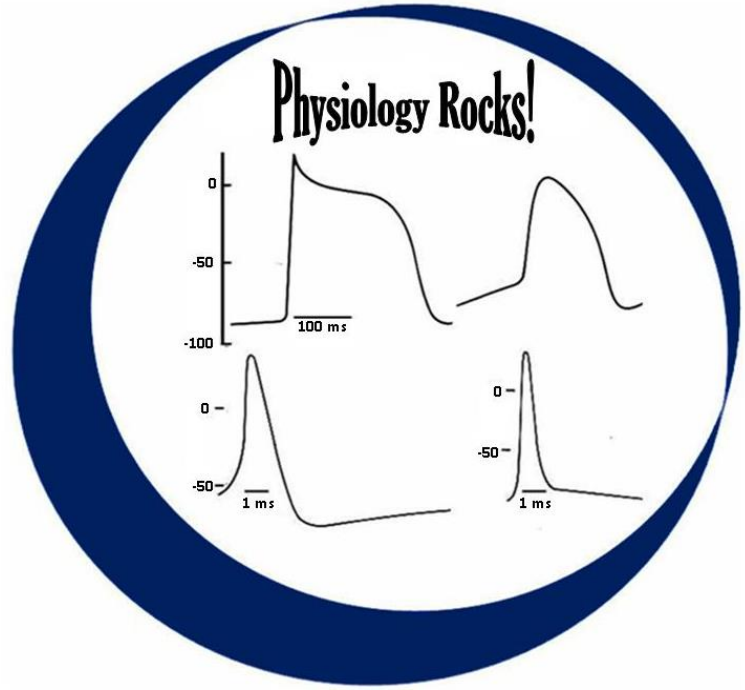
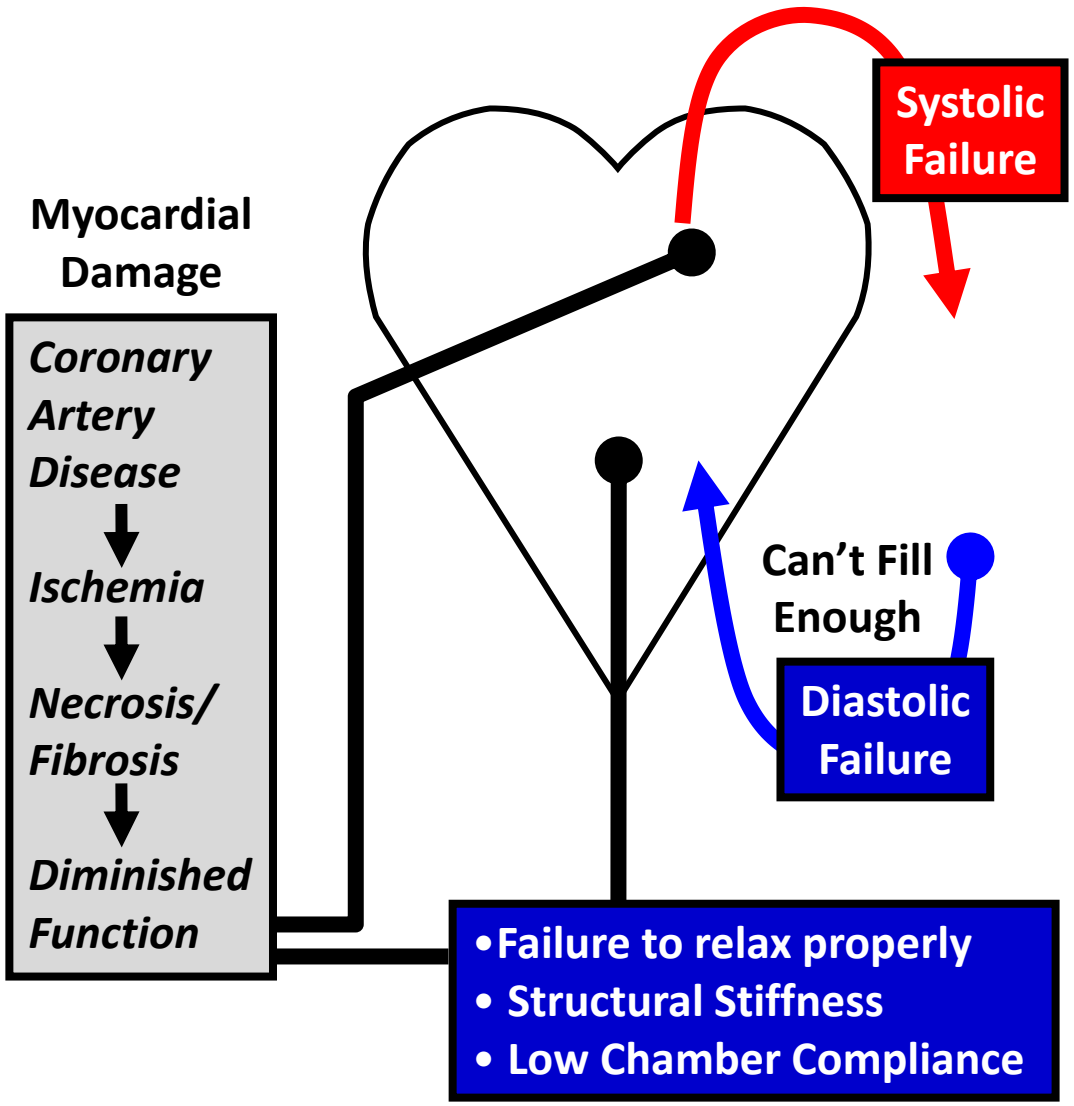
Lecture 27
Pump Failure and Hemodynamics



HN Mayrovitz PhD
mayrovit@nova.edu
drmayrovitz.com

Pump Failure → Heart Failure: Overview



PUMP FAILURE

May develops rapidly ('Acute')

- **M.I.**
- **Infection**
- **Post bypass surgery**

May develop over Time ('Chronic')

- **Pressure overload as with:**
  - **hypertension (HTN)**
  - **aortic stenosis (AS)**
- **Volume Overload as with:**
  - **aortic regurgitation (AR)**
  - **mitral regurgitation (MR)**

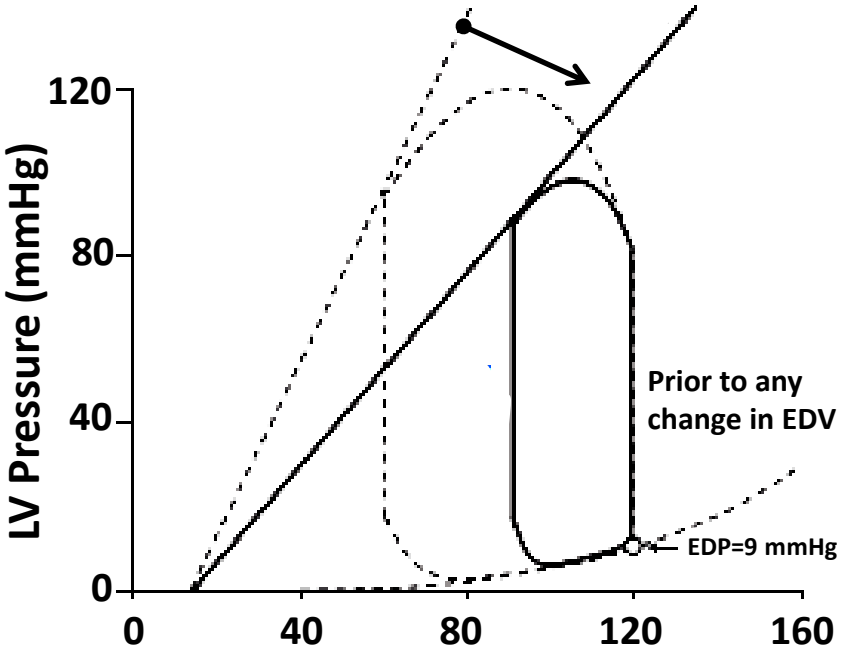
- **Adaptive Remodeling**
  - **Ventricular Hypertrophy**
  - **Chamber Dilation**

- **Functional Decline**

Pump Failure → Systolic vs. Diastolic Dysfunction

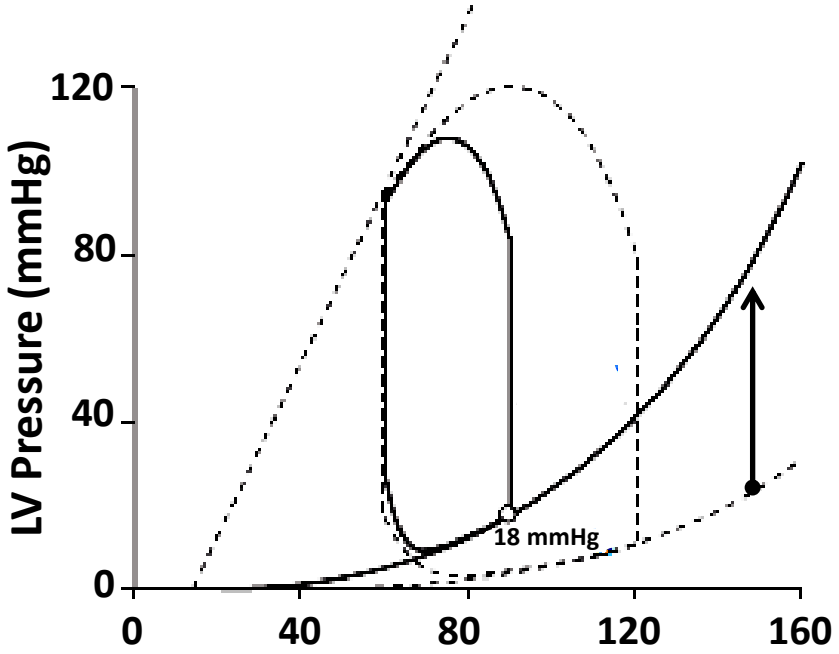
Acute Initial Changes

Systolic Dysfunction



- Contractility is reduced
- ESV is increased
- Stroke volume is reduced

Diastolic Dysfunction



- Contractility is unchanged
- EDP is increased
- Stroke volume is reduced

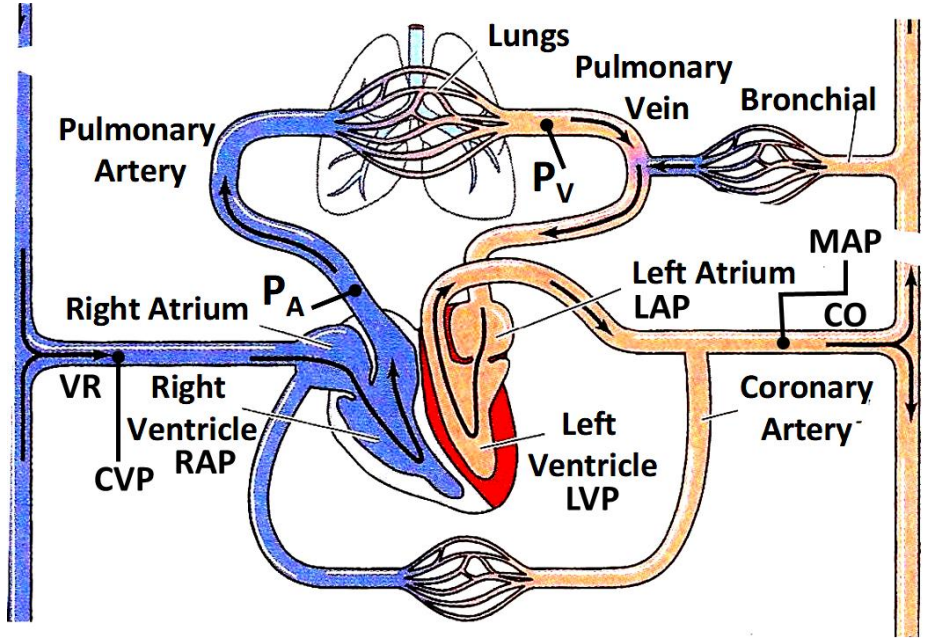
Cardiac Valve Conditions Affecting Pump Function

- Aortic Stenosis
- Mitral Stenosis

→ Pressure "overload"
- LVP
- LAP

- Aortic Insufficiency (Regurgitation)
- Mitral Insufficiency (Regurgitation)

→ Volume "overload"
- LV
- LA



P_A = Pulmonary artery pressure
P_V = Pulmonary vein pressure
MAP = Mean aortic pressure
CVP = Central venous pressure
RAP = Right atrial pressure
LAP = Left atrial pressure
LVP = Left ventricular pressure
RVP = Right ventricular pressure

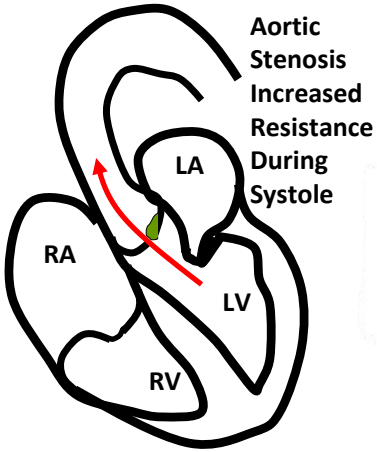
Aortic Stenosis

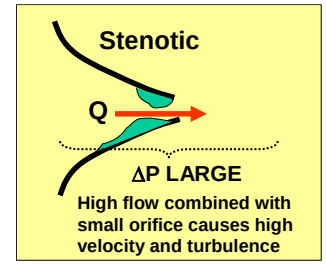
Outflow obstruction → **Systolic Velocity Increase** → **Systolic Murmur**

+ Ventricle Pressure

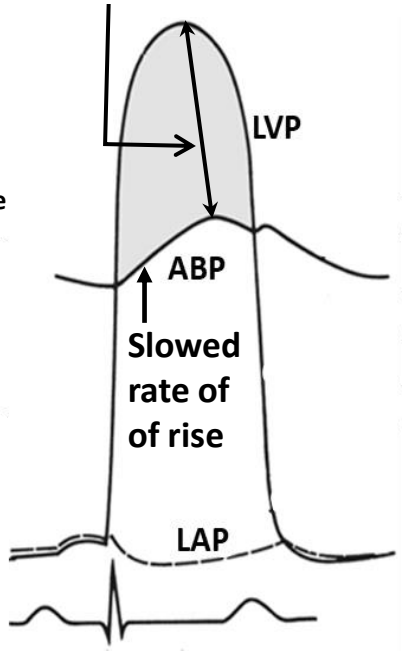
+ Pressure Loss

Decreased Stroke Volume





Gradient=LVP-ABP



Outflow obstruction summary

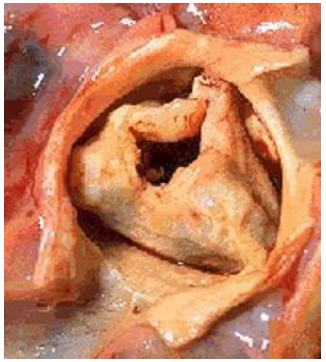
- (+) Valve Resistance and (+) LVP
- (-) SV and (-) SBP and (-) d(ABP)/dt
- + LVP predisposes to LVH
- Peripheral pulse weak and non-crisp on palpation
- Reduced valve area with high flow (CO) causes high Reynold's number → systolic murmur

Older Age

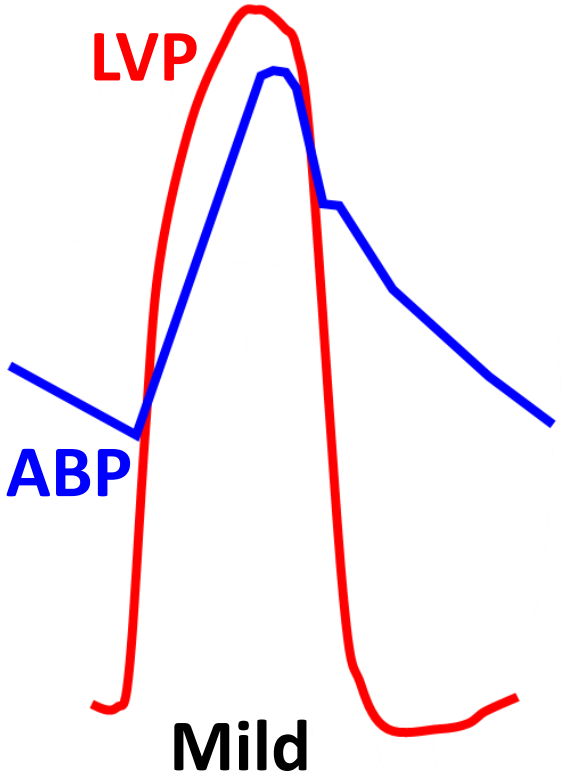
- Calcification

Rheumatic

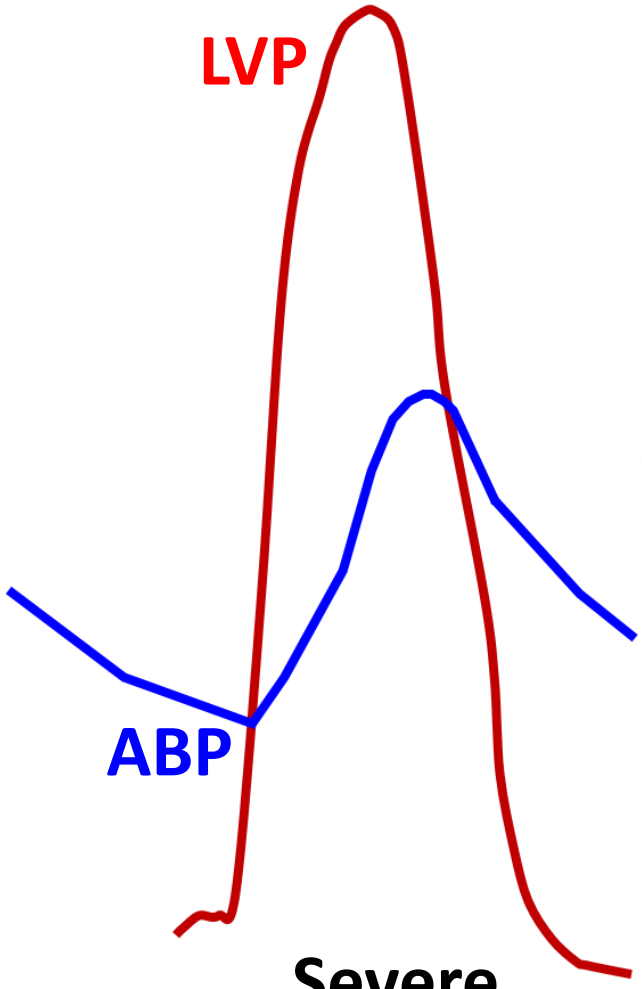
- Fibrosis
- Calcification



Aortic Stenosis: Mild vs. Severe



Mild



Severe

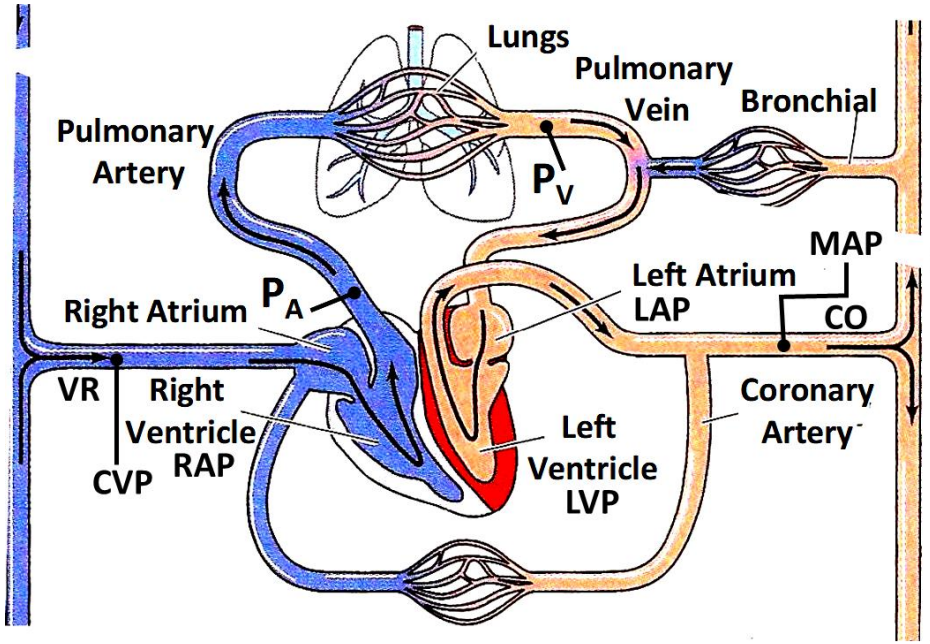
(+) LVP

(-) ABP

(+) Gradient

(-) d(ABP)/dt

Interactive Question



In the early stages of a hemodynamically significant aortic stenosis, which one of the *following* pressures increases first?

A) RAP

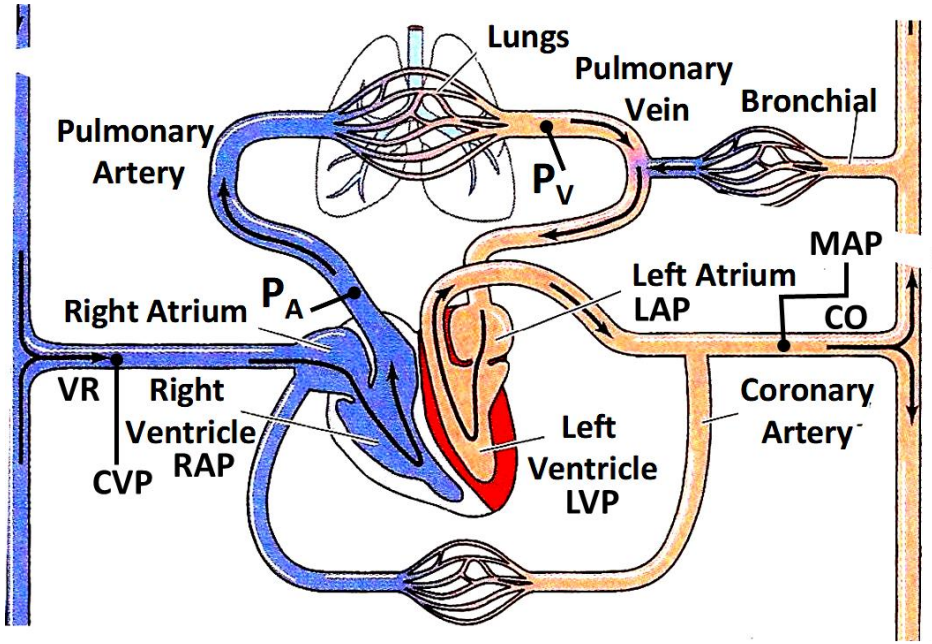
B) CVP

C) MAP

D) LAP

E) P_A

Interactive Question



Bill is a 72-year-old gentleman with a history of aortic stenosis and significant arterial hypertension. He is complaining of breathing difficulties. An elevation in which one of the following pressures most directly contributes to his symptom?

A) RAP

B) CVP

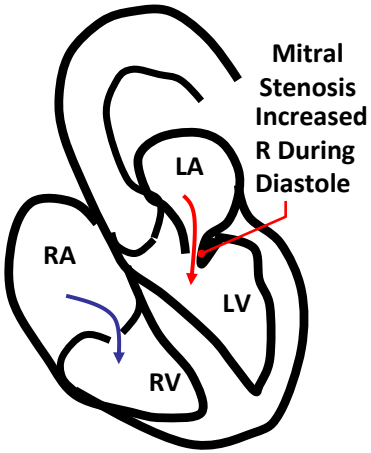
C) MAP

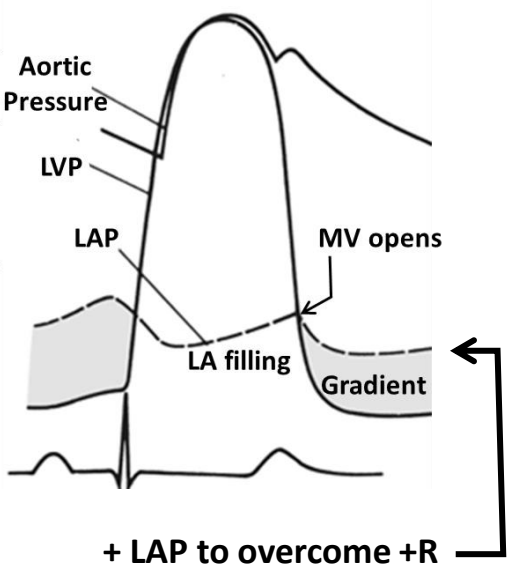
D) LVP

E) P_V

Mitral Stenosis

Inflow obstruction → **Diastolic velocity increase** → **Diastolic Murmur**

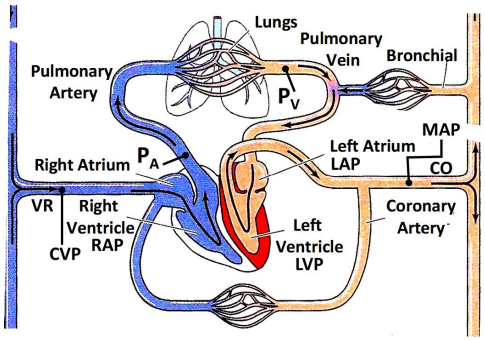




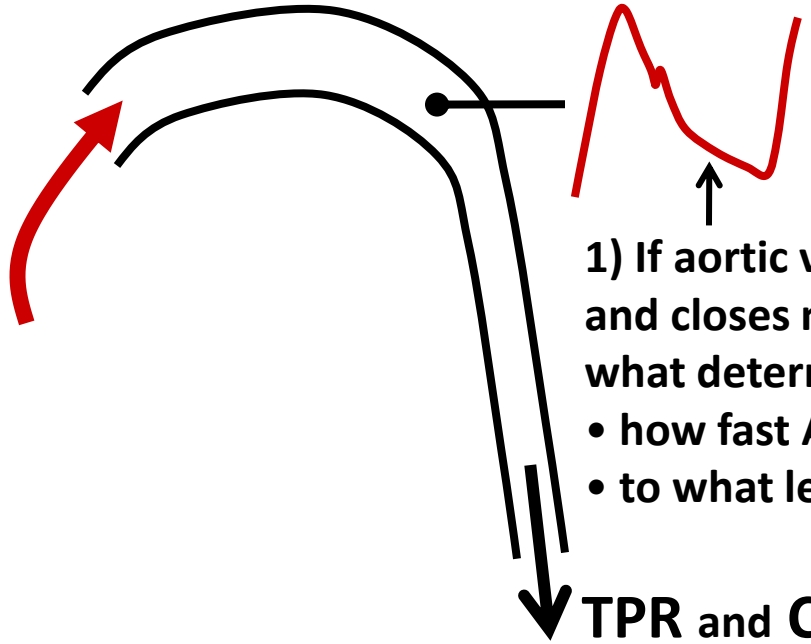
Inflow obstruction summary

- + Valve resistance and + LAP
- + LAP predisposes to
  - → LA enlargement and volume increase
  - → Atrial Arrhythmias
  - → Pulmonary edema
- Severity measurable via the LAP – LVP gradient
- Since ventricular filling is during diastole, the stenosis causes a diastolic murmur

Rheumatic Carditis
- Fibrosis
- Calcification

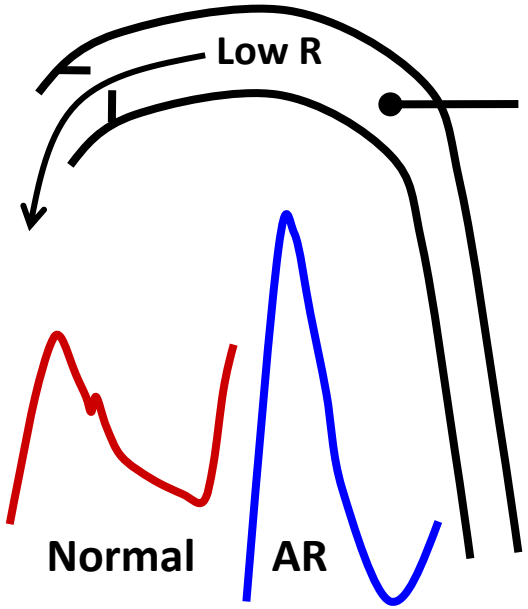


Aortic Insufficiency – Regurgitation (AR)



1) If aortic valve is normal and closes normally what determines:
- how fast ABP falls?
- to what level it falls?

TPR and **C** are main factors affecting ABP fall

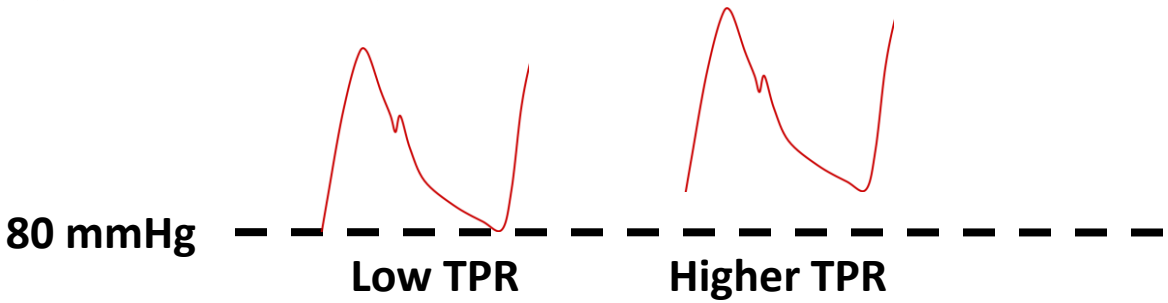


3) What happens if the valve fails to close normally?

4) What accounts for the increased Systolic Pressure?

+Preload → +SV

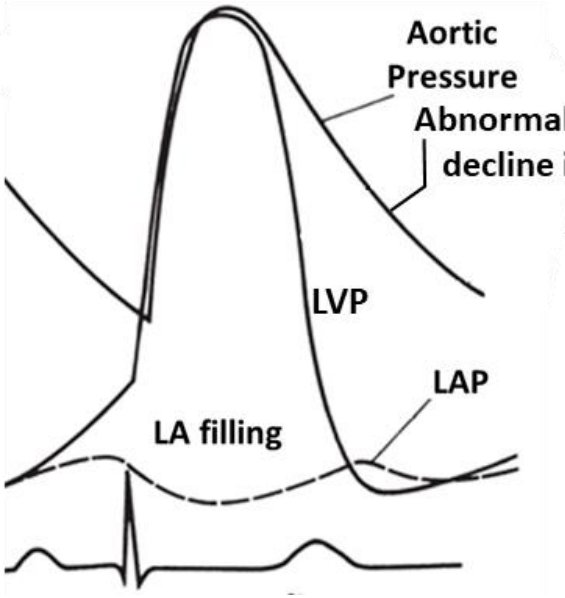
2) If TPR increases, what would you expect to happen to diastolic pressure?



Aortic Insufficiency – Regurgitation: Summary

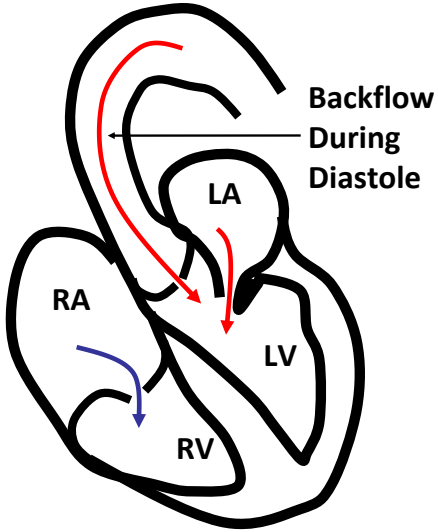
Diastolic backflow → Diastolic velocity increase → Diastolic Murmur

- + EDV → + SV → + Systolic Pressure
- Low R pathway → - Diastolic Pressure
- Combination → + Pulse Pressure



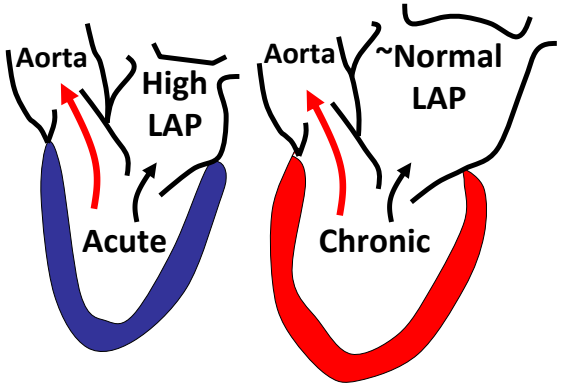
Aortic Insufficiency summary

- Aortic valve does not close fully during diastole
- Backflow from aorta to LV as long as ABP >LVP
- This low resistance pathway causes a rapid decline in ABP
- Effective SV is compromised
- Ventricle will hypertrophy (LVH) as it tries to compensate for "lost" effective SV
- Reduced valve area causes increased N_R during backflow
- Diastolic murmur!

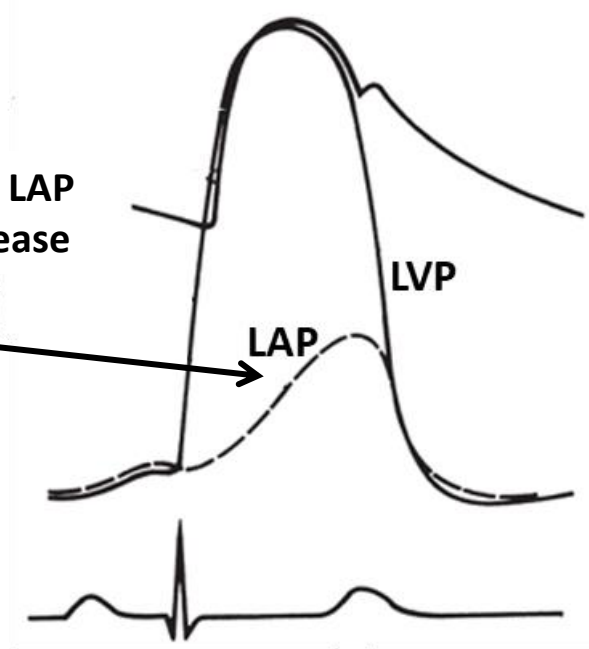


Mitral Insufficiency - Regurgitation

Systolic backflow → Systolic Murmur



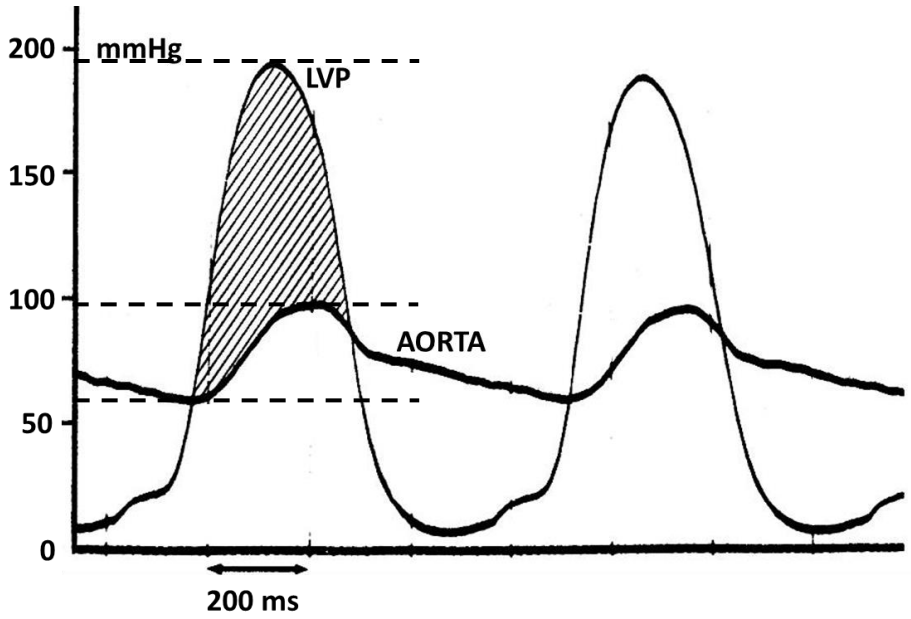
Causes LAP to increase



Mitral Insufficiency Summary

- Effect depends on if acute or slowly developing
- Acute (e.g. rupture of the chordae tendineae) causes volume to enter atrium during systole
- Result is increase in LAP since no adaption of atrial size to accommodate increased volume
- Chronic, that develops over time permits atrium to adjust to accommodate added volume with a lessor increase in LAP

Interactive Question



The figure shows hemodynamic measurements in a 62-year old patient with a childhood history of rheumatic fever.

1) Which of the following cardiac valve conditions is most likely present?

A) Mitral stenosis

B) Aortic stenosis

C) Aortic regurgitation

D) Aortic insufficiency

E) Mitral regurgitation

2) His gradient is closest to which of the following values in mmHg?

A) 50

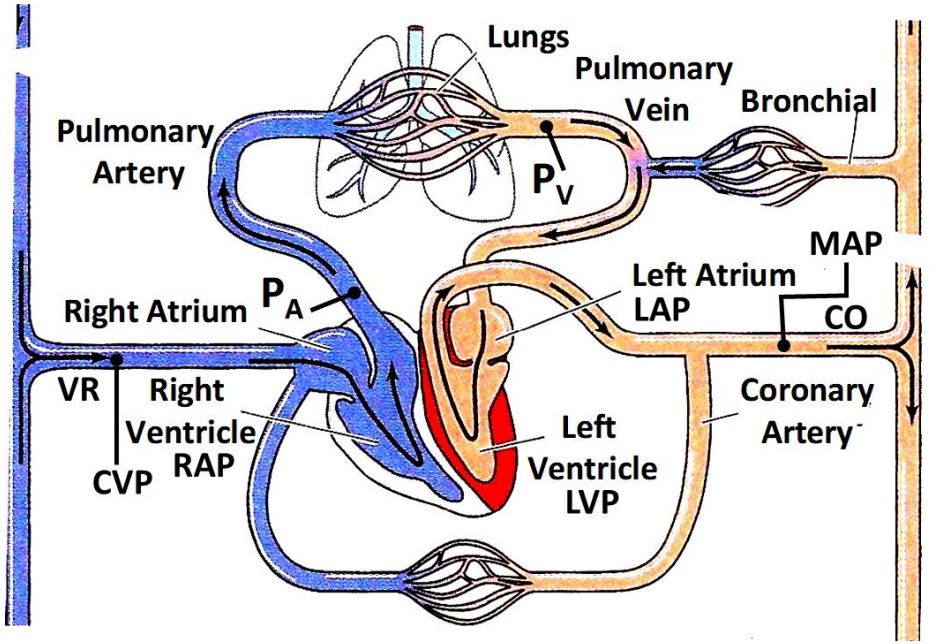
B) 75

C) 100

D) 150

E) 200

Interactive Question



Jill is a 68-year-old retired nurse who presents with significant bilateral ankle edema (swelling) and breathing difficulties on exertion. An elevation in which one of the following pressures *most directly* contributes to her ankle edema?

A) LAP

B) CVP

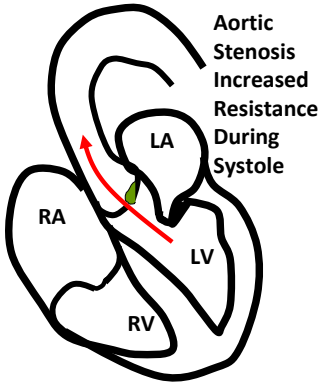
C) MAP

D) LVP

E) P_V

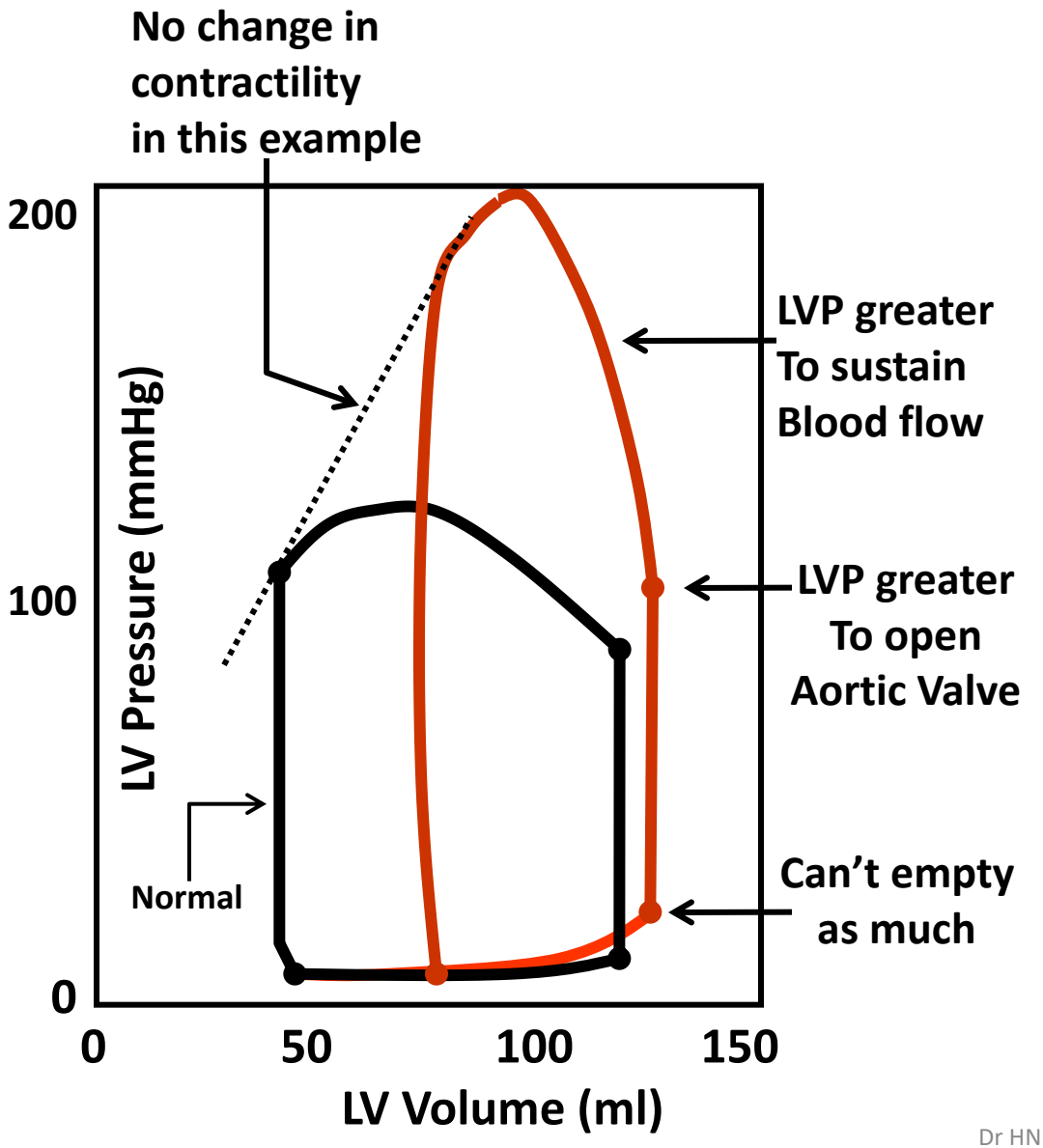
Impact of Valve Dysfunction on P-V Loops

Aortic Stenosis: P-V LOOPS

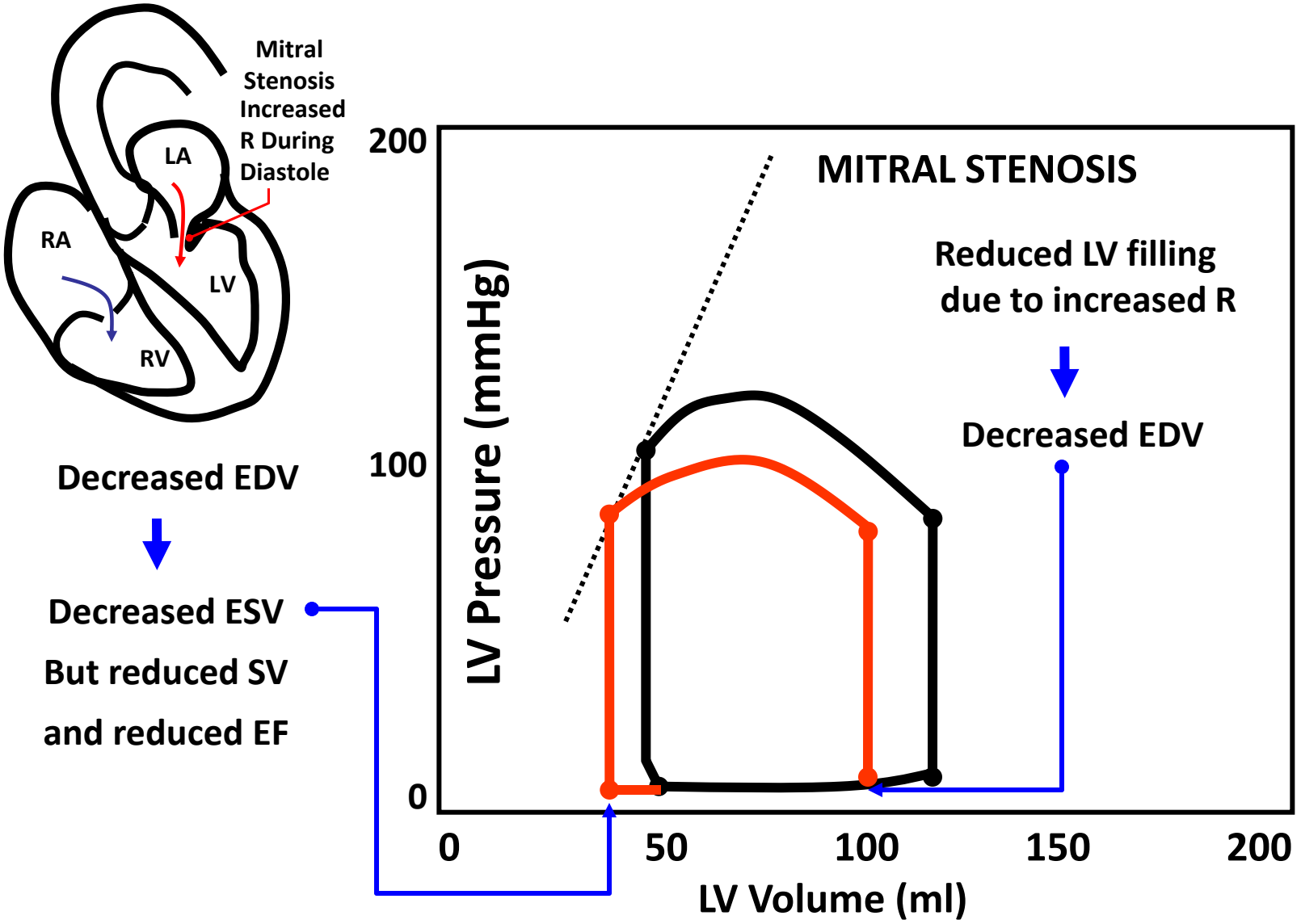


AORTIC STENOSIS

- Increased outflow R causes increase in effective afterload
- SV & EF are reduced
- LV pressures are elevated and don't represent aortic pressure as they normally would

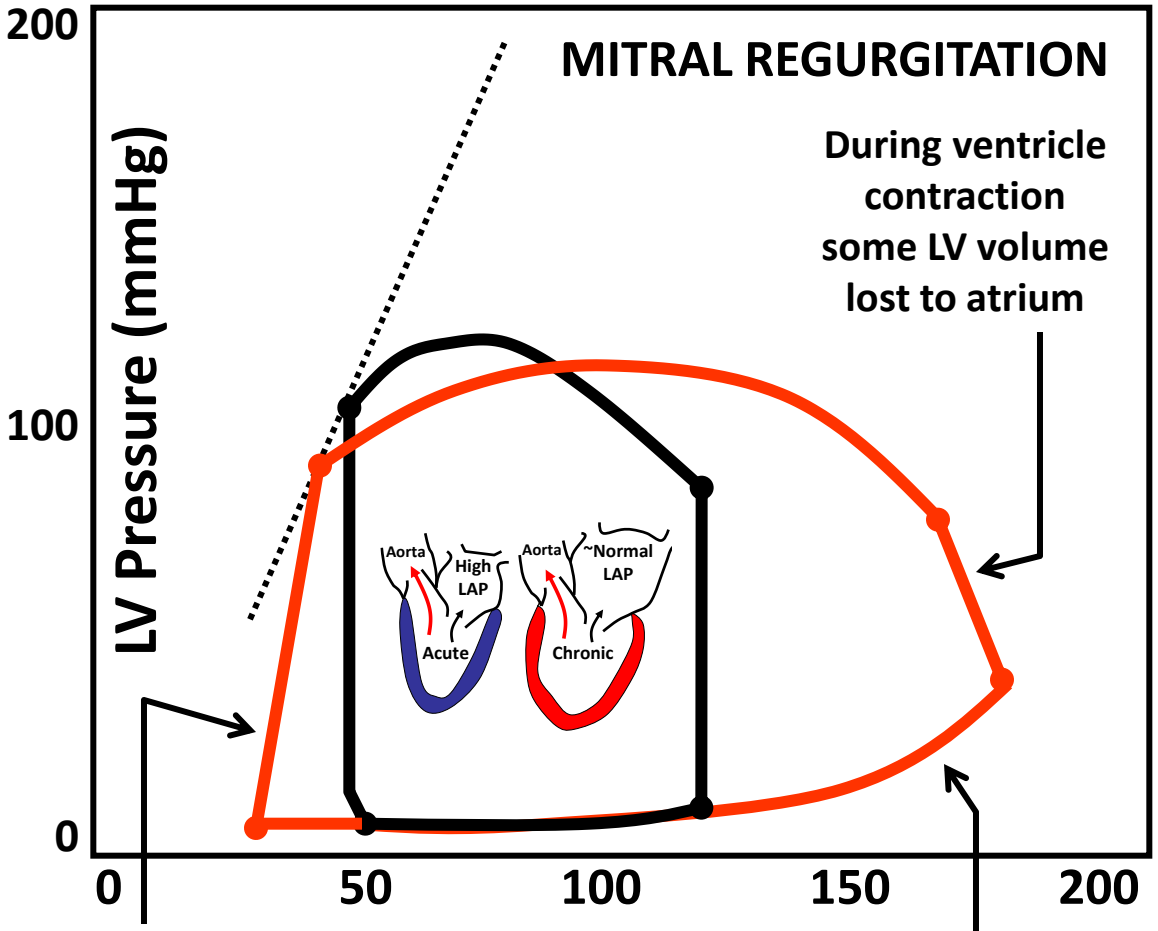


P-V LOOPS: Mitral Stenosis (MS)



P-V LOOPS: Mitral Regurgitation (MR)

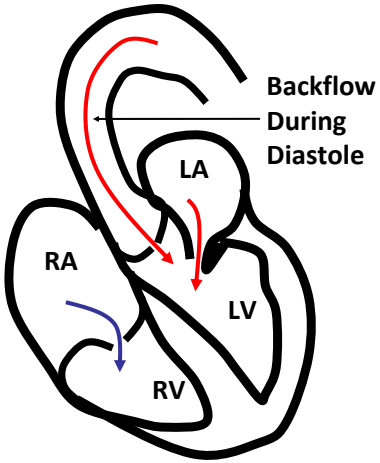
- Systolic backflow into Left Atrium (LA)
- Elevated LAP transmitted to LV during filling
- EDV is increased
- Adaptation over time to compensate for lost *EFFECTIVE* SV further increases EDV
- No isovolumic contraction or relaxation



P-V LOOPS: Aortic Regurgitation (AR or AI)

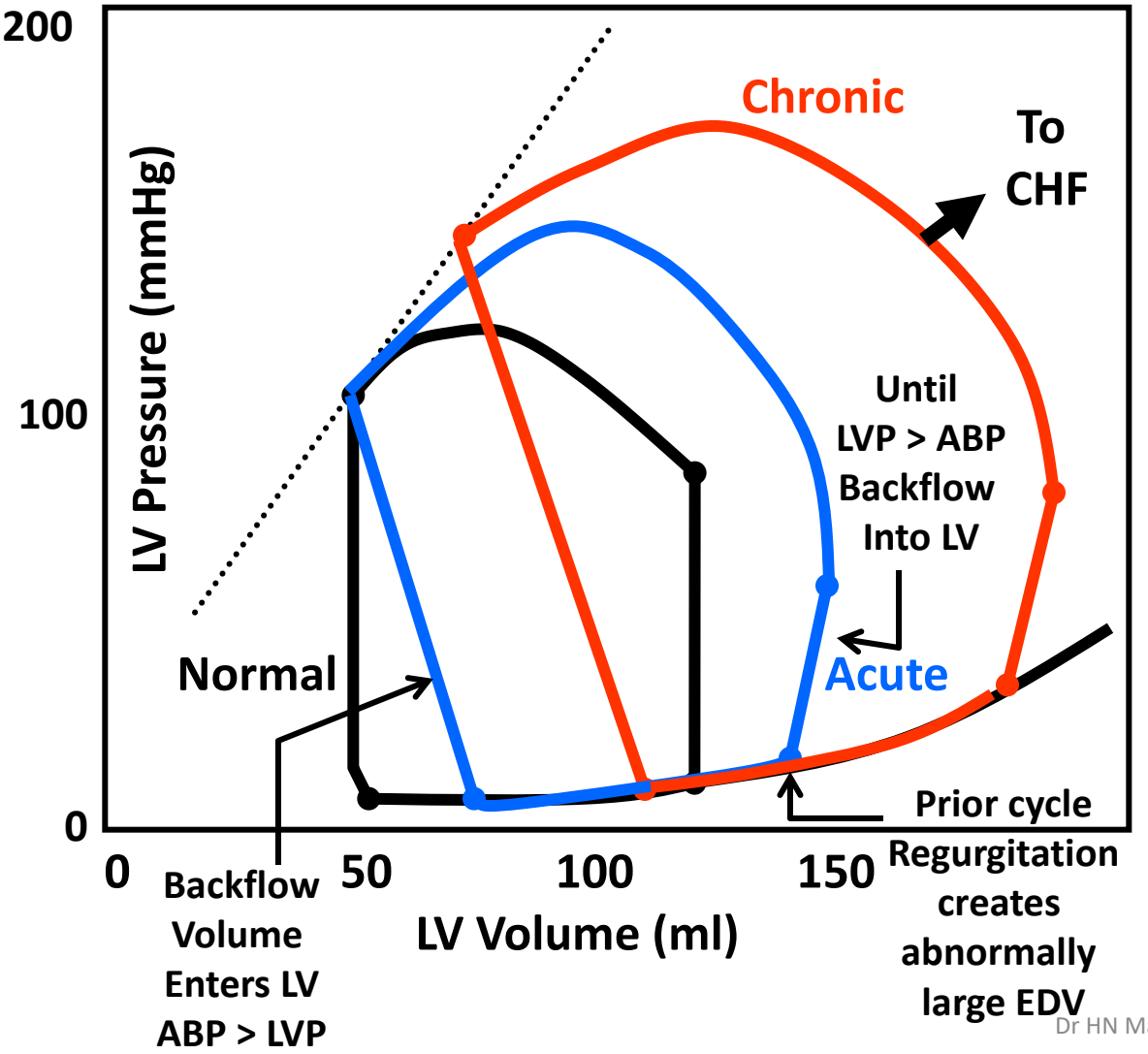
AORTIC REGURGITATION

- Regurge during ***diastole*** increases EDV and ESV



Relaxation & Contraction NOT isovolumic

Remodeling over time adds to EDV increase (eccentric hypertrophy)

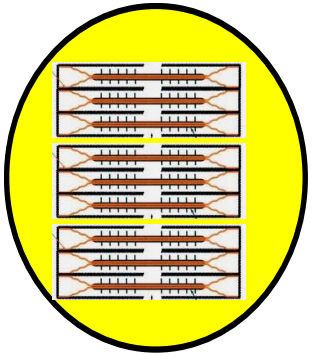


Adaptations and Remodeling

Adaptations / Remodeling

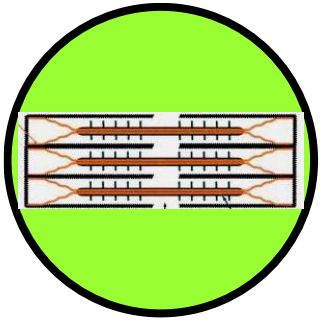
+ Afterload

more force needed to overcome greater load



Concentric
+ Muscle Mass
AS or HTN

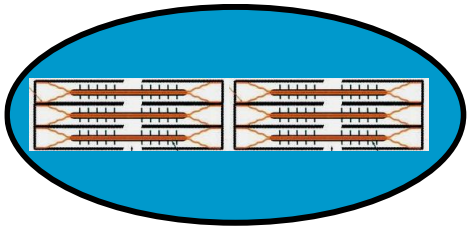
HYPERTROPHY



Normal Mass & Volume

+ Preload

chamber expands to accommodate larger volume



Eccentric
+ Chamber Size
MR or AR

Summary of Systolic Dysfunction

Systolic Dysfunction

-Myocardial Contractility

↓

Impaired Contraction

↓

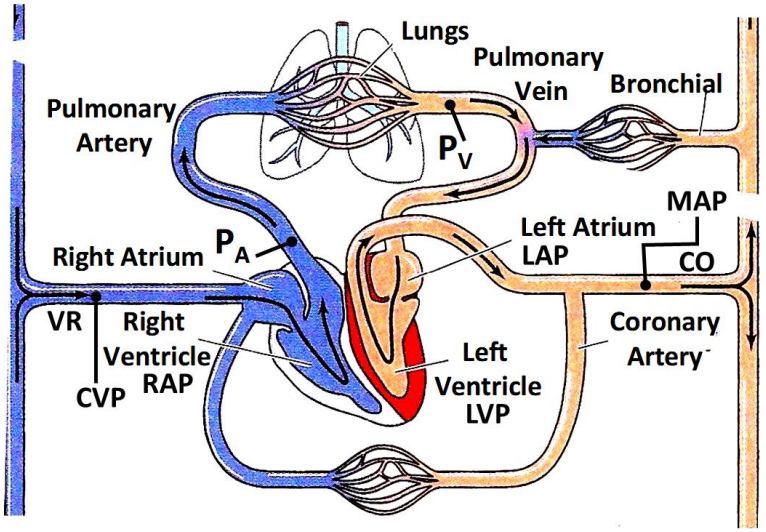
-SV

↓

+EDV

↓

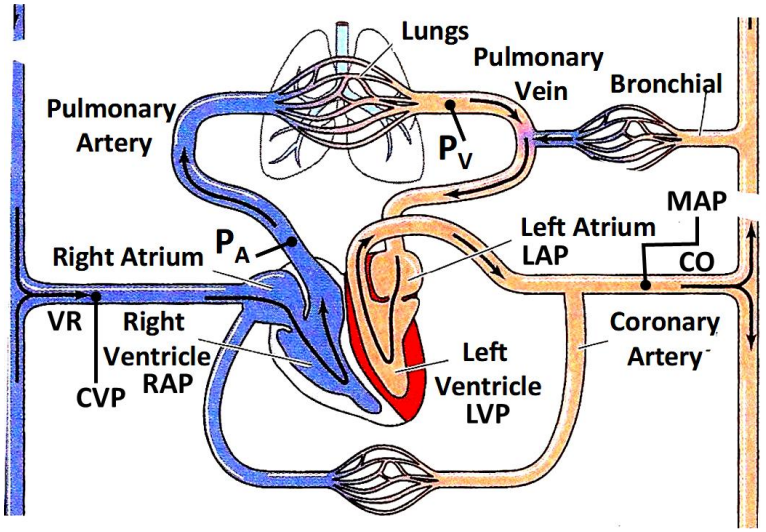
+EDP →



Intrinsic dysfunction of contractile apparatus e.g. - inotropy	Loss of Viable Contracting Muscle e.g. M.I.

IF LV involved: → initially pulmonary congestion & edema
IF RV involved: → initially peripheral edema and ascites

Summary of Diastolic Dysfunction



Diastolic Dysfunction

-Ventricle Compliance

- EDV → - SV

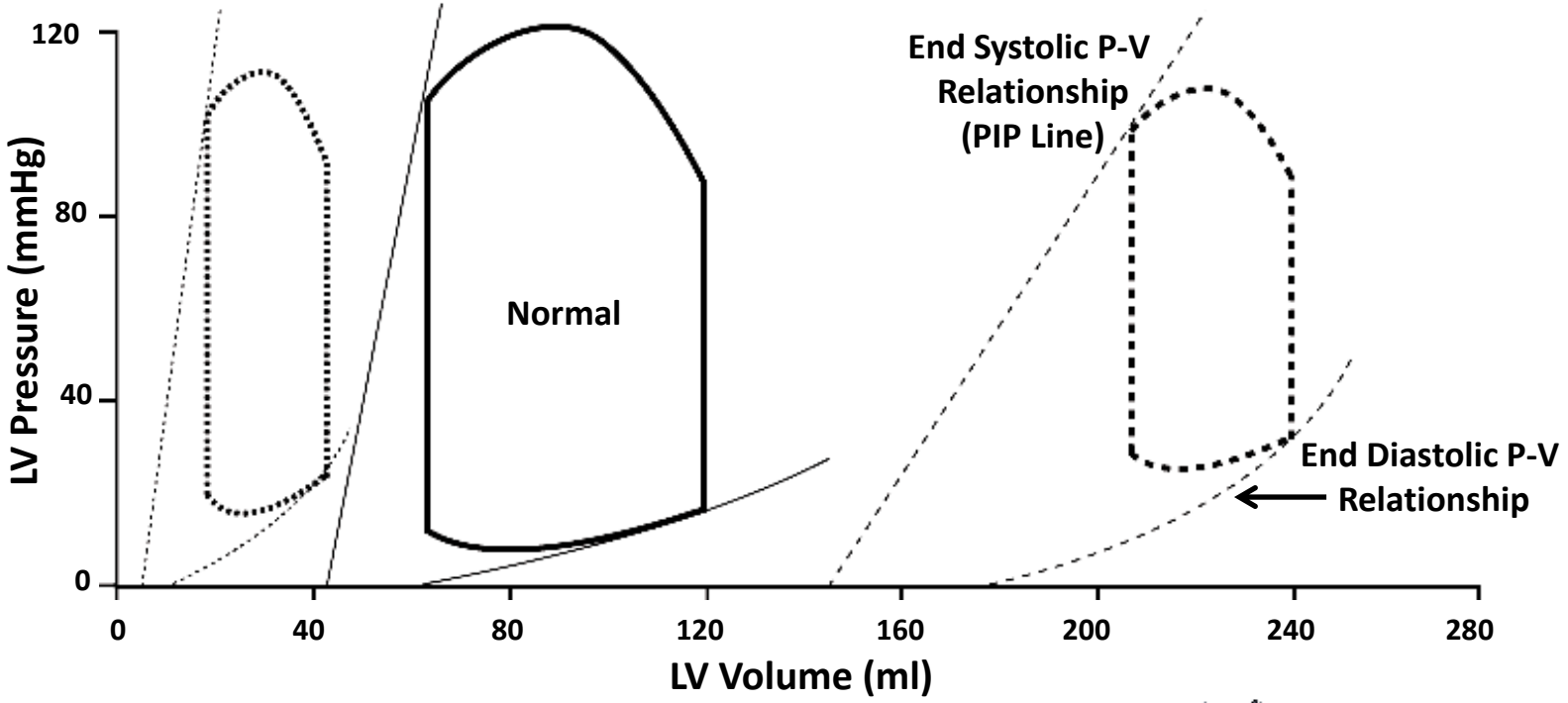
+ EDP → Pulmonary Congestion

- Reduced lusitropy
- Structural Changes

Reduced removal rate or amount of Ca^{++} from SR during diastole

Hypertrophy
+ Muscle mass
+ Wall Thickness
+ Tissue fibrosis

Remodeling Impacts on P-V Loops: Overview



Caused by Ventricular Pressure Overload

Concentric Hypertrophy
- Diastolic Failure
- EDP Increased
- EDV Decreased
- SV Decreased

Normal

Caused by Ventricular Volume Overload

Increased wall stress
$\sigma = P(r/W)$

Eccentric Hypertrophy
- Systolic Failure
- EDP Increased
- EDV Increased
- SV Decreased

End Lecture 27
Interactive Questions if Time