Cardiovascular Physiology

Cardiac Cycle - 2

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At end of this lecture you should be able to:

- ✓ **discuss the pressure & volume changes in the left ventricle, left atrium & aorta during cardiac cycle**
- ✓ **discuss the volume-pressure relationship in the left ventricle**
- ✓ **identify the systolic & diastolic early & late periods**

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Cardiac Cycle

VOLUME CHANGES

Volume changes

Phase	Ventricular volume
1. Atrial systole	
2. Isometric contraction phase	
3. Rapid ejection phase	
4. Reduced ejection phase	
5. Protodiastole	
6. Isometric relaxation phase	
7. Rapid filling phase	
8. Reduced filling phase	

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Cardiac Cycle

PRESSURE CHANGES

Pressure changes:

- Aortic pressure
- Arterial pressure waves
- Pulmonary artery pressure

- Atrial pressure
- Jugular venous pulse wave

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Pressure changes:

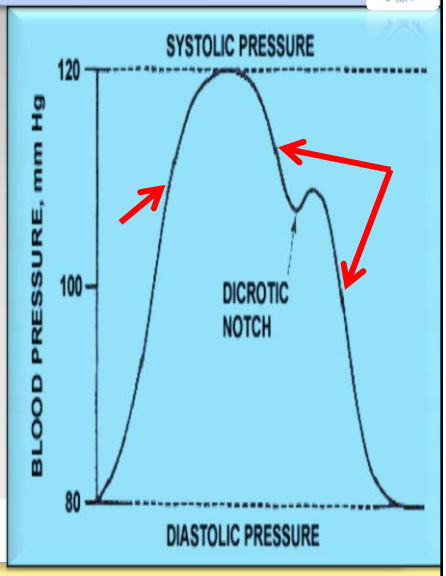
1. Aortic pressure changes … 120/80

a. Ascending or anacrotic limb:

- With max ejection phase
- Aortic press ↑ up to 120 mmHg

b. Descending or catacrotic limb:

- With reduced ejection phase
- Passes in 4 stages:



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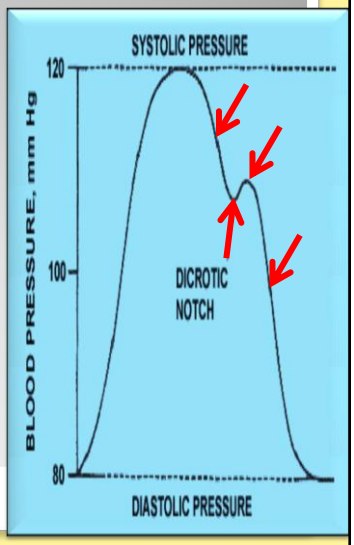
Stages of the Descending or catacrotic limb:

1. **↓ Aortic press:**
   - Amt of blood enters aorta < leaves
2. **Dicrotic notch (incisura):**
   - = Sudden drop in aortic press
   - Due to sudden closure of aortic v
   - At end of protodiastole phase
3. **Dicrotic wave:**
   - = Slight ↑ in aortic press
   - Due to elastic recoil of aorta
4. **Slow ↓ aortic press:** up to 80 mmHg
   - Due to continued flow of blood from aorta → systemic circulation



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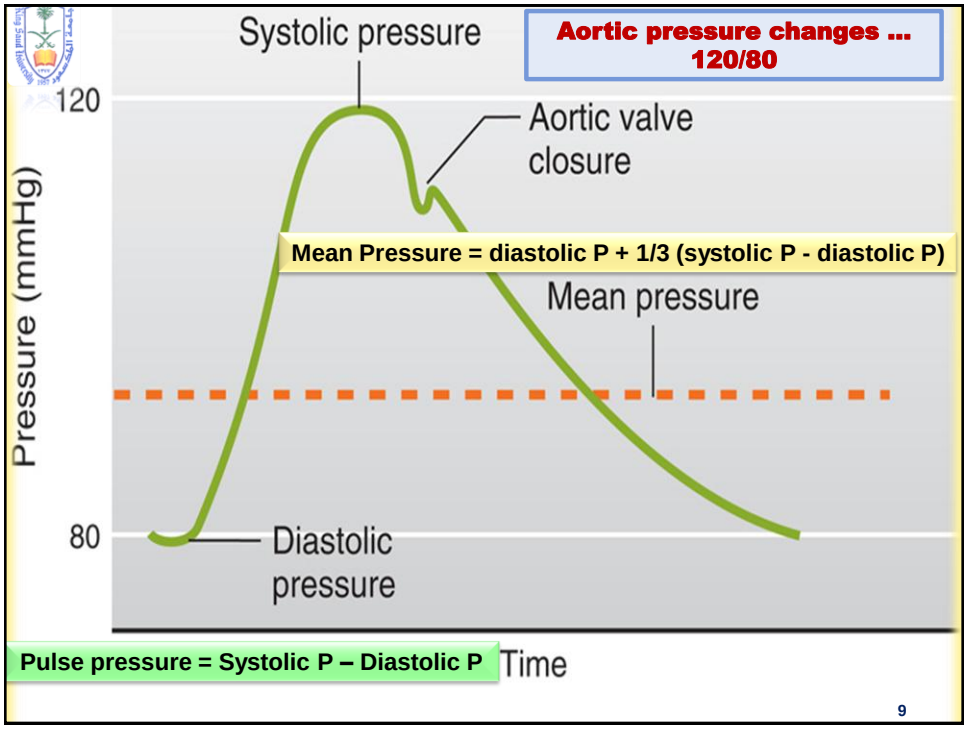
Systolic pressure
Aortic pressure changes ... 120/80
120
Aortic valve closure
Mean Pressure = diastolic P + 1/3 (systolic P - diastolic P)
Pressure (mmHg)
Mean pressure
80
Diastolic pressure
Pulse pressure = Systolic P – Diastolic P
Time
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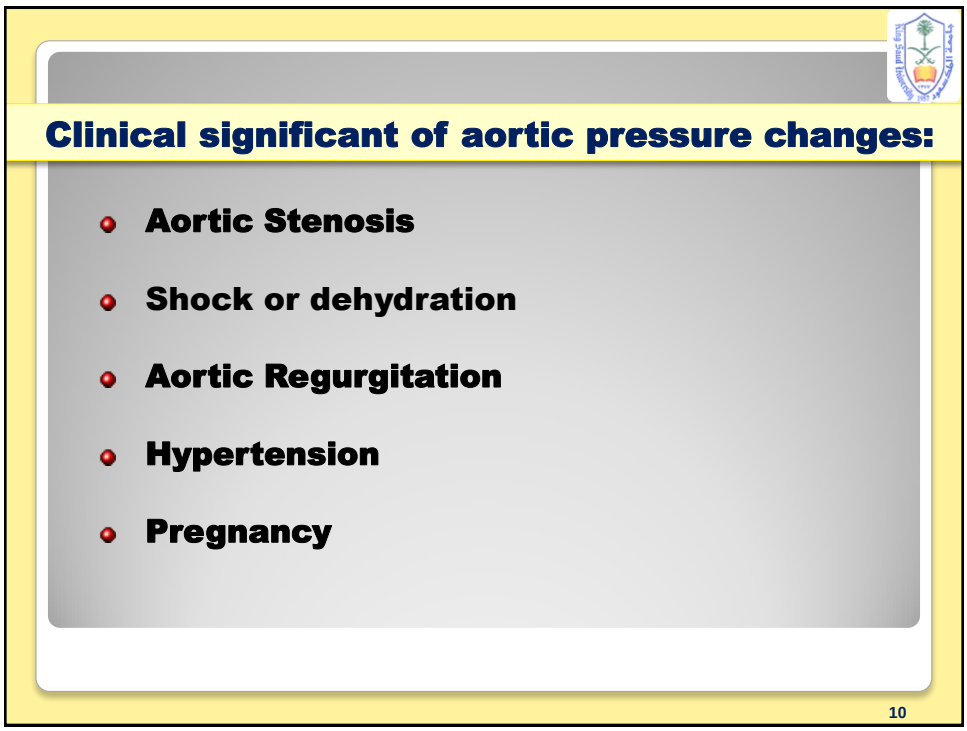
Clinical significant of aortic pressure changes:
Aortic Stenosis
Shock or dehydration
Aortic Regurgitation
Hypertension
Pregnancy
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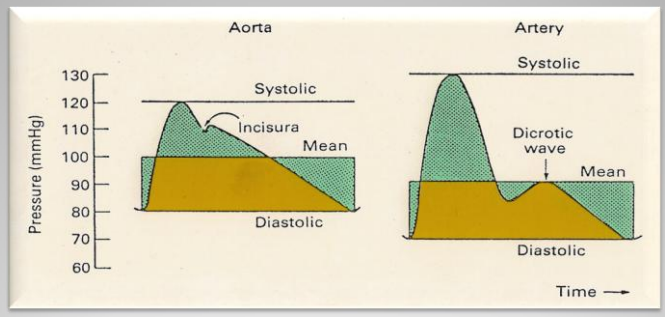
Pressure changes:
2. Arterial pressure changes … 110-130/70-90



- Similar to aortic pressure waves but **sharper**
- Reflects a systolic peak pressure of 110-130 mmHg & a diastolic pressure of 70-90 mmHg

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Pressure changes:
3. Pulmonary artery pressure changes … 25-30/4-12

- Similar to aortic pressure changes but with **difference in magnitude**

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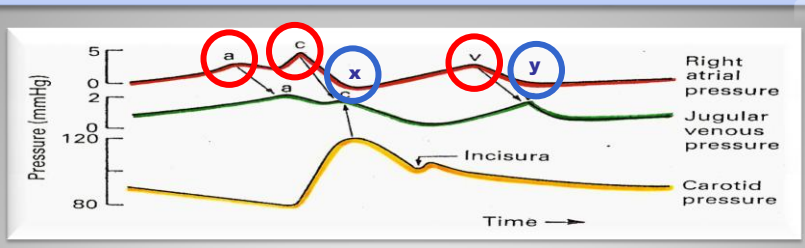
Pressure changes:

4. Atrial pressure changes:



- **Results in:**
  - **3 upward deflection → a, c, & v**
    - 2 components in each wave: +ve (↑ press), -ve (↓ press)
  - **2 downward deflection → x & y**
- The 3 wave (a, c, & v) are equal to ONE cardiac cycle = 0.8 sec

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Causes of atrial pressure waves:

- **'a' wave: Atraial systole**
- **'c' wave: Ventricular sytole**
  - **+ve** → bulging of TV into RA during 'isovolumetric contraction phase'
  - **-ve** → pulling of atrial ms during ventricular contraction (rapid ejection phase)
- **'v' wave**: **Atrial diastole or ↑ VR**
  …↑ RA pressure due to filling of atrium w blood

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Causes of atrial pressure waves … (Cont.)

- **'x' descent:** Downward displacement of TV during reduced ejection phase
- **'y' descent:** Rapid blood flow from RA to RV during rapid filling phase

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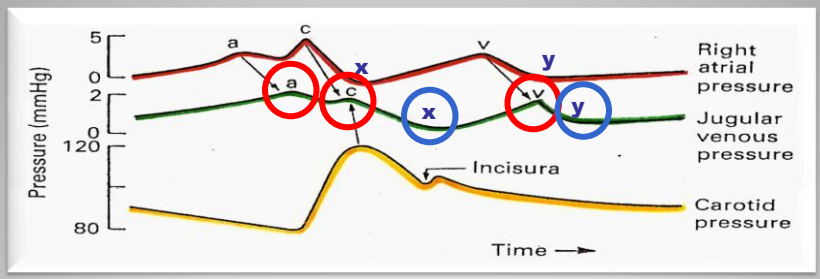
Pressure changes:

5. Jugular venous pulse changes:



- **Also results in recording of transmitted:**
  - 3 upward waves: a, c, & v
  - 2 downward waves: x & y

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Pressure Versus Volume

Left Ventricular Pressure – Volume Loop

Demonstrates changes in intraventricular volume & pressure during one cardiac cycle

- It plots **LV** pressure against **LV** volume through one complete cardiac cycle

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Basic Myocardial Muscle Mechanics:

- Both ventricular systole & diastole can be divided into early & late phases
- **Systole:**
  - Early systole is 'Isovolumetric contraction'
  - Late systole is 'Isotonic contraction'
- **Diastole:**
  - Early diastole is 'Isovolumetric relaxation'
  - Late diastole is 'Isotonic relaxation'

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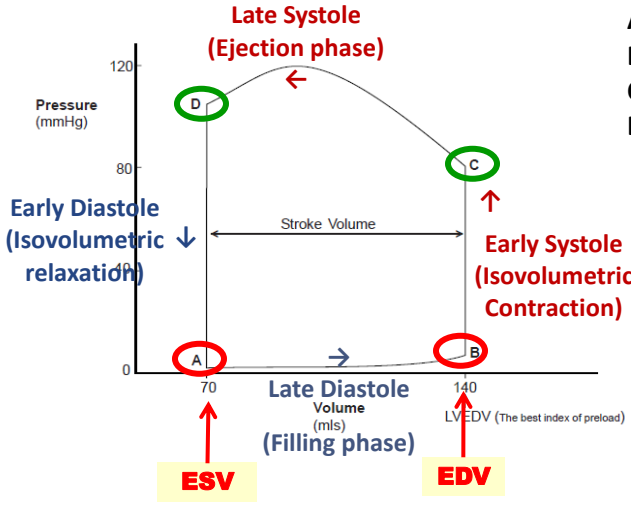
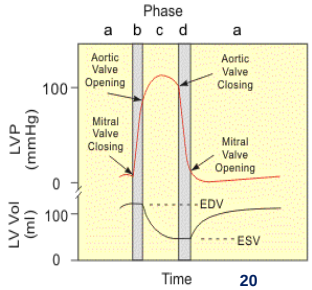
Ventricular Pressure - Volume Loop



A – Mitral valve opens
B – Mitral valve closes
C – Aortic valve opens
D – Aortic valve closes



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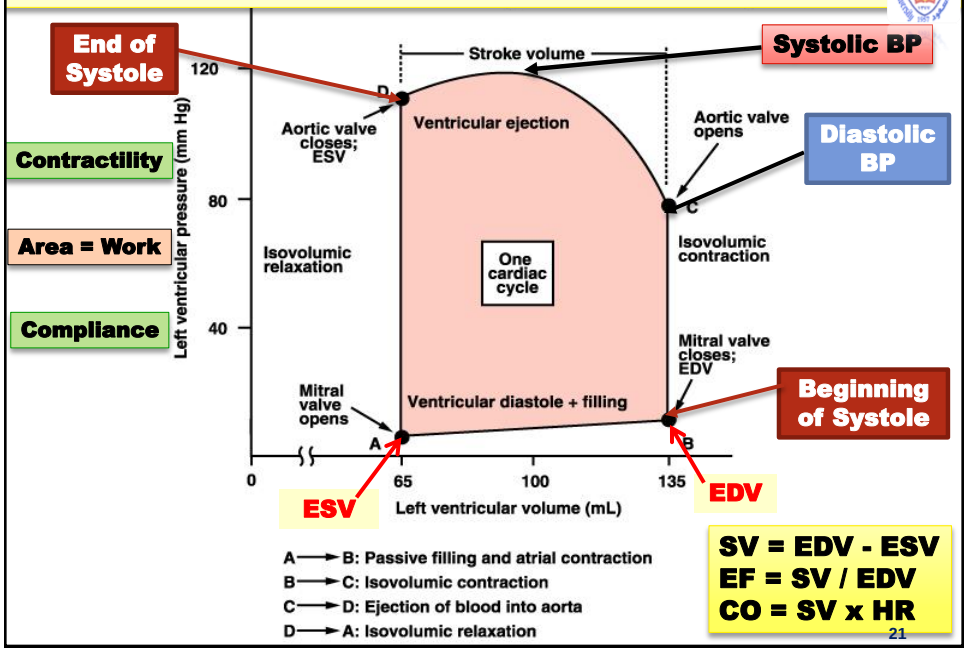
Ventricular Pressure - Volume Loop



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What you should remember about pressure – volume loop?

- Closer & opening of mitral & aortic- vs during each phase
- Beginning of systole (B) & end (D)
- Early & late systolic periods
- Beginning of diastole (D) & end (B)
- Early & late diastolic periods
- Diastolic filling occurs between points A & B
- Ejection occurs between points C & D

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What Affects Systole and Diastole ?

- **Systole:** is measured by contractility
- **Diastole:** is measured by compliance

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During Ventricular Systole:

- Muscle contracts & generates pressure
- Pressure causes a change in volume
- This is measured by '**Contractility**'
- Is affected by:
  - Function of the muscle
  - Initial volume (Preload)
  - Initial pressure (Afterload)

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What Affects Systole ?

- **Preload:**
  - Passive load that establishes the initial muscle length of the cardiac fibers prior to contraction

  = EDV
- **Afterload:**

  Sum of all loads against which the myocardial fibers must shorten during systole
- **Contractility:**
  - The change in volume per time caused by a change in pressure
  - Contractility = (dV/dT) / dP

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During Ventricular Diastole:

- Muscle is relaxing & venous return to the heart
- Results in changes in absolute volume & pressure

  $C = \Delta V / \Delta P$
- This relationship is measured by '**Compliance**'
- Is affected by:
  - Connective tissue
  - Venous pressure
  - Venous resistance

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Increasing Ventricular Preload Increases SV

- **Preload:**
  The muscle length prior to contraction, dependent on EDV
- **↑ Preload,** by ↑EDV (i.e. ↑ venous return)
  - Enhances shortening of myocardium
  - Augments force generation w contraction
  - Ventricle develops greater pressure & ejects blood more rapidly
  - N.B. ventricle ejects blood to the same ESV
- **Net effect is ↑ SV**

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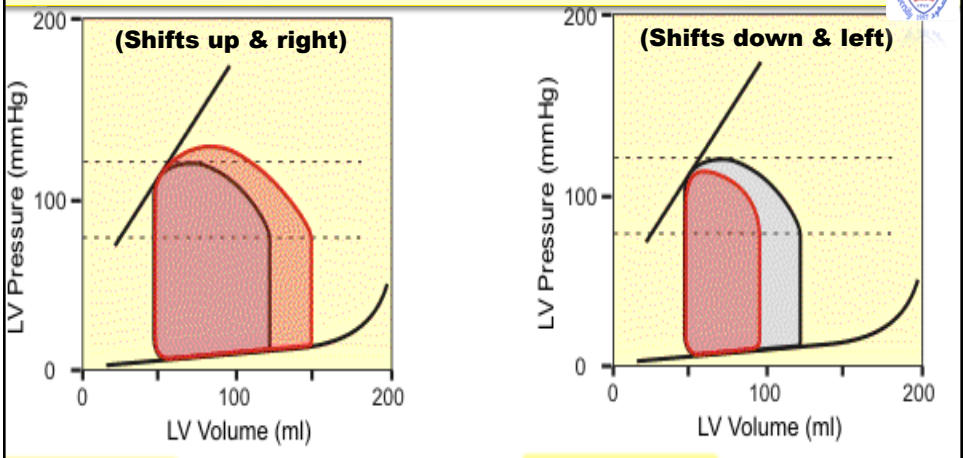
Increasing Ventricular Preload Increases SV



Increased preload (increased EDV; red loop) at constant aortic diastolic pressure and inotropy. SV increases and ESV remains unchanged; EF increases slightly. Dashed lines represent normal aortic systolic and diastolic pressures.

Decreased preload (decreased EDV; red loop) at constant aortic diastolic pressure and inotropy. SV decreases and ESV remains unchanged; EF decreases slightly. Dashed lines represent normal aortic systolic and diastolic pressures.

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Increasing Ventricular Afterload Decreases SV

- **Afterload:**
  The tension against which the ventricle must contract
- **↑ Afterload,** by ↑aortic diastolic pressure
  - Reduces the velocity of muscle fibre shortening
  - Reduces the velocity by which blood is ejected
- **Net effect is to ↑ ESV & to ↓ SV**

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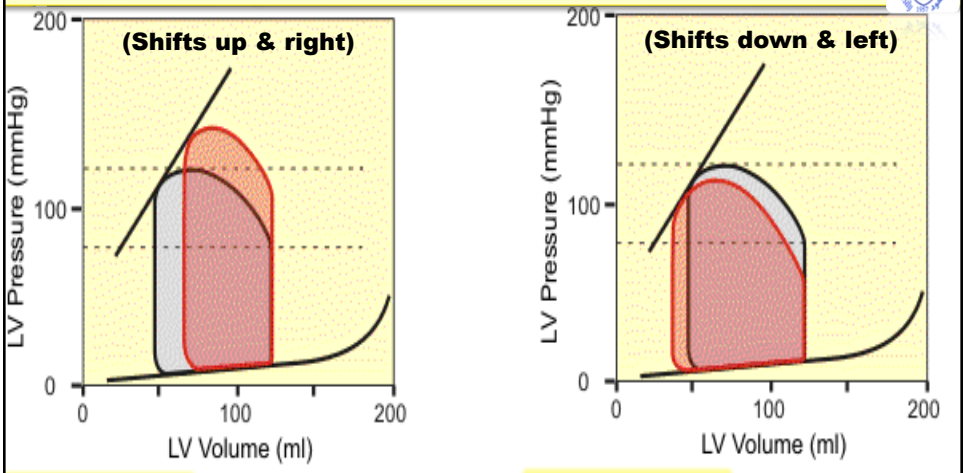
Increasing Ventricular Afterload Decreases SV



ncreased afterload increased aortic pressure; red loop) at constant preload (EDV) & inotropy. SV decreases and ESV increases; EF decreases. Dashed lines represent normal aortic systolic and diastolic pressures.

Decreased afterload (decreased aortic pressure; red loop) at constant preload (EDV) & inotropy. SV increases and ESV decreases; EF increases. Dashed lines represent normal aortic systolic and diastolic pressures.

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Increasing Ventricular Contractility Increases SV

- **Contractility:**
  The force of contraction for a given fibre length
- **↑ Inotropy,**
  - Increases the velocity of muscle fibre shortening
  - Increases the velocity of ventricular pressure development & ejection
- **Net effect is to ↓ ESV & to ↑ SV**

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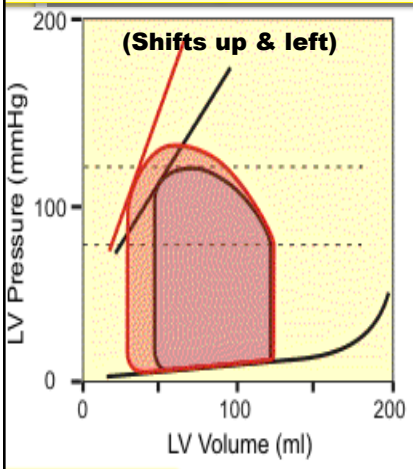
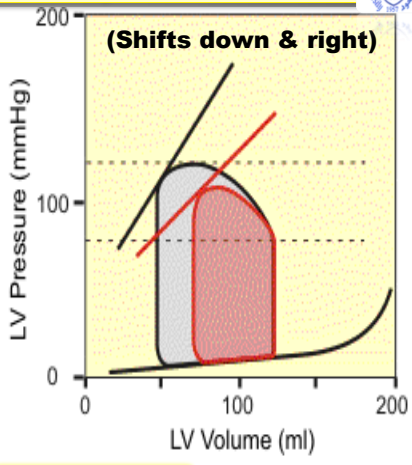
Increasing Ventricular Contractility Increases SV



Increased inotropy (red loop) at constant preload (EDV) & aortic diastolic pressure. SV increases and ESV decreases; EF increases. Dashed lines represent normal aortic systolic and diastolic pressures.



Decreased inotropy (red loop) at constant preload (EDV) & aortic diastolic pressure. SV decreases and ESV increases; EF decreases. Dashed lines represent normal aortic systolic and diastolic pressures.

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Thank You