جامعة الملك سعود
King Saud University

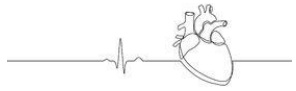
Please remember that is very important to completely understand physiology.
You may contact the physiology leader for any questions.

Cardiac Cycle I & II

Index:
Red: important Grey: extra information Green: doctor's notes yellow: numbers
Purple: only in female slides Blue: only in male slides

غيداء آل مصمع
عبدالرحمن الحيسوني
Revised by

Physiology
Team437



MED437
KING SAUD UNIVERSITY

OBJECTIVES

by the end of this lecture you will be able to:

- Main function of heart
- General principles of the cardiac cycle
- Identify events occurring during cardiac cycle: mechanical, electrical, volume & pressure changes, heart sounds.
- Understand the various phases of the cardiac cycle
- Identify the systolic and diastolic period.
- Discuss the changes of pressure and volumes in left ventricle, left atrium and the aorta during cardiac cycle
- Explain the meaning of isovolumetric contraction, period of ejection and isovolumetric relaxation.
- Discuss the volume-pressure relationship in the left ventricle.

ONLY in female slides

The Valves

- Atrioventricular valves:
  - Tricuspid valve: between right atrium & right ventricle.
  - Mitral valve: between left atrium & left ventricle.
- Semilunar valves:
  - Pulmonary valve: between right ventricle & pulmonary artery.
  - 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.
- When A-V valves open, semilunar valves close & vice versa.
- A-V cusps are held by chordae tendineae to muscular projections called “Papillary muscles”.

ONLY in female slides

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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.
- 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.

Facts About Our Heart

- It is the size of a fist and weighs ≈250g.
- In a lifetime it beats 2500 million times and pumps 110 million gallons of blood.
- Your heart creates enough energy daily to drive a truck 20 miles or 32 km.
- In a lifetime that is equivalent to driving to the moon & back.
- The heart creates its own electrical impulse and can continue to pump outside the body as long as O_2 is supplied.

Cardiac Cycle

Definition:The cardiac events that occur from the beginning of one heartbeat to the beginning of the next heart contraction.

Each cycle is generated by depolarization of SA node, followed by contraction of atria

The signal is transmitted to ventricles through A-V node & A-V bundle to cause ventricular contraction.

At a heart rate of 72 Beat/min the cardiac cycle time is 0.8 seconds long

To calculate: 60/72 =0.8

Cardiac cycle time is inversely proportional to heart rate

Events of Cardiac Cycle

Mechanical changes:

1-Phases of Cardiac Cycle

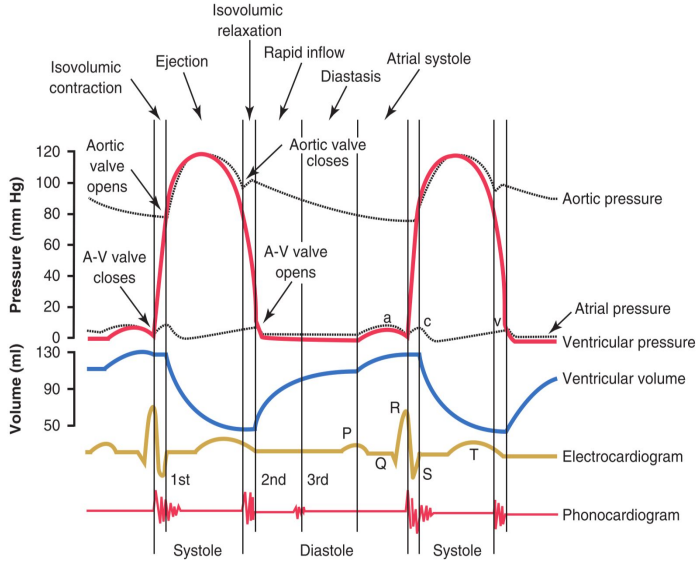
2-Heart Sounds

3-Pressure changes

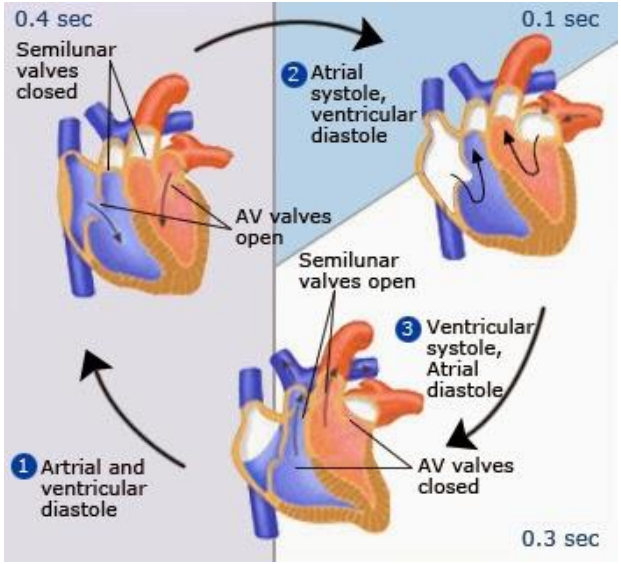
4-Volume changes

Electrical changes:

- Electrocardiogram (ECG/EKG)



Phases of Cardiac Cycle



Phases of Cardiac Cycle:

Atrial Events:

- Atrial Systole: 0.1 Seconds
- Atrial Diastole: 0.7 Seconds

Ventricular Events:

- Ventricular Systole: 0.3 Seconds
- Ventricular Diastole: 0.5 Seconds

Total length of cardiac cycle is usually 0.8 seconds

Cardiac cycle starts by systole of both atria (0.1 sec),

then systole of both ventricles (0.3 sec), then diastole of whole heart (0.4 sec).

Systole = Contraction

Diastole = Relaxation

Duration of relaxation of the heart (diastole) is longer than the duration of contraction (systole)

Variation in length of action potential & associated phenomena with cardiac rate

	Heart Rate 75/min	Heart Rate 200/min	Skeletal Muscle
Duration, each cardiac cycle	0.80	0.30	…
Duration of systole	0.27	0.16	…
Duration of action potential	0.25	0.15	0.007
Duration of absolute refractory period	0.20	0.13	0.004
Duration of relative refractory period	0.05	0.02	0.003
Duration of diastole	0.53	0.14	…

[a]All values are in seconds.

Courtesy of AC Barger and GS Richardson.

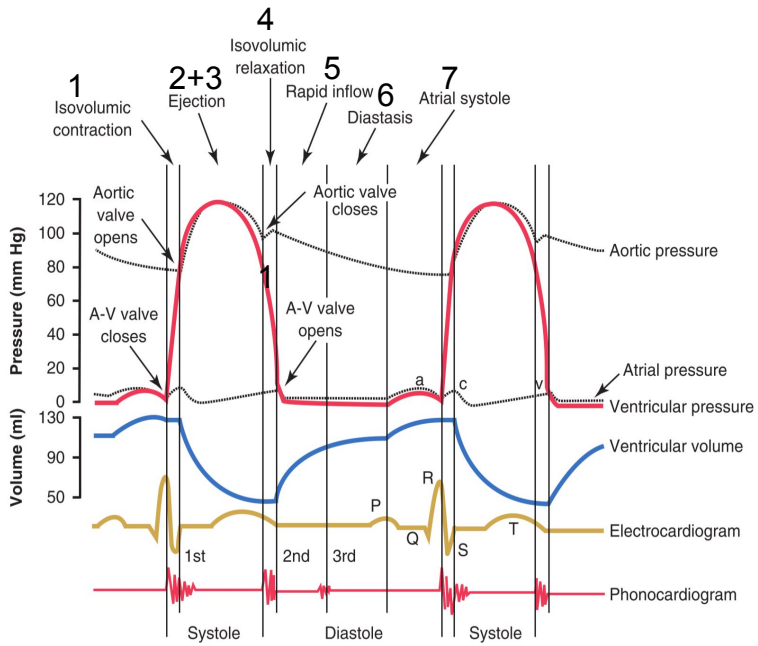
You can notice here:
Diastole phase is remarkably more decrease than systole.

In the females' slides ***atrial systole*** is the ***first event***

ONLY in male slides

Ventricular Events (7)

- Ventricular systole:
  - Isovolumetric contraction (1)
  - Ejection phase
    - 1. Rapid ejection (2)
    - 2. Slow/reduced ejection (3)
- Ventricular Diastole:
  - Isovolumetric relaxation phase (4)
  - Filling phase:
    - Rapid filling (5)
    - Slow filling (Continued filling) (6)
    - Last rapid filling (Atrial Systole) (7)



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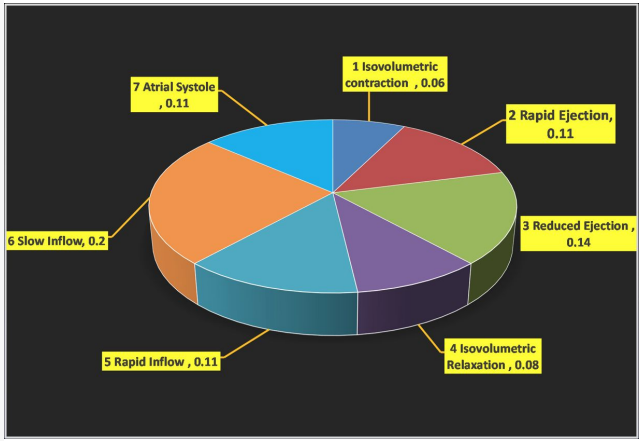
Ventricular Events (7)

Phases	Ventricular Pressure	Cause
1-Atrial Systole	First slightly ↑ Then ↓	Entry of blood from atria Dilatation of ventricles
2-Isovolumetric Contraction	↑ suddenly (80 mmHg)	All the valves are closed & the contraction is isovolumetric
3-Rapid Ejection	↑ sharply (120 mmHg)	Shortening of ventricular wall and ejection of blood
4-Reduced Ejection	↓ gradually	Volume of blood leaving ventricles > the decrease in ventricular volume.
5-Isovolumetric Relaxation	↓ rapidly	All the valves are closed & the relaxation is isovolumetric
6-Rapid Filling	Slightly ↑ but < atrial pressure	Entry of blood from atria
7-Reduced Filling	Slightly ↑ gradually	Entry of blood from atria

Phases of Cardiac cycle



Importance of long ventricular diastole?

1- Coronary blood flow

2- Ventricular filling

Ventricular SYSTOLE **(Peak of R wave of QRS complex to the end of T wave)**	**0.31 sec**
1- Iso-volumetric **Contraction**	0.06 sec
2- Maximum Ejection (2/3, 70%)	0.11 sec
3- Reduced Ejection (1/3, 30%)	0.14 sec
Ventricular DIASTOLE **(End of T wave to the peak of R wave of QRS complex)**	**0.52 sec**
-Protodiastolic phase	0.04 sec
4- Iso-volumetric **Relaxation**	0.06 sec
5- Rapid **inflow**	0.11 sec
6- Slow **inflow** / Diastasis	0.2 sec
7- Atrial systole / last rapid **filling**	0.11 sec
Total = 7 Phases of cardiac cycle	**0.8 sec**

Continues

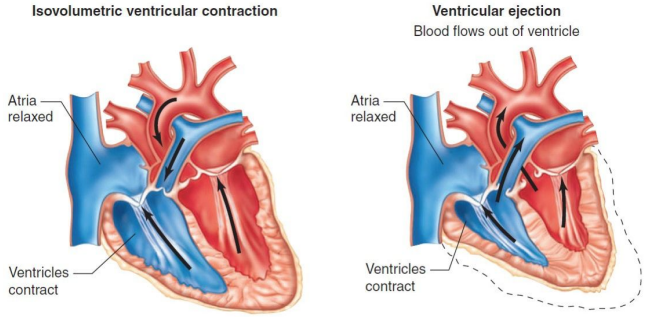
Isovolumetric ventricular contraction:
In this phase, only the pressure increase so the heart will prepare for ejection period BUT no change will occur in the volume.the valves are closed

ventricular ejection:
In this period the heart is ready for ejection so the aortic and pulmonary valve will open.

Isovolumetric ventricular relaxation:
The pressure of the ventricular is begin to decrease until it get lesser than the atrium so the blood can come from atrium but remember no volume change

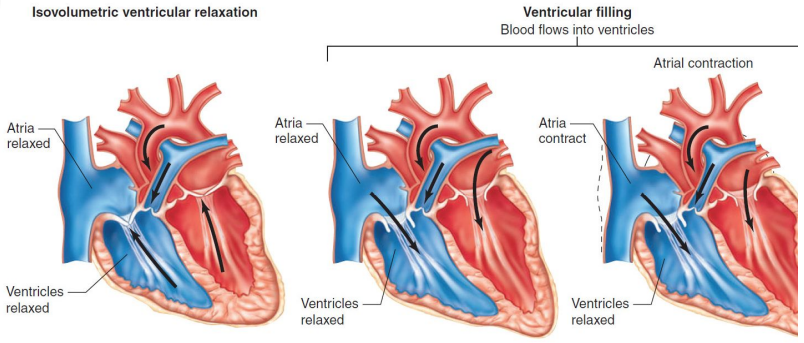
ventricular filling:
The AV valve will open and the blood will go to the ventricular

A Systole
ISO=same



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

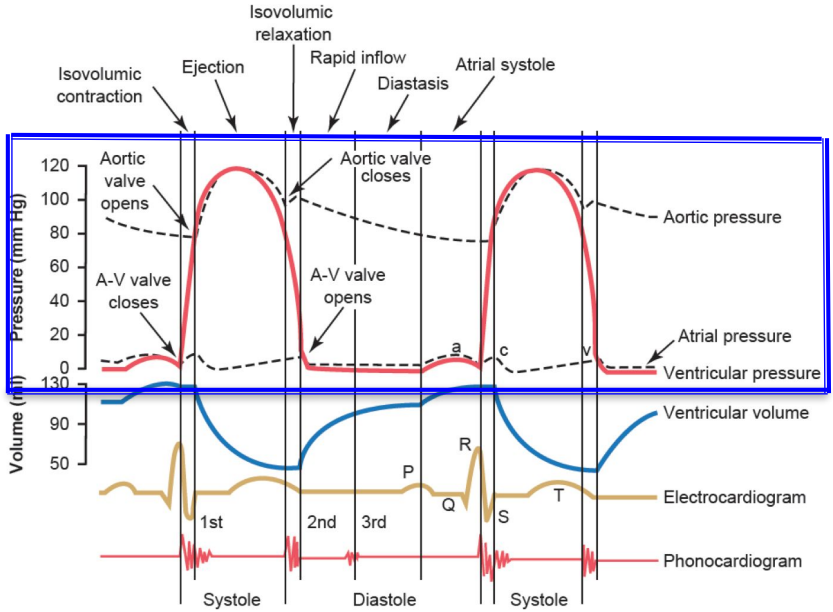
B Diastole



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

Pressure change

Chambers	Normal ranges (mm of Hg)
Right Atrium	2 - 8
Right Ventricular (Systolic) (Diastolic)	15-25 2-8
Pulmonary Artery (Systolic) (Diastolic)	15-25 8-15
Left Atrium	2-10
Left Ventricular (Systolic) (Diastolic)	100-120 2-10

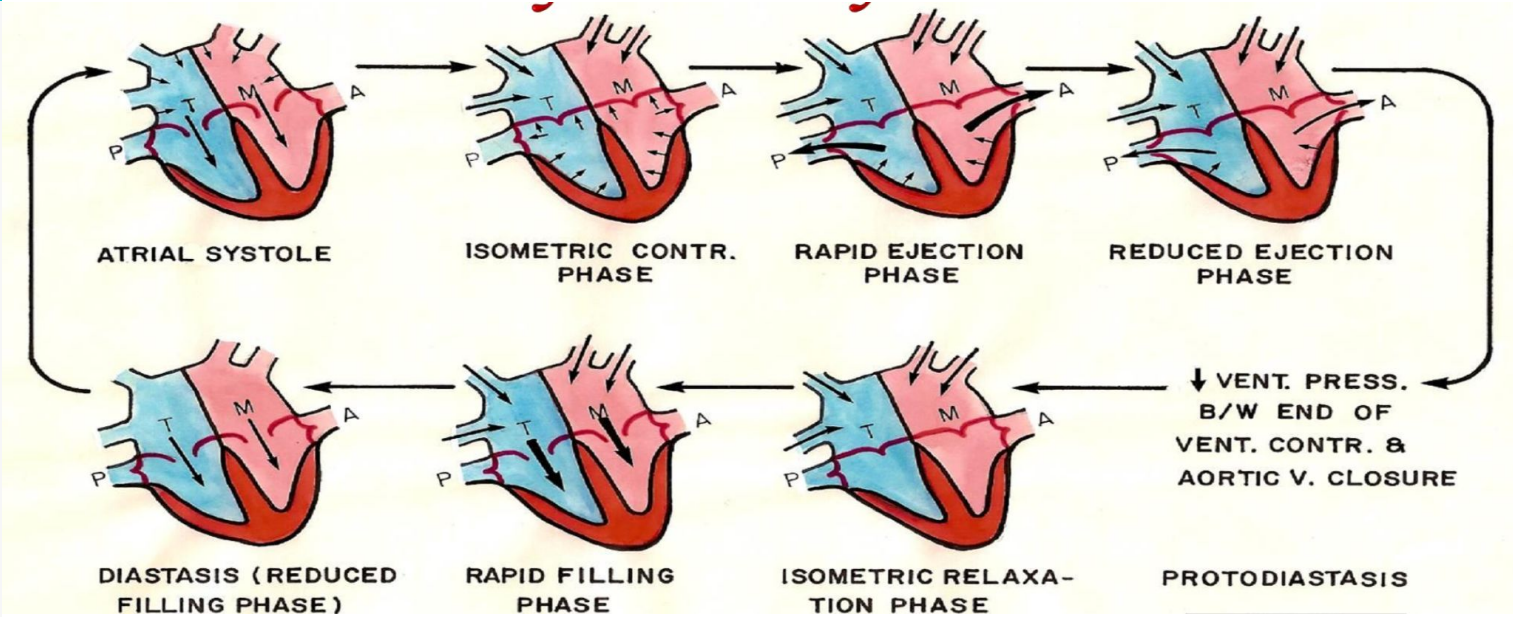


Volume Changes

End-diastolic volume (EDV)	Volume of blood in ventricles at the end of diastole = **(110- 130) (110-120)mL**
End-systolic volume (ESV):	Amount of blood left in ventricles at the end of systole = **(40-60) (40-50) mL.**
Stroke volume (SV):	○ Amount of blood ejected from ventricles during systole =**70 mL/beat.** ○ Stroke volume (SV) = EDV – ESV
Ejection fraction (EF):	○ EF is the percentage of ventricular end diastolic volume (EDV) which is ejected with each stroke. ○ EF=(SV/EDV)X100 ○ (75/120)X 100=62.5% ○ Normal ejection fraction is about 60 – 65 %. Ejection fraction is good index of ventricular function

ONLY in female slides

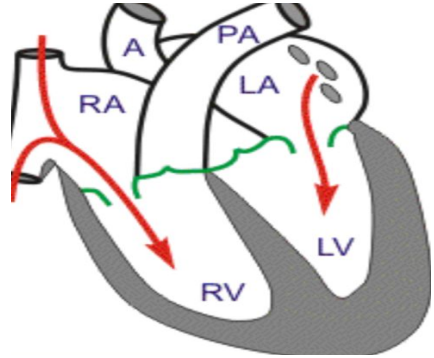
Phases of cardiac cycle



N.B. Considered ‘8’ phases if including 1st phase of diastole

ATRIAL SYSTOLE

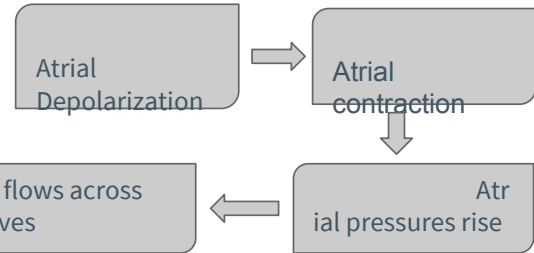
- It is a phase of atrial contraction, occurs at end of ventricular diastole.
- It lasts for ≈ 0.1 sec.
- It is preceded by atrial depolarization.
- Valves: A-V valves open (semilunar valves closed). blood goes from atria to ventricles.
- Ventricular volume: ↑ due to blood passage into ventricle. It reaches the end diastolic volume (EDV) 130 ml.
- 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 P.
- Atrial pressure: First ↑ due to systole of atria. Then ↓ due to blood passage into ventricles.
- 4th Heart sound heard.



ATRIA = PRIMER PUMPS

Ventricular filling :

- 80% - direct flow from SVC & IVC
- 20% - atrial contraction



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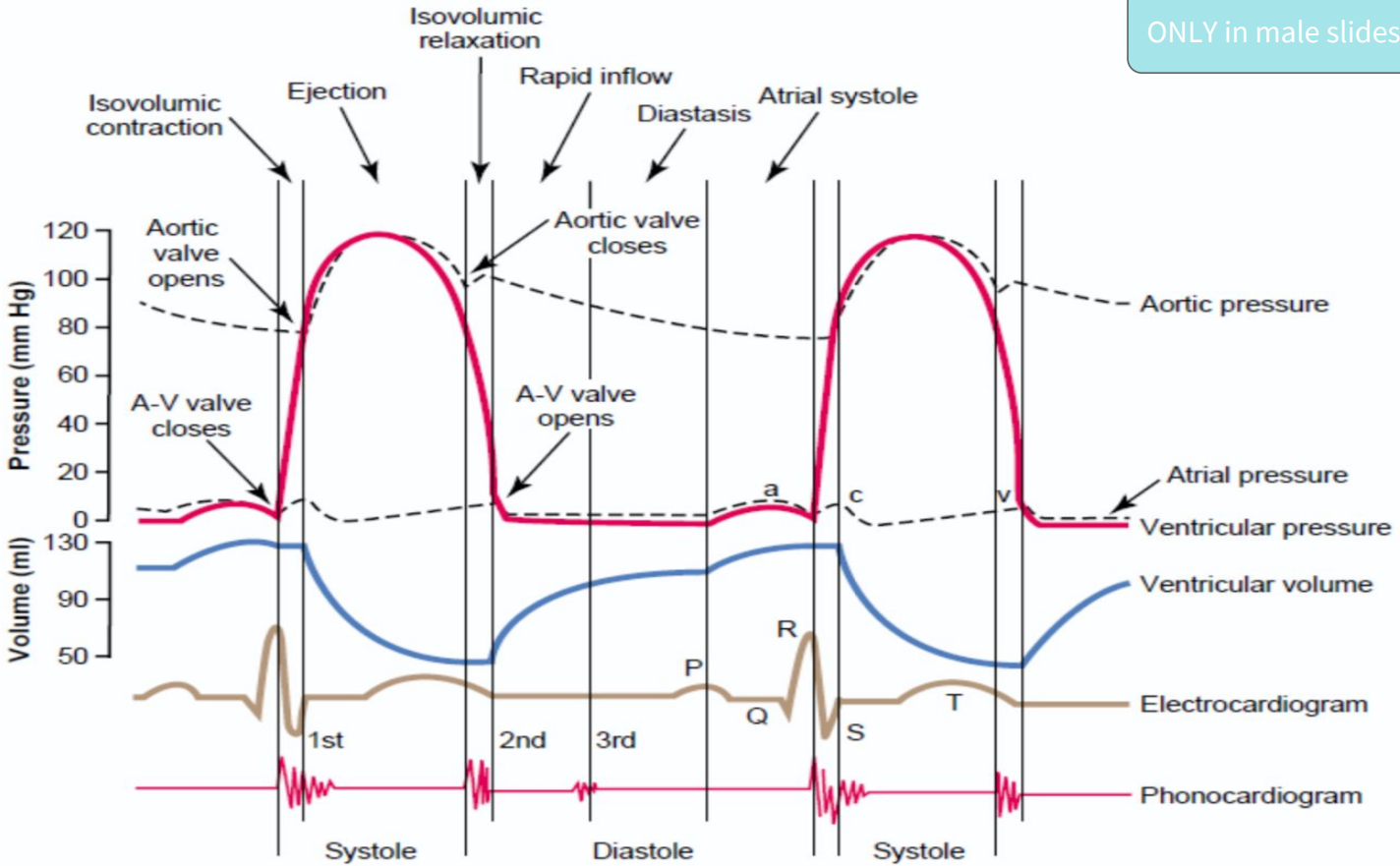
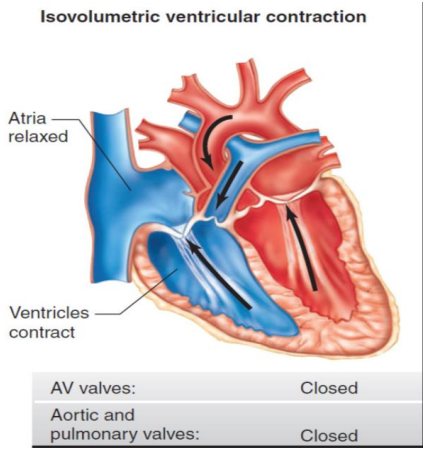


ISOVOLUMETRIC CONTRACTION

- It occurs at beginning of ventricular systole. It lasts for ≈ 0.04 sec.
- Starts with closure of A-V valves.
- 1st Heart sound heard.
- Semilunar valves: Still closed.
- Ventricle is a closed chamber. It contracts with no changes in volume (isometrically, no shortening)
- Volume in ventricle = EDV
- Ventricular pressure ↑ suddenly
- Aortic valve opens at the end of this phase, when LV exceeds 80mmHg.
- Atrial pressure: ↑ due to doming of cusps of closed A-V valves into atria.(c wave)



increase in ventricular pressure > atrial pressure → AV valves close

After 0.02s, semilunar valves open.

Period between AV valve closure and semilunar valve opening → heart prepares for contraction without shortening→ occurs without emptying.

Tension develops without change in muscle length

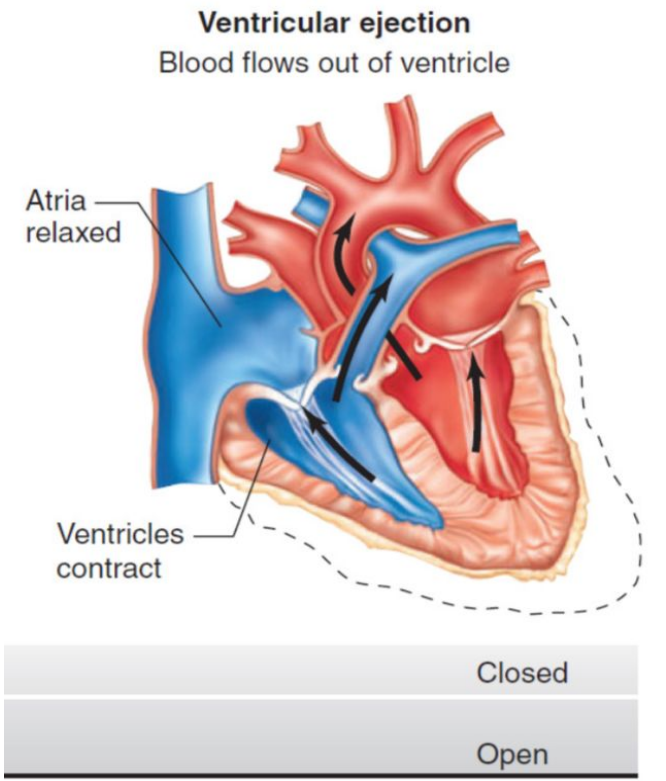
ONLY in male slides

EJECTION

- When LV pres >80 mmHg
  - RV pres >8 mmHg, The semilunar valves open.

- Rapid Ejection – 70% emptying in first 1/3 duration
- Slow Ejection – 30% in last 2/3 time

- When the slow ejection begins?
  - the pressure of the ventricular at the beginning will be high and that represents the rapid phase.so when the pressure start to decrease the slow phase will begin.
- The pressure in the ventricle keeps decreasing until it becomes lower than that of the great vessels.(after that the semilunar valve will close)



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Maximum (rapid) ejection phase

- The ventricles contract isotonically (with shortening) pushing most of blood (75% of ventricular blood) into aorta & pulmonary artery.
- Duration: 0.15 sec.
- Semilunar valves open at beginning of this phase when LV pressure exceeds 80 mmHg.
- AV valves: Still closed.
- Ventricular pressure reaches 120 mmHg in left V .
- Ventricular volume: ↓ sharply due to shortening of ventricular wall and ejection of blood.
- Atrial pressure: First ↓ because when ventricles contract, they pull fibrous AV ring with AV valves downward thus ↓ atrial P.

Reduced ejection phase

- 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).
- Duration: 0.1 sec.
- AV valves: Still closed.
- Semilunar valves: Still opened.
- Atrial pressure: Still ↑ gradually due to accumulation of venous blood. Ventricular volume: Continue ↓ gradually till it reaches the end systolic volume (60 ml).
- Ventricular pressure: ↓ gradually, as volume of blood leaving ventricles > the decrease in ventricular volume.

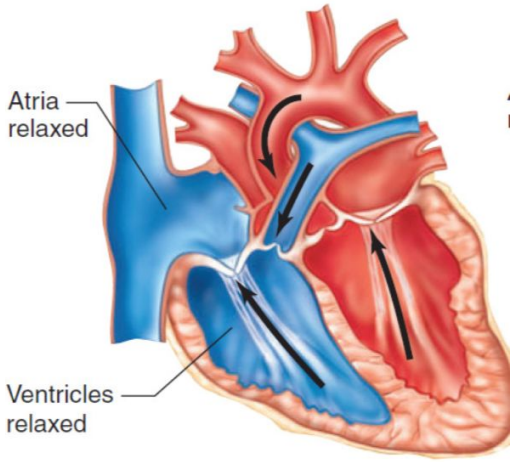
ISOVOLUMETRIC RELAXATION

- When ventricular pressure < arterial pressure → backflow of blood → forces semilunar valves to close.
- For 0.03-0.06 s, ventricle relaxes despite no change in its volume
- AV and Semilunar valves are closed
- Meanwhile, atria fill up and atrial pressure gradually rises
- Pressures in ventricle keep falling till it is < atrial pressure

- The ventricles relax without changing their volume. It occurs at the beginning of diastole.
- It lasts for ≈ 0.04 sec.
- Ventricular volume is constant at the ESV (60 ml).
- Semilunar valves: close at the beginning of the phase.
- 2nd Heart sound is heard.
- A-V valves: Still closed.
- Ventricular pressure: ↓ rapidly, because the valves are closed & the relaxation is isometric.
- Atrial pressure: Still ↑ gradually due to accumulation of venous blood.

B Diastole

Isovolumetric ventricular relaxation



AV valves:	Closed
Aortic and pulmonary valves:	Closed

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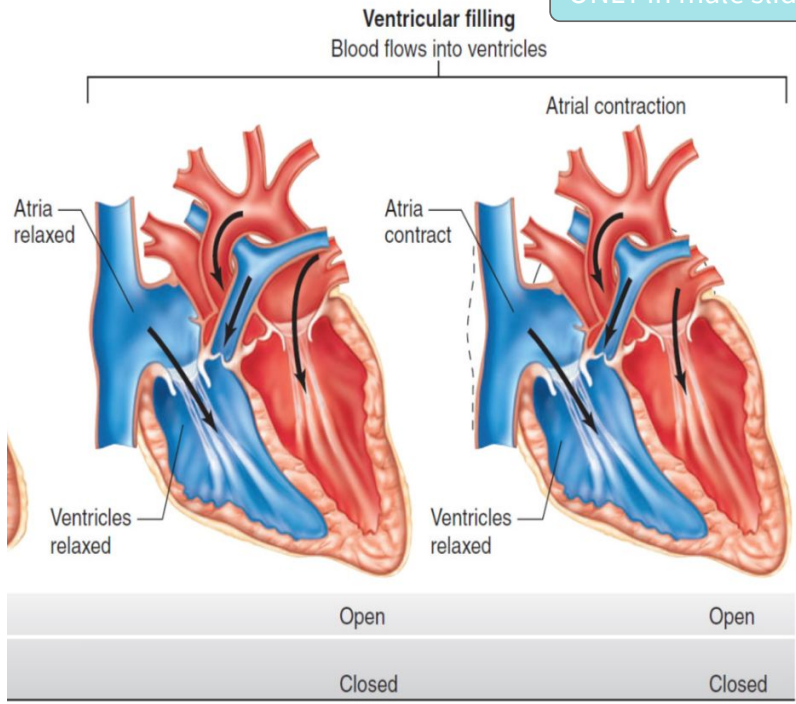
VENTRICULAR FILLING

- Begins with the opening of AV valves
- Rapid filling – first 1/3 of diastole (60-70% blood)
- Reduced filling(Diastasis)– middle 1/3 of diastole
- Atrial contraction – last 1/3 of diastole (27-30% blood)



As the atrial pressures fall, the AV valves close and left ventricular volume is now maximum → EDV (120 ml in LV)

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Rapid filling phase

Atrial pressure > ventricular pressure. A-V valves open.

≈ 60-70% of blood passes passively to the ventricles along pressure

gradient.

Duration ≈ 0.1 sec.

3rd Heart sound heard due to rush of blood into ventricles and vibration in ventricular wall.

Semilunar valves: Still closed.

Atrial pressure: First sudden ↓ due to rush of blood from atria to ventricles. Then gradually ↑ due to entry of venous blood. Ventricular volume: ↑ because it is being filled with blood. Ventricular pressure: Slightly ↑ but < atrial pressure (لانه لو صار اعلى ما راح يجي الدم للبطين)

Reduced filling phase

Remaining atrial blood flows slowly into ventricles by pressure gradient. Duration ≈ 0.2 sec.

A-V valves still open.

Semilunar valves: Still closed.

Atrial pressure: Still ↑ gradually due to continuous venous return.

Ventricular volume: Still ↑ due to entry of blood into ventricles.

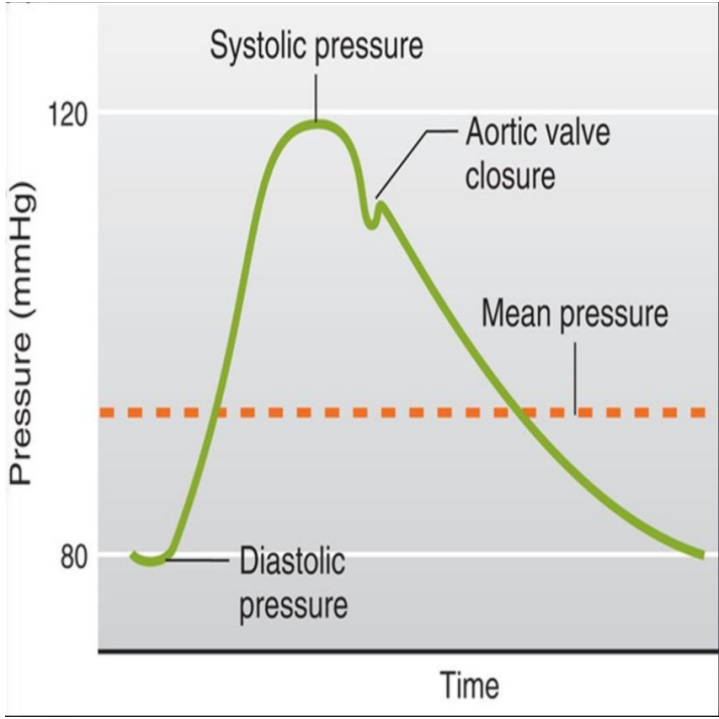
Ventricular pressure: Slightly ↑ gradually because the increase in volume is less than the entering blood.

Aortic Pressure Curve

Ascending or anacrotic limb:

- This coincides with the ‘rapid ejection phase’
- The amount of blood enters aorta > leaves
- Aortic pressure ↑ up to 120 mmHg

b. Descending or catacrotic limb: (Has 4 stages)



Pulmonary artery pressure changes are similar to the aortic pressure changes but with difference in magnitude. Normal pulmonary artery pressure during the cardiac cycle ≈ 25-30/4-12 mmHg

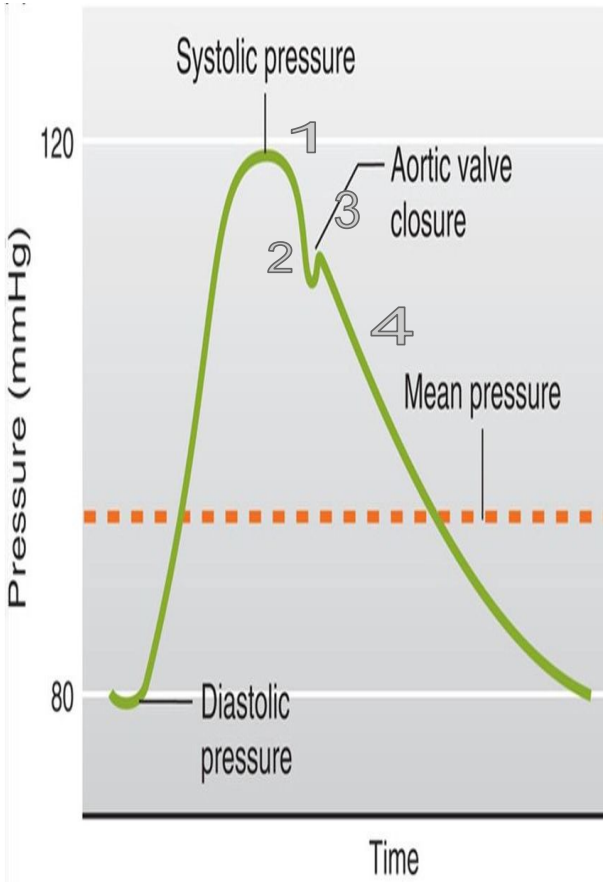
Descending / catacrotic limb – 4 STAGES

1. Aortic pressure:
This coincides with the 'reduced ejection phase'
The amount of blood enters aorta < leaves

2. Dicrotic notch (incisura):
Due to closure of aortic valve
There is sudden drop in aortic pressure .
This notch is seen in the aortic pressure curve at end of ventricular systole .

3. Dicrotic wave:
Due to elastic recoil of the aorta
Slight ↑ in aortic pressure

4. Slow ↓aortic press: up to 80 mmHg
Due to continued flow of blood from aorta → systemic circulation



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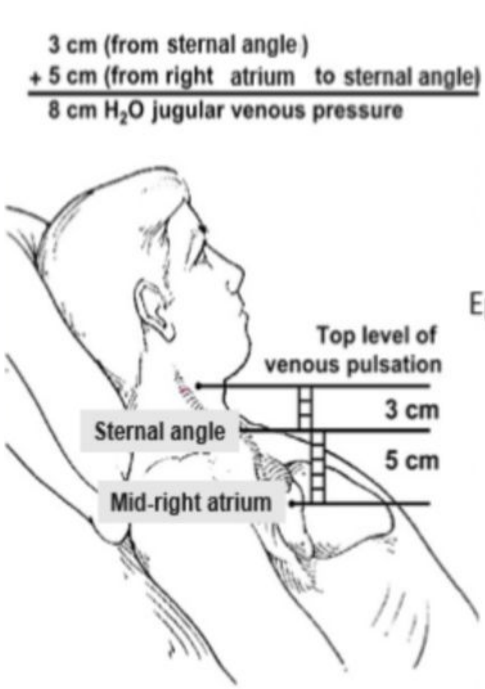
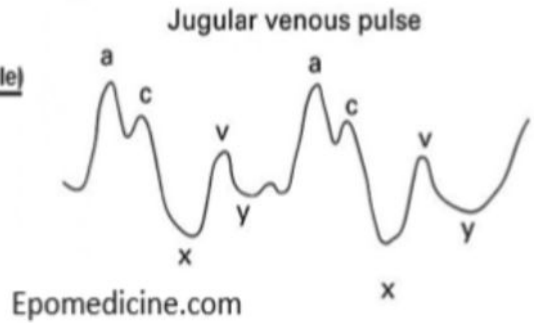
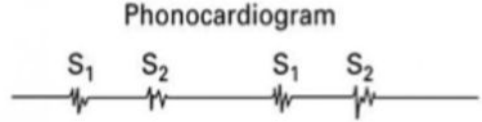
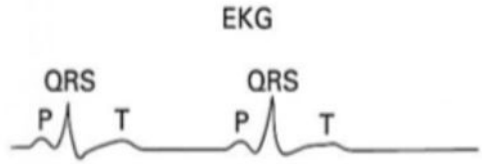
Atrial pressure changes during the cardiac cycle
THE JUGULAR VENOUS PULSE (JVP)









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Practical Box 13.2 Measurement of jugular venous pressure

The patient is positioned at about 45° to the horizontal (between 30° and 60°), wherever the top of the venous pulsation can be seen in a good light.

The jugular venous pressure is measured as the vertical distance between the manubriosternal angle and the top of the venous column.

The normal jugular venous pressure is usually less than 3 cmH_2O, which is equivalent to a right atrial pressure of 8 cmH_2O when measured with reference to a point midway between the anterior and posterior surfaces of the chest.

The venous pulsations are not usually palpable (except for the forceful venous distension associated with tricuspid regurgitation).

Compression of the right upper abdomen causes a temporary increase in venous pressure and makes the JVP more visible (hepatojugular reflux).

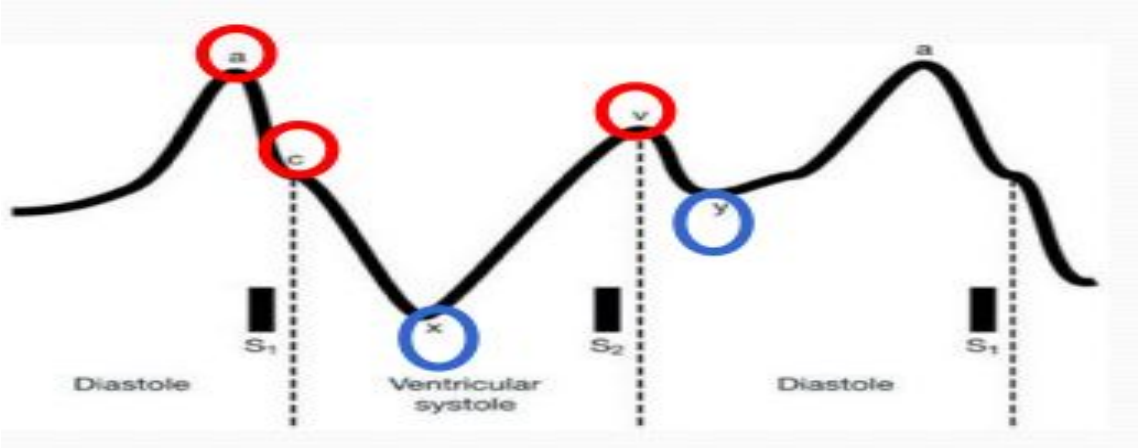
Atrial Pressure Changes:

Results in:

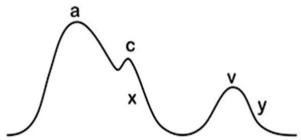
3 upward deflection: a, c, & v

2 components in each wave: +ve (atrial pressure),-ve (atrial pressure)

2 downward deflection: x & y



Causes of atrial pressure waves



‘a’ wave: Atrial systole:

+ve due to atrial systole

-ve due to blood passage into ventricles.

‘c’ wave: Ventricular systole

+ve due to the bulging of A-V valves into the atria during ‘isovolumetric contraction phase.’

-ve due to the pulling down of the atrial muscle & A-V cusps during ‘rapid ejection phase’, resulting in decreased atrial pressure.

‘v’ wave:

+ve due to increased venous return during atrial diastole.

-ve due to entry of blood into ventricles during ‘rapid filling phase.’

‘x’ descent:

Downward displacement of A-V valves during ‘reduced ejection phase.’

‘y’ descent:

atrial pressure due to entry of blood into ventricles during ‘reduced filling phase.

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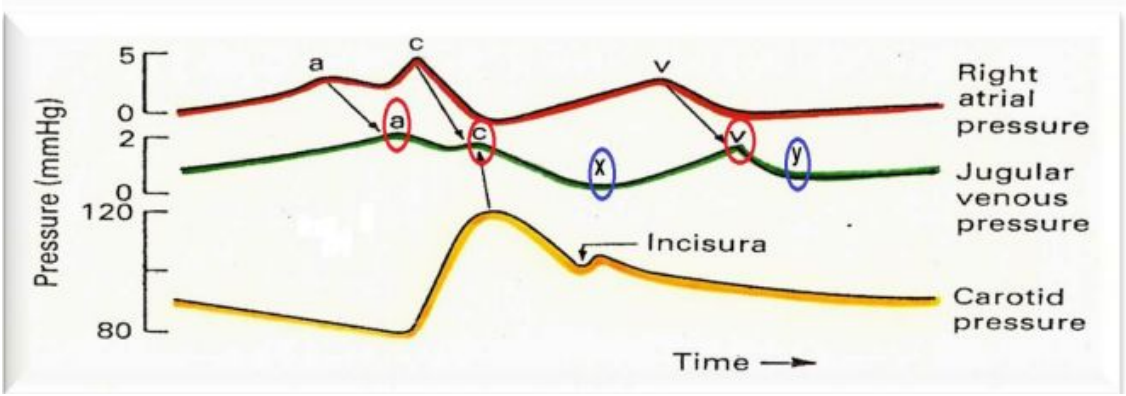
Jugular venous pulse changes:

Similar recordings of transmitted delayed atrial waves:

3 upward waves: a, c, & v

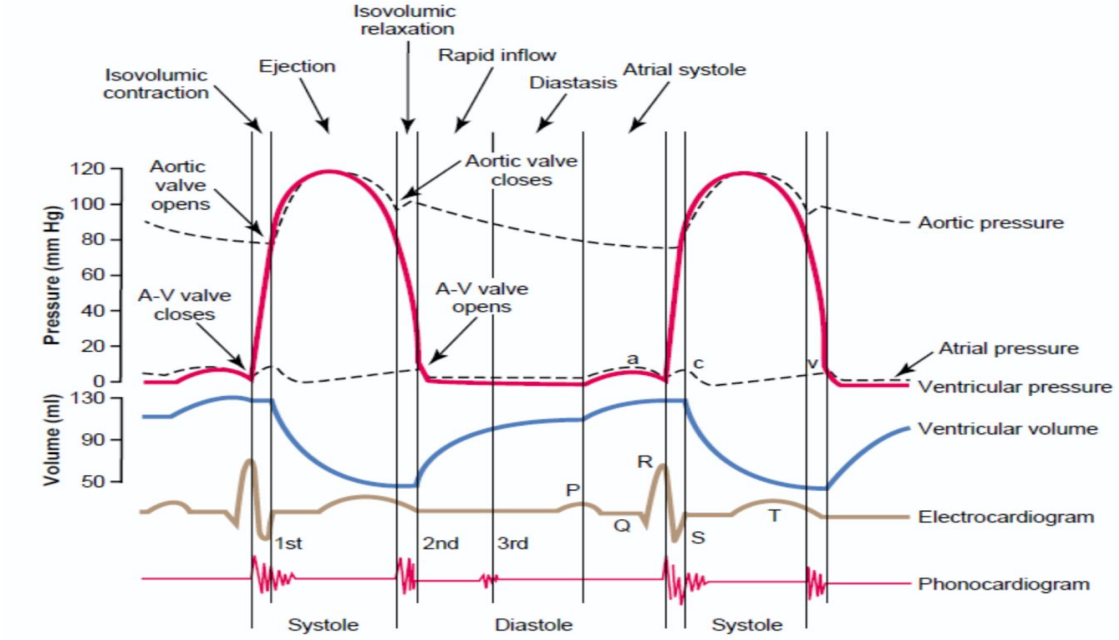
2 downward waves: x & y



The coming slides is very important
It depends on this diagram

Remember:
1-Sounds occurs during closes the valves

2-contraction occurs at the end depolarization and relaxation at the end repolarization
Example:
The ventricular contraction occurs at the end of QRS complex which is the depolarization of the ventricular



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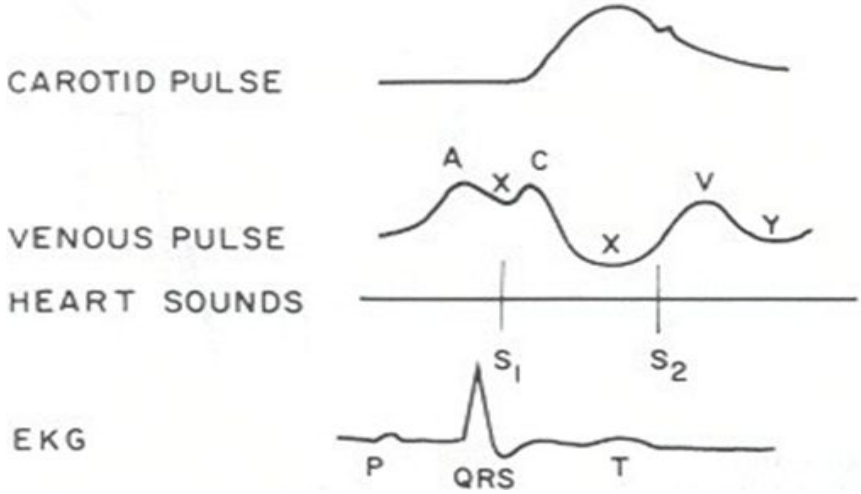
ATRIAL SYSTOLE

- **JVP** – ‘a’ wave
- **ECG** – P wave precedes the atrial systole. PR interval – depolarization proceeds to the AVN. The brief pause allows complete ventricular filling
- **Heart sounds** - S4 – pathological. Vibration of the ventricular wall during atrial contraction. Heard in ‘stiff’ ventricle like in hypertrophy and in elderly. Also heard in massive pulmonary embolism, cor pulmonale, TR (tricuspid regurgitation)

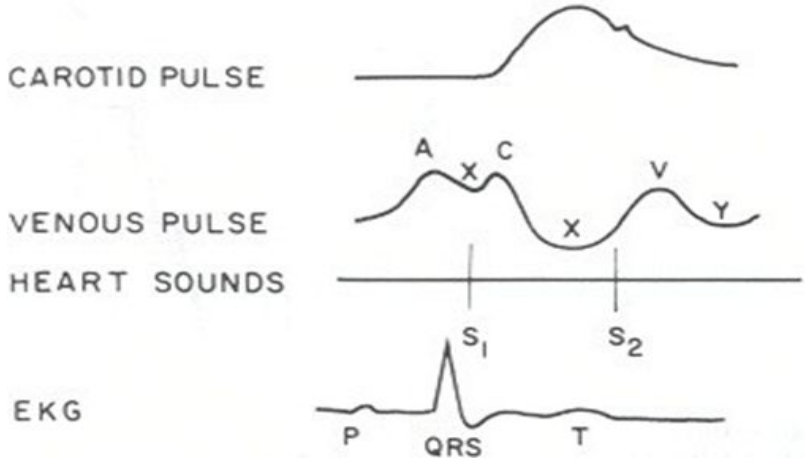


ISOVOLUMETRIC CONTRACTION

ONLY in male slides

- Volume does not change
- All valves are closed

- **JVP** – ‘c’ wave → due to the bulging of the Tricuspid valve into RA secondary to increased pressure in the ventricle.
- **ECG** – End of QRS complex.
- **Heart Sounds** – S1 : closure of the AV valves.



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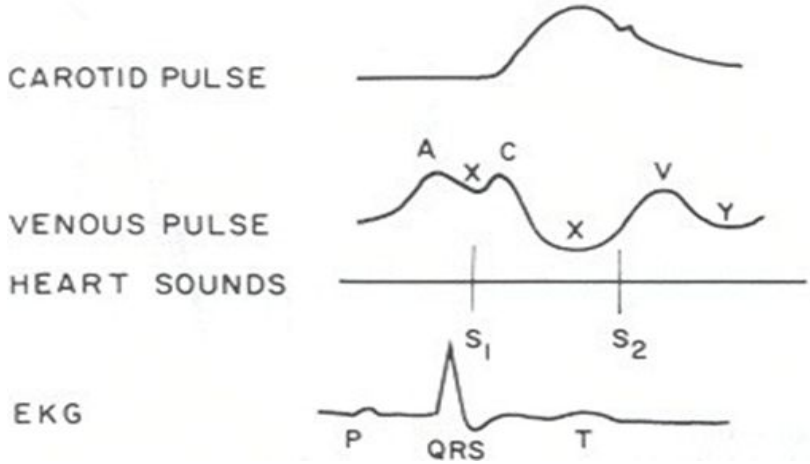
EJECTION

- Rapid
- Slow

- **JVP** – no waves
- **ECG** – T wave
- **Heart sounds** – none
- **Aortic pressure** - Rapid rise in the pressure = 120 mm Hg. Even at the end of systole pressure in the aorta is maintained at 90 mm Hg because of the elastic recoil



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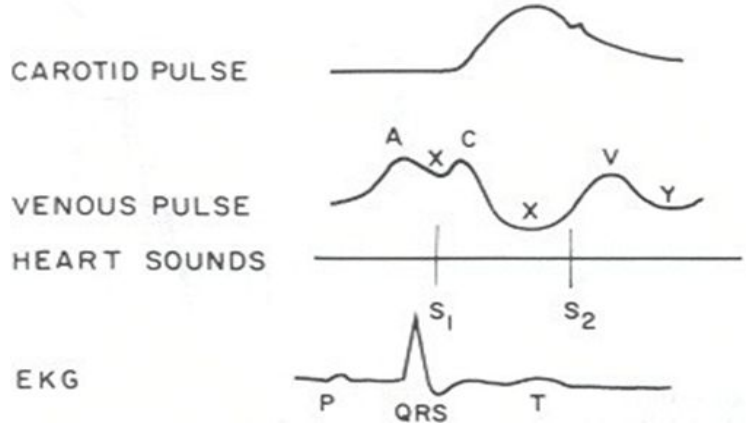
ISOVOLUMETRIC RELAXATION

- Volume does not change
- All valves are closed

- **JVP:** ‘v’ wave – due to venous return to the atria from SVC and IVC
- **ECG:** End of T wave
- **Heart sounds:** S2 : closure of the semilunar valves coincides with this phase.
- **Aortic pressure curve:** INCISURA - when the aortic valve closes. Caused by a short period of backflow before the valve closes followed by sudden cessation of the backflow when the valve closes



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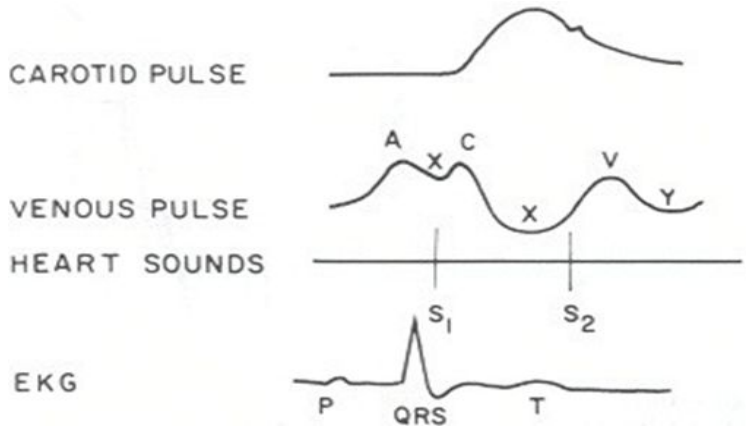
VENTRICULAR FILLING

- Rapid filling
- Reduced filling
- Atrial contraction

- **JVP** – ‘y’ descent in first 2/3 & ‘a’ wave in last 1/3
- **ECG** – P wave before atrial systole
- **Heart sounds** - S3 - Pathological in adults. Seen in dilated congestive heart failure, MI, MR, severe hypertension. Normal in children.



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Heart Sounds

Detected over anterior chest wall by:

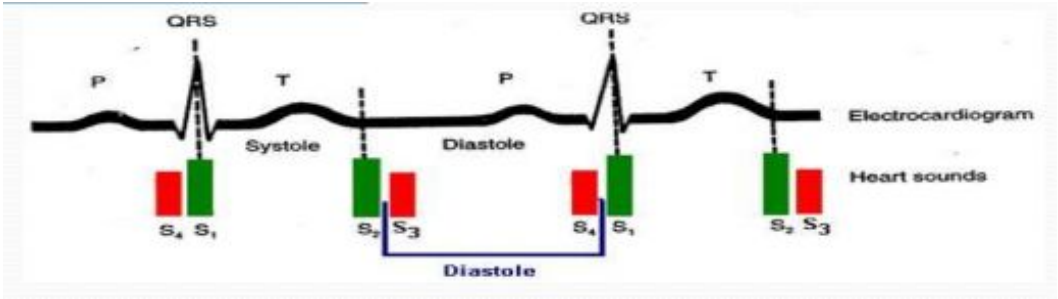
Auscultation… (Stethoscope.)

Phonocardiography… (Sound recording device.)

Four heart sounds can be detected:

1st & 2nd heart sounds … (usually audible)

3rd & 4th heart sounds … (of low pitch, usually not audible) Important for diagnosis of valvular heart diseases (murmurs)



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Heart Sounds during Cardiac cycle

Phase	Heart Sound	Causes of the Sound
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 of 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-Isovolumetric 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**	

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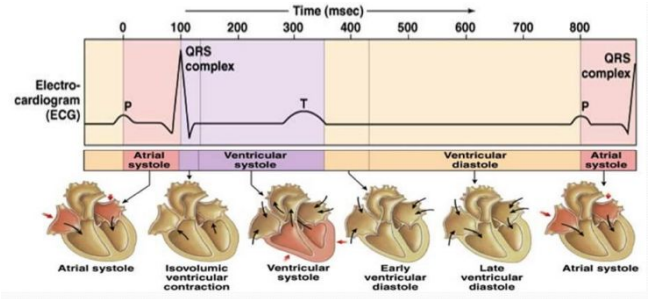
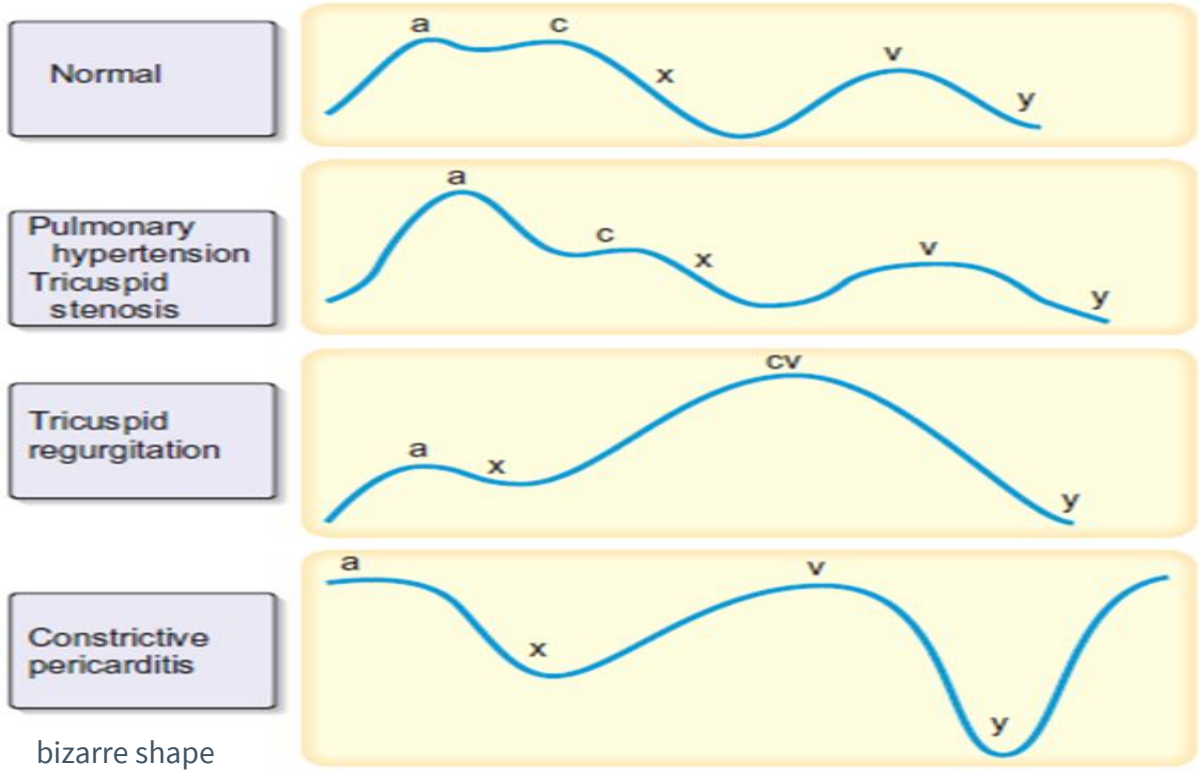
ECG changes during the Cardiac cycle



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-Isovolumetric 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.**



bizarre shape

Fig. 13.12 Jugular venous waveforms.

ONLY in male slides

ABNORMALITIES OF “a” WAVE

- **Elevated a wave :**

  Tricuspid stenosis

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

- **Cannon a wave :**

  Atrial-ventricular asynchrony (atria contract against a closed tricuspid valve)

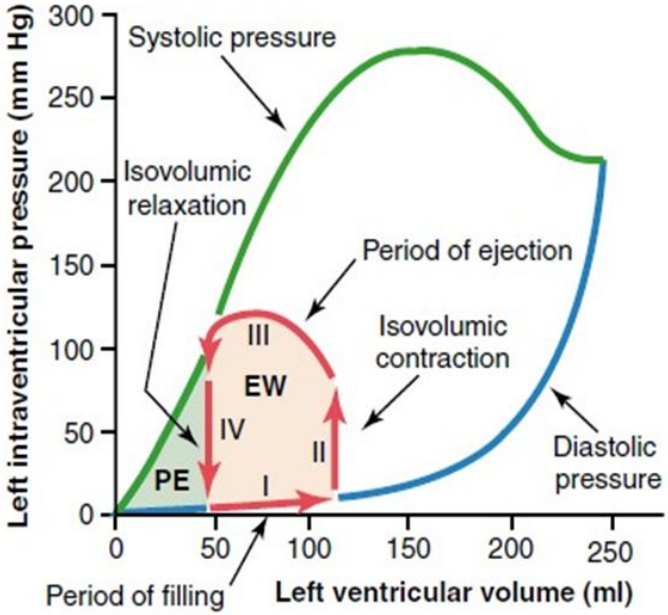
  complete heart block, following premature ventricular contraction, during ventricular tachycardia, with ventricular pacemaker

- **Absent a wave :**

  Atrial fibrillation or atrial standstill

  Atrial flutter

“Volume-Pressure Diagram” During the Cardiac Cycle; Cardiac Work Output.



BASIC MYOCARDIAL MUSCLE MECHANICS

- Both ventricular systole & diastole can be divided into early & late phases.

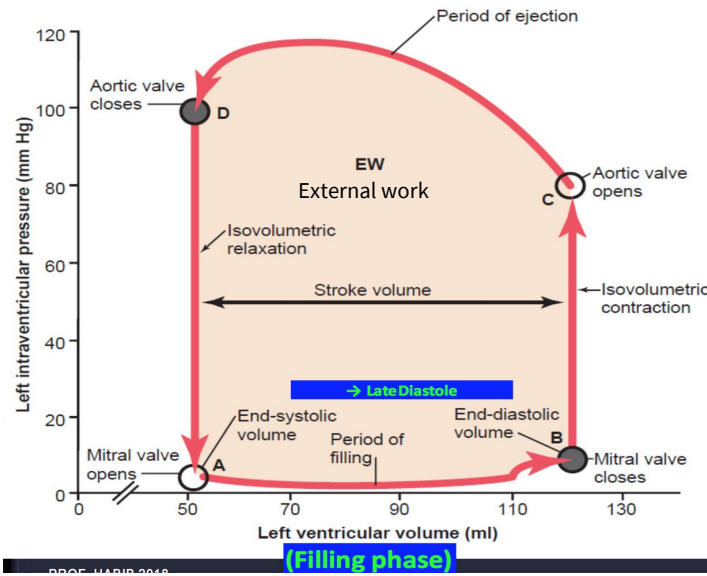
- Systole:
  - Early systole = ‘Isovolumetric Contraction’.
  - Late systole= Isotonic Contraction ‘Ejection Phase’.

- Diastole:
  - Early diastole = ‘IsovolumetricRelaxation’.
  - Late diastole= IsotonicRelaxation ‘FillingPhase’.

VENTRICULAR PRESSURE – VOLUME LOOP

- Plots LV pressure against LV volume through one complete cardiac cycle.

- Systole: divided into Early systole Late systole.
- Diastole: divided into Early diastole Late diastole.
- 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).



Explanation of the previous slide

from point A to point B

Phase I: Period of filling

Phase I in the volume-pressure diagram begins at a ventricular volume of about 50 ml and

a diastolic pressure of 2 to 3 mmHg. The amount of blood that remains in the ventricle after the previous heartbeat, 50 milliliters, is called the end-systolic volume. As venous blood flows into the ventricle from the left atrium, the ventricular volume normally increases to about 120 milliliters, called the end-diastolic volume.

Phase II: Period of isovolumic contraction. During isovolumic contraction, the volume of the ventricle does not change because all valves are closed. However, the pressure inside the ventricle increases to equal the pressure in the aorta, at a pressure value of about 80 mm Hg, as depicted by point C

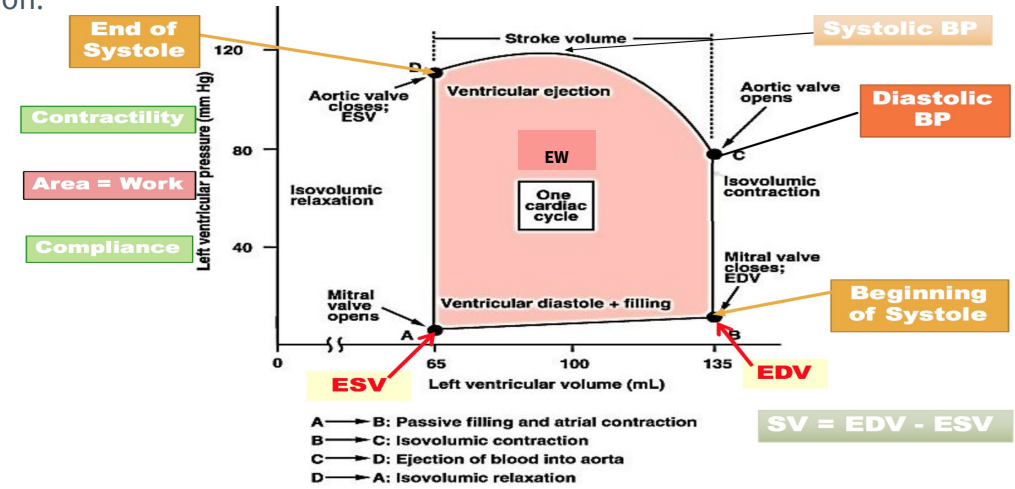
Phase III: Period of ejection(from C to D). During ejection, the systolic pressure rises even higher because of still more contraction of the ventricle. At the same time, the volume of the ventricle decreases because the aortic valve has now opened and blood flows out of the ventricle into the aorta.

Phase IV: Period of isovolumic relaxation. At the end of the period of ejection (point D)

the aortic valve closes and the ventricular pressure falls back to the diastolic pressure level. The decrease in intraventricular pressure without any change in volume. Thus, the ventricle returns to its starting point, with about 50 milliliters of blood left in the ventricle and at an atrial pressure of 2 to 3 mm Hg.

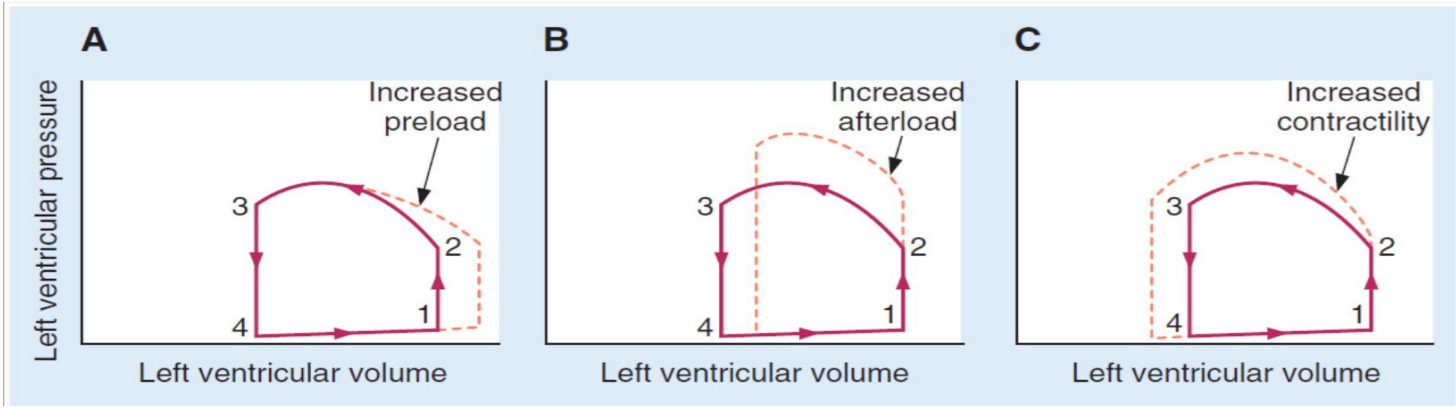
IMPORTANCE OF VENTRICULAR PRESSURE - VOLUME LOOP

- This diagram is used for calculating cardiac work output.
- The shaded area, labeled “EW” represents the net external work 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.



a. Increased preload: n refers to an increase in end-diastolic volume and is the result of increased venous return. causes an increase in stroke volume based on the Frank–Starling relationship....reflected in increased width of the pressure–volume loop.

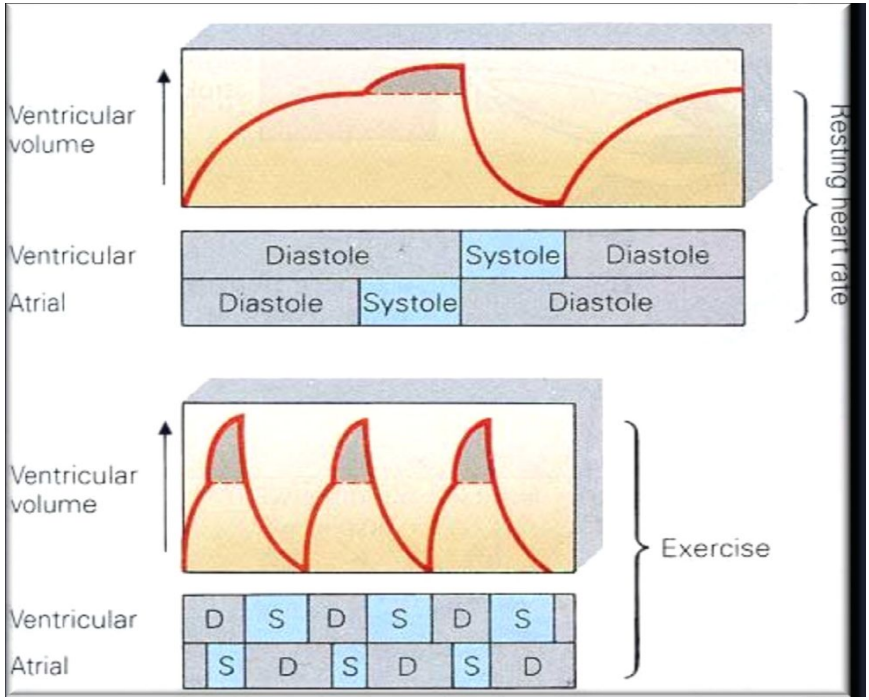
b. Increased afterload refers to an increase in aortic pressure.The ventricle must eject blood against a higher pressure, resulting in a decrease in stroke volume....is reflected in decreased width of the pressure–volume loop.The decrease in stroke volume results in an increase in end-systolic volume**.**



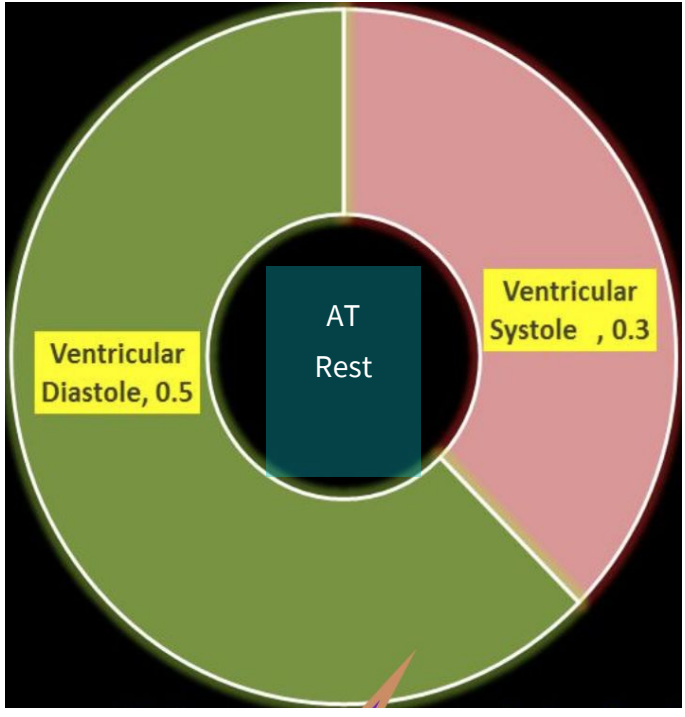
Effects of changes in **(A)** preload, **(B)** afterload, and **(C)** contractility on the ventricular pressure–volume loop.

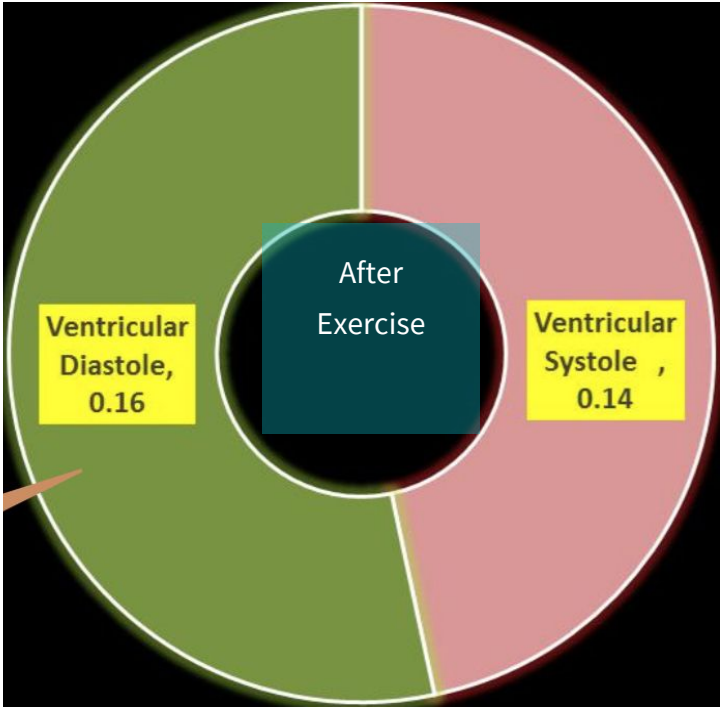
EFFECT OF ATRIAL CONTRACTION ON VENTRICLE FILLING

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



Heart Rate & Cardiac Cycle





Heart Rate & Cardiac Cycle

Higher the rate lesser is duration of Cardiac cycle. However, the duration of systole is much more fixed than that of diastole.

When the heart rate is increased, diastole is shortened to a much greater degree. For example, at a heart rate of 65 beats/min, the duration of diastole is 0.62 s, whereas at a heart rate of 200 beats/min, it is only 0.14 s.

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

Summary

Phases of cardiac cycle

Atrial systole 0,1s
Atrial diastole 0.7s

Ventricular events:

Ventricular systole 0.3s
Ventricular diastole 0.5s

Total length of cardiac cycle is usually 0.8 seconds

Ventricular events (7)
Ventricular **systole** 0.31s

Isovolumetric contraction 0,06s
Maximum Ejection 0.11s
Reduced Ejection 0.14s

Ventricular **diastole** 0.52s

Protodiastole 0.04s
Isovolumetric relaxation 0.06s
Rapid inflow 0.11s
Slow inflow / diastasis 0.2s
Atrial systole / last rapid felling 0.11 s

Total 7 phases of cardiac cycle = 0.8s

Pressure changes in mm of Hg

Right Atrium 2-8
RIght ventricular systole 15-25
RIght ventricular diastole 2-8

Pulmonary artery systole 15-25
Pulmonary artery diastole 8-15

Left atrium 2-10
Left ventricular systole 100-120
Left ventricular diastole 2-10

Volume Changes

End diastolic volume EDV
Volume of blood in ventricles at the end of diastole = **(110- 130) (110-120) mL**

End systolic volume ESV
Amount of blood left in ventricles at the end of systole = **(40-60) (40-50) mL.**

Stroke volume SV
Amount of blood ejected from ventricles during systole =**70 mL/beat.**

Ejection Fraction EF

EF is the percentage of ventricular end diastolic volume (EDV) which is ejected with each stroke

Quiz

1-Which of the following has the most high pressure?

A-left ventricle (answer)

B-left atrium

C-right ventricle

D-right atrium

2-What is the most period that affected when the heart rate increase?

A-diastole (answer)

B-systole

C-absolute refractory

D-action potential

3-Atrial systole occurs after which of the following?

A-P wave (answer)

B-QRS complex

C-T wave

D-C wave

4-During the rapid filling of ventricle:

A-Ventricular pressure>atrial pressure

B-Ventricular pressure< atrial pressure (answer)

C-AV valve close

D-semilunar valve open

5-First heart sound heard at which on of the following period ?

A-isovolumetric contraction (answer)

B-isovolumetric relaxation

C-ejection phase

D-filling phase

6-First ⅓ duration of ejection phase, the amount of blood ejected is about :

A-⅓ of the stroke volume

B-⅔ of the stroke volume (answer)

C-no blood ejected

D-30% of the stroke volume.

Quiz

1-During cardiac cycle, when the atria fail to function.
Can the heart continue to operate under most conditions?
Explain your answer

Answer : Yes it can, because the atrial contraction usually causes an additional 20 percent filling of the ventricles, so the difference is unlikely to be noticed unless a person exercise.

2-What cause the pressure in the arteries (aortic and pulmonary arteries) remains at high pressure after contraction of the ventricles ?

Answer: Elastic walls of the arteries

3-Why there is a slight increase in aortic pressure after closure of the aortic valve ?

Answer: when the pressure of the ventricle decrease, the blood in aorta will try to come back to the ventricle and because of that, the aortic valve will close and as a result the pressure will increase slightly from forcefully back flow of the blood.

Thank you for checking our work

Team Leader:

العنود سلمان

Male Team:

أنس السويداء
أنس السيف
خالد شويل
ريان الموسى
سعد الهداب
سعود العطوي
سيف المشاري
عبدالجبار اليماني
عبدالرحمن آل دحيم
عمر الفوزان
فهد الحسين
نايف المطيري
نواف اللويمي
محمد الحسن
هشام الشايع
خالد العقيلي
سعد الفوزان
عبدالله الزيد
نواف اللويمي

Female Team:

الآء الصويّغ
رناد المقرن
رهف الشنيبر
روان التميمي
روان مشعل
ريم القرني
ليلى الصباغ
فلوة السعوي
نورة بن حسن
نورة الحربي
نورة العثيم
مجد البراك
لينا العوهلي
عهد القرين
مها النهدي
مها بركة
سارة الفليج
هند العريعر
ريناد الغريبي
عائشة الصباغ

Any questions?

Contact us at

- twitter:@physio437
- physiologyteam437@gmail.com