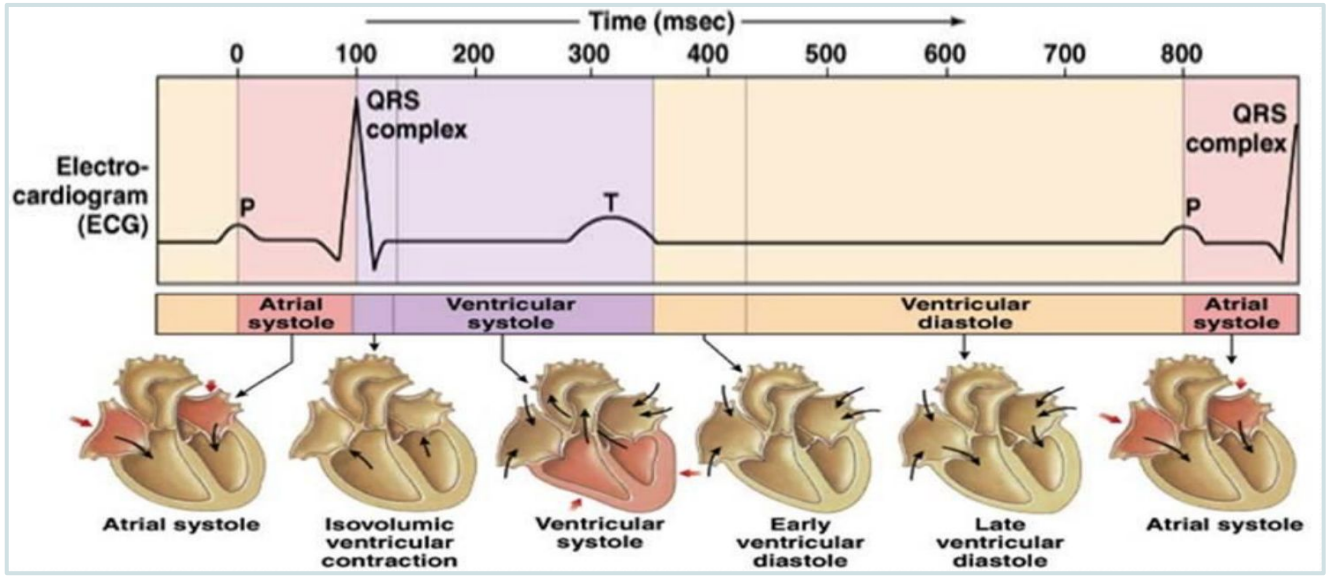
- **3 upward waves: a, c, & v**
- **2 downward waves: x & y**

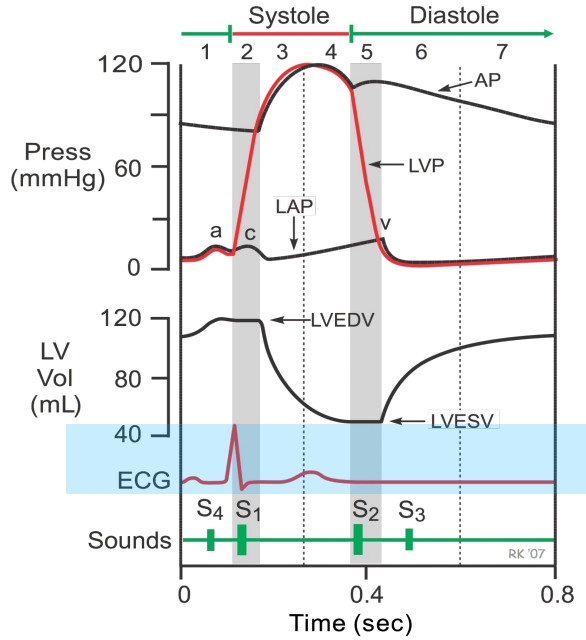


ECG Changes

Electrical impulse always shows before mechanical (contraction).

Phase	ECG Changes
1-Atrial Systole	P- wave starts 0.02 sec before atrial systole & continues. 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.





Only in female slides

Basic Myocardial Muscle Mechanics

Ventricular phases

Systole

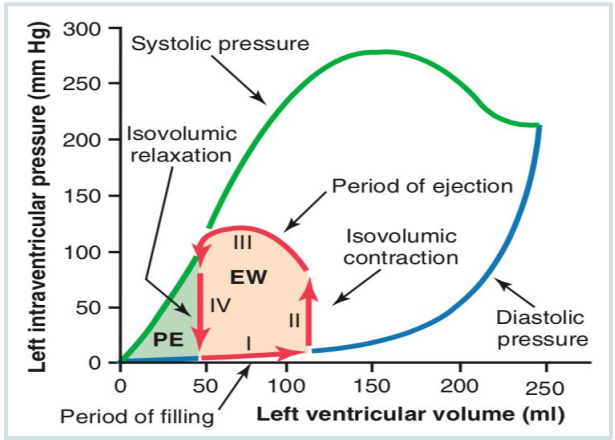
Early Systole: Isovolumetric contraction
Late Systole: Isotonic contraction "Ejection Phase"
accurately : reduced ejection phase

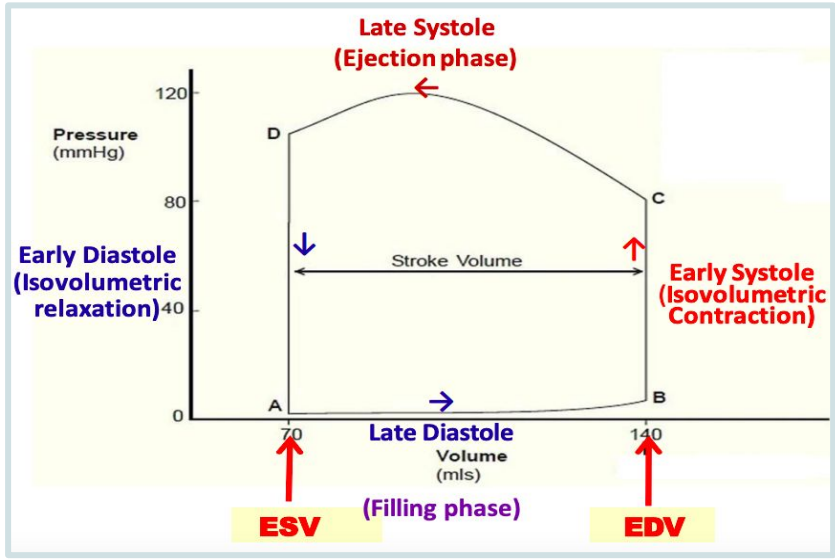
Diastole

Early Diastole: Isovolumetric relaxation
Late Diastole: Isotonic relaxation "Filling Phase"accurately : reduced filling phase

Left Ventricular Pressure - Volume Diagram (loop)

- 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**

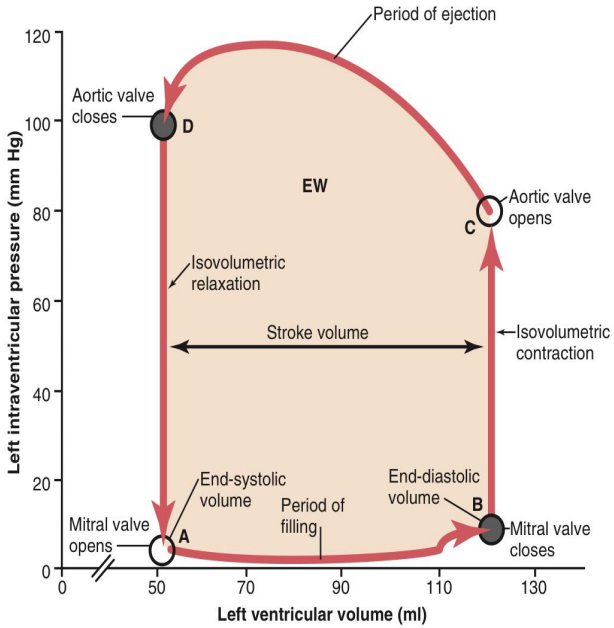




Female slide ONLY

Left Ventricular Pressure - Volume Loop

Phase III (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.



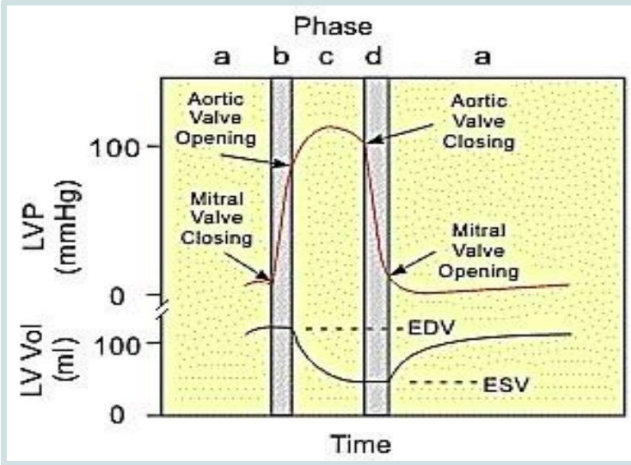
Phase IV (Isovolumic relaxation phase):
- At the end of ejection period (point D), the aortic valve closes
- Ventricular pressure falls back to the diastolic pressure level.
- The ventricle returns to its starting point **(point A)**.
(all valves are closed)

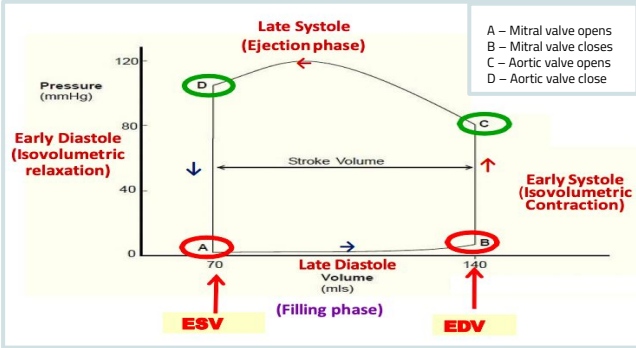
Phase II (isovolumic contraction phase):
- The volume of the ventricle does not change.
- Ventricular pressure rises to about 80 mm Hg **(point C)**.

Phase I (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)

What you should remember about Pressure - Volume loop?

- **Diastolic filling** occurs between points A & B.
- **Ejection** occurs between points C & D.
- **Mitral valve** open at the beginning of filling phase (point A) and close at its end (point B)
- **Aortic valves** open at the beginning of ejection phase (point C) and close at its end (point D)





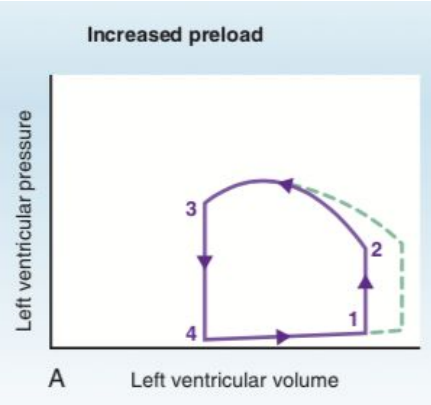
Importance of Ventricular Volume-Pressure Loop

- **This diagram is used for calculating cardiac work output.**

The shaded area, labeled "EW" **represents the net external work output** (not cardiac output) of **the ventricle during cardiac cycle**.

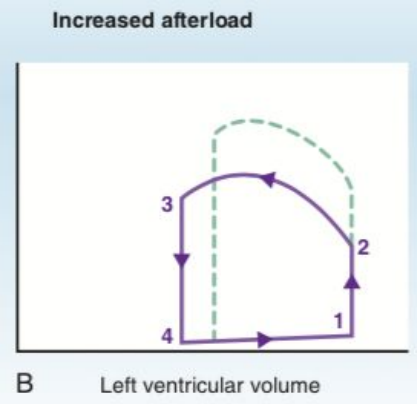
When the heart pumps large quantities of blood, the area of the work diagram becomes much larger. As during sympathetic stimulation.

Effects of changes in (A) preload, (B) afterload, and (C) contractility on the Ventricular Volume-Pressure Loop*



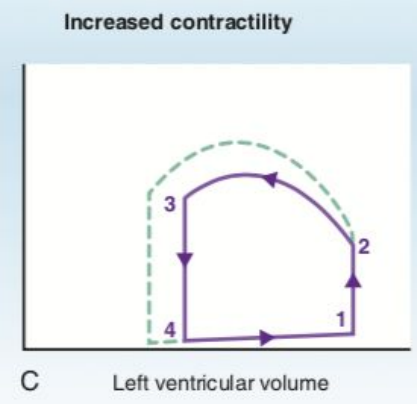
A. Increased preload: → <u>increased width</u> of the PV loop

- Refers to an ↑ in EDV and is the result of ↑ VR
- Causes an ↑ in SV based on the Frank–Starling relationship.



B. Increased afterload: →<u>decreased width</u> & increased height of the PV loop

- Refers to an ↑ in aortic pressure.
- The ventricle must eject blood against a higher pressure, resulting in ↓ in SV, resulting in an ↑ in ESV.



C. Increased contractility (ex: sympathetic stimulation)**:→<u>increased width & height</u> of the PV loop.**

- The ventricle develops greater tension than usual during systole, causing an ↑ in SV, resulting in a ↓ in ESV.

*Refer to CO & SV Lecture for better understanding

Quiz:

1-in which of the cardiac cycle phases the ventricular volume doesn't remain constant?
A) Atrial systole
B) Protodiastolic
C) Isometric Relaxation
D) Isometric contraction

2-what is the reason of the mild elevation of aortic pressure during the dicrotic wave of catacrotic limb?
A) blood flow to aorta
B) elastic recoil of the aorta
C) closure of aortic valve
D) blood flow from aorta

3- At which phase of the cardiac cycle the Aortic notch appears?
A) Isovolumetric contraction
B) Isovolumetric relaxation
C) Slow ejection
D) B&C

4- In which Atrial pressure wave the systole starts?
A) The beginning of c wave
B) The end of a wave
C) The beginning of v wave
D) A&B

5- a wave is followed by which wave in ECG?
A) p wave
B) T wave
C) QRS complex
D) A&B

6- At which point of the PV loop does the aortic valve close?
A) Point A
B) Point B
C) Point C
D) Point D

7- What happens at point B → C of the PV loop?
A) filling phase
B) isovolumic contraction phase
C) Ejection phase
D) Isovolumic relaxation phase

8- what causes increased width & height of the PV loop?
A) Increased preload
B) Increased afterload
C) Increased Contractility
D) Increased Conduction

9-Which of the following events occurs at the end of the period of ventricular ejection?
A) A-V valves close
B) Aortic valve opens
C) Aortic valve remains open
D) Pulmonary valve closes

10- **Which of the following phases of the cardiac cycle follows immediately after the beginning of the QRS**
A) Isovolumic contraction
B) Ventricular ejection
C) Atrial systole
D) Diastasis

Answer Key: 1A - 2B - 3D - 4D - 5C
6D - 7B - 8C - 9D-A10

Quiz:

1- mention THREE conditions that can be associated with elevated 'a' wave .

2- what is the importance of the LV pressure - Volume loop?

3-mention the phase of each heart sound

A1: ventricular failure, pulmonic valve stenosis, or pulmonary hypertension

A2: it is used for calculating cardiac work output.

A3: **S1>**Isovolumetric contraction phase **S2>** Isovolumetric Relaxation Phase **S3>**MAXIMUM (rapid) filling phase S4>atrial systole phase

Team Leaders

Teif Almutairi

Abdulaziz Alsuhaim

Sub-Leaders

Sarah AlQahtani

Sadem Al Zayed

Members:

Ghada Alothman

Hessah Alalyan

Nawaf Alghamdi

Abdulaziz Alkraida

Basel Fakeeha

Mohammed AlQhidan

Reviewer:

Shatha Aldhohair