HEART SOUNDS & MURMURS

01:00

I. HEART SOUNDS

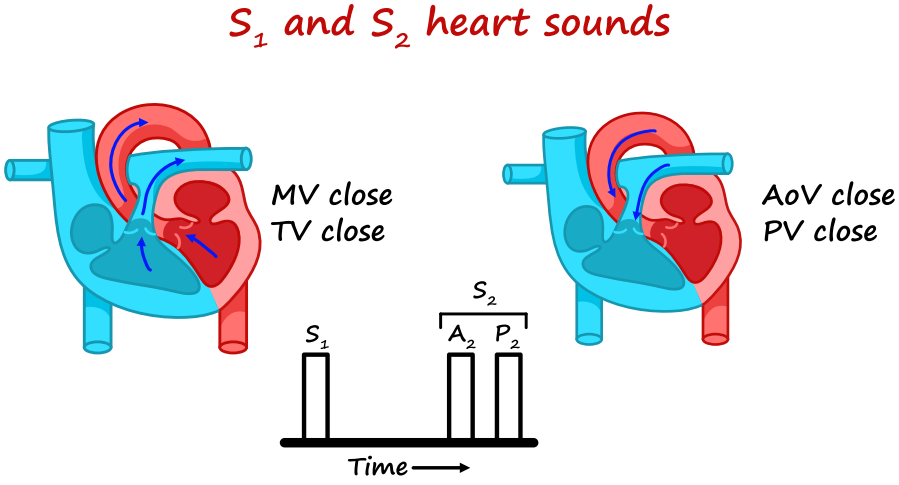
A. S1 AND S2

S1

- **S1 Heart Sound Representation:**
  - Timing of S1: Occurs during **ventricular systole**
    - Closure of → Mitral valve and Tricuspid valve
    - Opening of → Aortic valve and Pulmonary valve
- **Physiology behind S1 Heart Sound:**
  - → ↑Ventricular pressure during systole
  - → Ventricular pressure rises above aortic/pulmonary pressures.
  - → Opens up aortic/pulmonary valve pushing blood into arteries
  - → Ventricular pressure rises above atrial pressures
  - → Closes Tricuspid and Mitral valve, preventing backflow into atria

S2

- **S2 Heart Sound Representation:**
  - Timing of S2: occurs during ventricular diastole
    - Closure of → Aortic and Pulmonary valve
    - Opening of → Mitral and Tricuspid valve
- **Physiology behind S2 Heart Sound:**
  - → ↓Ventricular pressure during diastole
  - → Ventricular pressure drops below aortic/pulmonary pressures
  - → Closes aortic/pulmonary valve prevents backflow into ventricles
  - → Ventricular pressure drops below atrial pressures
  - → Opens tricuspid and mitral valve allowing blood into ventricles
- **Specific details about S2 heart sound:**
  - This can be divided into the respective valves closing:
    - **A2** (aortic valve closure)
      - This closes early since the aortic pressure is a high-pressure system in comparison to pulmonary arteries
    - **P2** (pulmonary valve closure)



B. S3 and S4

03:35

S3

- **S3 Heart Sound Representation:**
  - Represents the abrupt cessation in rapid ventricular filling early in ventricular diastole in the setting of ventricular dilation
    - → Creating turbulence in blood flow
    - → Blood bounces off the walls of ventricles, creating a murmur

S4

- **S4 Heart Sound Representation:**
  - Represents significant atrial contraction or "**atrial kick** "late in ventricular diastole
    - → The atria need to push the remaining blood into ↓compliant ventricles in the setting of ventricular systole
    - → "**The atrial kick**" creates the characteristic murmur

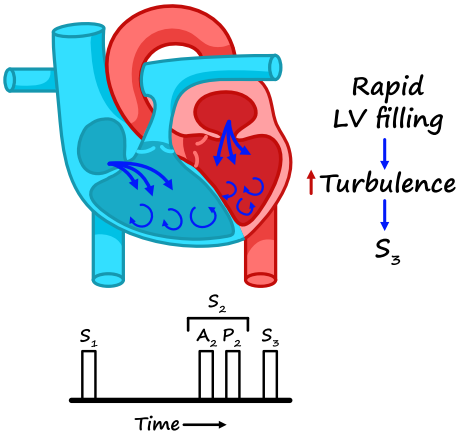
Causes of S3:

- Systolic HF
- Dilated cardiomyopathy
- Physiologic:
  - In young, healthy athletes → Ability to trigger large SV

Causes of S4:

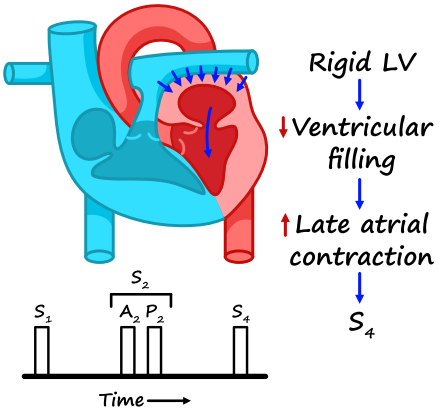
- Diastolic HF
- Anything that causes LVH:
  - Aortic stenosis
  - Chronic hypertension

S_3 and S_4 heart sounds



Causes of S_3:

- Systolic HF
- Dilated CMP
- Young athletes



Causes of S_4:

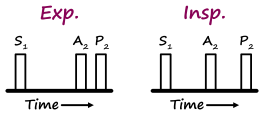
- Diastolic HF
- A. stenosis → LVH
- HTN → LVH

D. Splitting of S2

1. Physiologic Split of S2 — 09:21

- **Pathophysiology of Respirophasic Variation in S2:**
  - **Inspiration** → ↑Right-Sided Venous Return → ↑Blood flow moving across pulmonary valve → ↑Time required to close pulmonary valve given ↑Blood flow into pulmonary artery → Leads to delayed closure of P2
  - **Expiration** → ↓Right-Sided Venous Return → ↓Blood flow moving across pulmonary valve → ↓Time required to close pulmonary valve given ↓Blood flow into pulmonary artery → leads to early closure of P2

↑R. venous return



Physiologic split S_2 causes:
- Respirophasic changes

2. Wide Split of S2 — 11:47

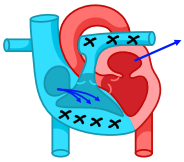
- **Pathophysiology:**
  - **Delayed RV depolarization or ↑Pulmonary afterload** → ↑Delay in RV ejection of blood → ↑Time required to open and close pulmonary valve given delay in RV ejection of blood → Leads to further delay in closure of P2, **especially during inspiration** when there is ↑Right-Side Venous Return
- **Specific details about Wide split S2:**
  - The splitting is heard in both expiration and inspiration
    - During inspiration → A2 and P2 sound much more distinguishable
    - During expiration → A2 and P2 sound less distinguishable

Causes of Wide Split:

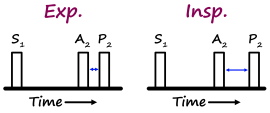
- **RBBB**
  - Delayed RV depolarization → Delay in RV contraction → Delay in closure of P2
- **Pulmonary Hypertension**
  - ↑Pulmonary afterload → ↓RV ejection of blood → Delay in closure of P2

What Happens During Inspiration?

- During inspiration, the strained right heart receives more venous return than it can handle, causing a more pronounced splitting



↑↑R. venous return in strained r. heart



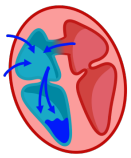
Wide split S_2 causes:
- RBBB
- Pulmonary HTN

3. Fixed Split of S2 — 17:19

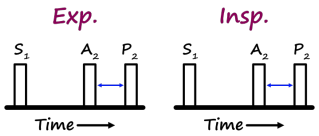
- **Pathophysiology:**
  - ↑Right venous return that is fixed during inspiration and expiration secondary to both intrathoracic pressure changes during inspiration and ASD shunting of blood during expiration

Cause:

- **Atrial septal defect (ASD)**
  - **During expiration:**
    - LA pressure > RA pressure → Shunting of blood to the right heart → Filling the right heart with ↑ blood → ↑Time to squeeze blood from the right heart & close pulmonary valve
  - **During Inspiration:**
    - ↓Intrathoracic pressure → ↑Right-sided venous return to right heart → Takes a longer time to squeeze blood out of the right heart & close pulmonary valve



↑R. venous return that is fixed



Fixed split S_2 causes:
- ASD

4. Paradoxical Split of S2 — 21:37

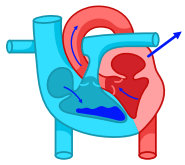
- **Pathophysiology:**
  - **Delayed LV Depolarization or ↑Pulmonary Afterload** → ↑Delay in LV ejection of blood → ↑Time required to open and close aortic valve given the delay in LV expulsion of blood → Leads to further delay in closure of A2, **especially during expiration** when there is a ↑left-sided venous return

Causes of Paradoxical Split

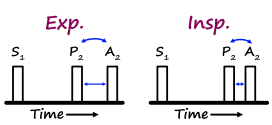
- **LBBB**
  - Delayed LV depolarization → Delay in LV contraction → Delay in the closure of A2
- **HTN, Aortic Stenosis, and HCM**
  - ↑Aortic Afterload → ↓LV ejection of blood → Delay in the closure of A2

Why is Splitting Narrower During Inspiration?

- During expiration:
  - → ↑Blood flow in the left heart → Makes it more difficult to get blood out of an already strained LV
- During inspiration:
  - → ↓Blood flow in the left heart → Makes it less difficult to get blood out of strained LV when it's not volume-overloaded



Delay in LV expulsion of blood



Paradoxical split S_2 causes:
- LBBB
- Aortic stenosis
- HCM
- Systemic HTN

II. MURMURS

A. Auscultation Locations

1. Aortic area:

- Right 2nd Parasternal Intercostal Space (ICS)
  - Systolic murmur
    - Aortic stenosis

2. Pulmonic area:

- Left 2nd Parasternal ICS
  - *Think Pulmonic Valve Diseases*

3. Erb's point:

- Left 3rd Parasternal ICS
  - Diastolic murmur
    - Aortic regurgitation (Valvular)
    - Hypertrophic Cardiomyopathy (HCM)

4. Tricuspid area:

- Left 4th Parasternal ICS
  - Holosystolic murmur
    - Ventricular Septal Defect (VSD)

5. Mitral area:

- Left 5th ICS → Think Mitral Valve Diseases
  - Holosystolic murmur
    - Mitral regurgitation
  - Systolic murmur
    - Mitral valve prolapse
  - Diastolic murmur
    - Mitral stenosis

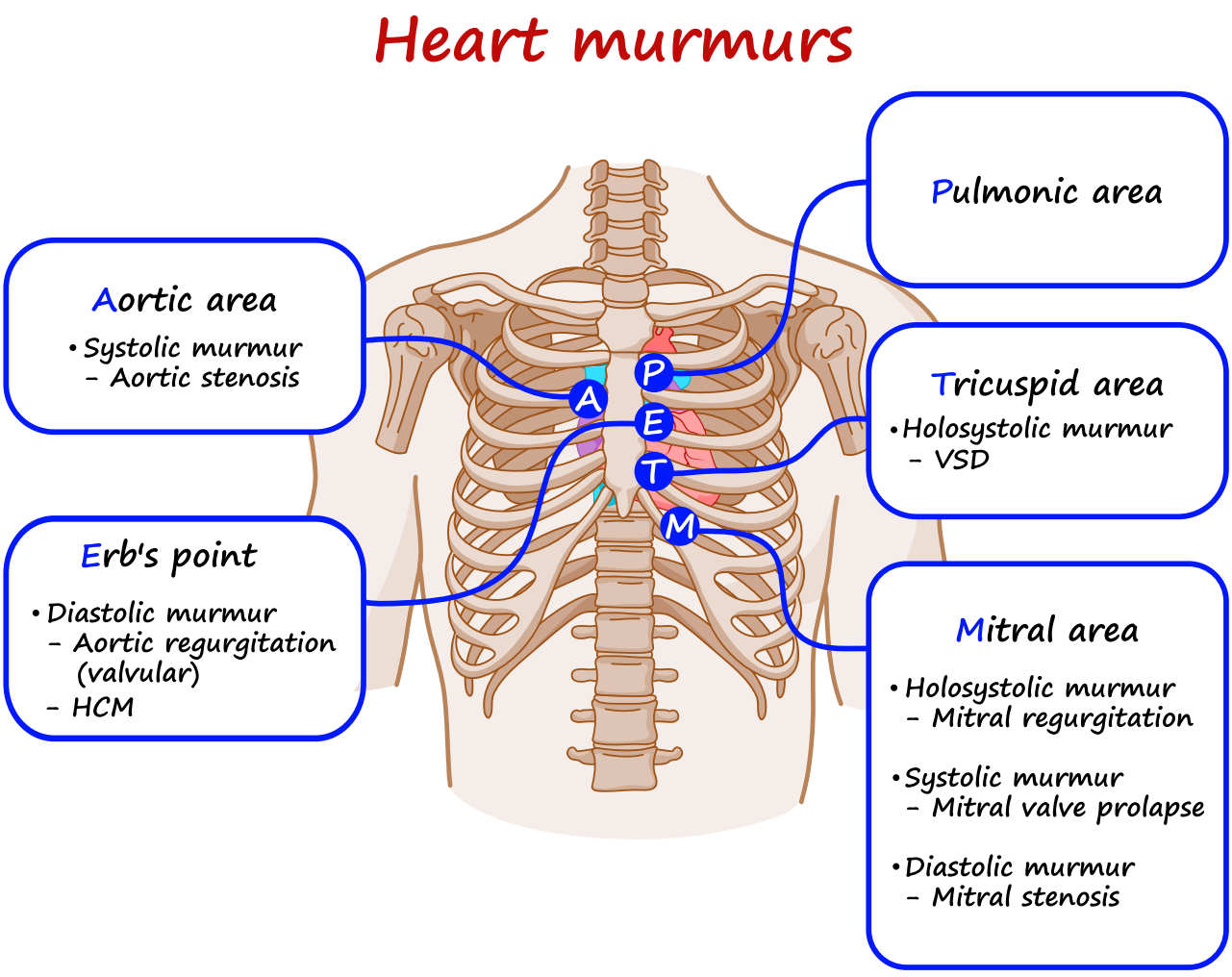
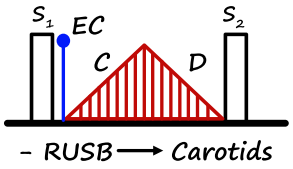


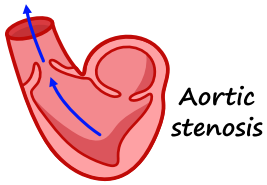
Figure 1. Auscultation Locations.

1. Crescendo-Decrescendo Murmurs

a) Aortic Stenosis

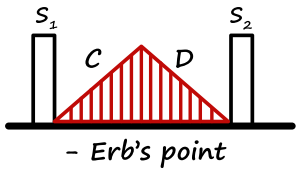
- **Ejection click** + crescendo-decrescendo murmur
  - Signifies difficulty ejecting blood from the LV to the aorta → Bends and bows the valve → Producing an **ejection click**
- Heard at the **right upper sternal border (RUSB)**
  - **Radiation** to the **carotids**





b) Hypertrophic Cardiomyopathy

- **No Ejection click,** but does have crescendo-decrescendo murmur
  - Signifies difficulty ejecting blood from the LV through the narrow **left ventricular outflow tract (LVOTO)**
- Heard at **Erb's point**
  - **NO radiation** to **carotids**



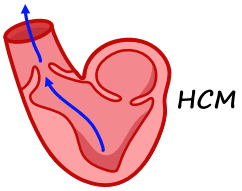


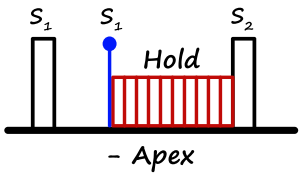
Table 1. Differentiating between aortic stenosis and HCM.

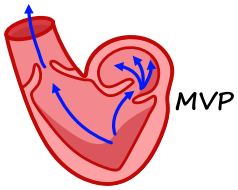
	Aortic Stenosis	Hypertrophic Cardiomyopathy
	Crescendo-decrescendo murmur	
Ejection click	(+)	(-)
Location	Right upper sternal border	Erb's point
Radiation	Radiates to the carotids	(-)

2. Holosystolic Murmurs

a) Mitral Valve Prolapse

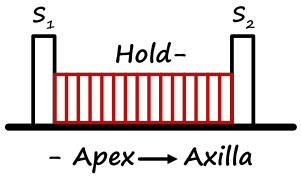
- **Ejection click** + holosystolic murmur
  - **Holosystolic murmur** signifies mitral regurgitation due to a dysfunctional mitral valve that does not change in intensity and is heard throughout the systolic process. Audible after the ejection click
  - **Ejection click** signifies buckling of the mitral valve, and this click can move earlier if the patient has a ↓venous return or later if there is a ↑venous return
- Heard at the **apex or Left 5th ICS, mid-clavicular line**

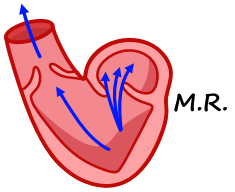




b) Mitral Regurgitation

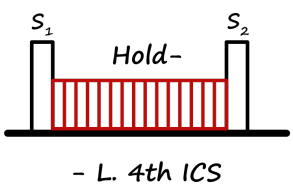
- **Holosystolic murmur** signifies mitral regurgitation due to a dysfunctional mitral valve that does not change in intensity and is heard throughout the systolic process
- Heard at the **apex** and radiates to the **axilla**





c) Ventricular Septal Defect (VSD)

- Holosystolic murmur in VSD signifies shunting of blood from LV to RV, creating a turbulence in blood flow across the VSD
  - The murmur changes with the size of the defect:
    - Smaller defect, louder murmur
    - Larger defect, softer murmur
- Heard at the **left 4th intercostal space**



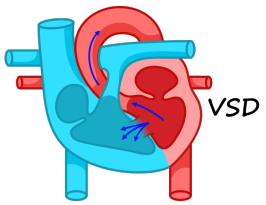


TABLE 2. DIFFERENTIATING MV PROLAPSE, MV REGURGITATION, & VSD.

	Mitral Valve Prolapse	Mitral Regurgitation	Ventricular Septal Defect
	Holosystolic murmur		
Ejection click	(+)	(-)	(-)
Location	Apex		Left 4th ICS
Radiation	(-)	Radiates to axilla	(-)

The murmurs mentioned are **left-sided** murmurs and are therefore more concerning and more common

Aortic and pulmonic stenosis will have the same type/quality of murmur but with different locations

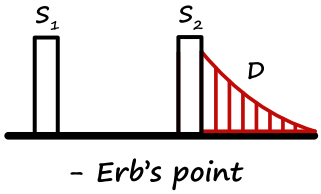
Similarly, mitral and tricuspid regurgitation have the same murmur characteristics but with different locations

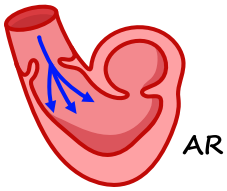
C. Diastolic Murmurs 30:28

Decrescendo Murmurs

a) Aortic Regurgitation

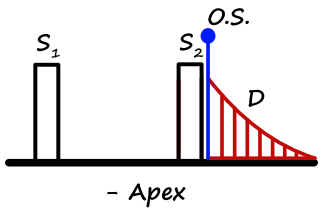
- **Decrescendo murmur** signifies regurgitation of blood from the aorta to LV across a dysfunctional aortic valve, which creates turbulence in blood flow when it hits LV wall, leading to a murmur.
- Heard at the **Erb's point** (left 3rd ICS)
  - *As compared to **pulmonic regurgitation,** which can be heard at the left 2nd ICS*





b) Mitral Stenosis

- **Opening snap** followed by a **decrescendo murmur**
  - **Opening snap** signifies atria pushing blood against the stenotic mitral valve, eventually leading to bending or bowing of the valve, precipitating a "**snap**" sound.
  - **Decrescendo murmur** signifies blood moving through a narrow bowed open mitral valve opening into LV and is loudest in the beginning of diastole and softer as you move later in diastole.
- Heard at the **apex**



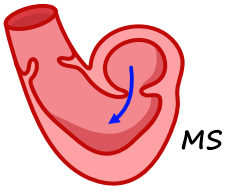


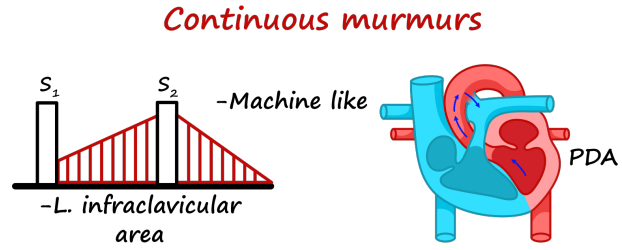
Table 3. Differentiating between aortic regurgitation and mitral stenosis.

	Aortic Regurgitation	Mitral Stenosis
	Decrescendo murmur	
Opening snap	(-)	(+)
Location	Erb's point	Apex
Radiation	(-)	(-)

D. Continuous Murmurs 33:34

Patent Ductus Arteriosus

- A continuous "**Machine-like murmur**" signifies blood is moving across the PDA from the aorta into the pulmonary artery during systole, and then blood flow continues to move across the PDA even during diastole as the pressure in the aorta remains greater than the pulmonary artery throughout the entire cardiac cycle. The primary reason this murmur is continuous.
- Heard at the **left infraclavicular area**



E. Summary 36:26

Location → Timing → Maneuvers → Echo

- Auscultate the **Location**
  - Remember **APTM**
- What is the **timing?**
  - Systolic?
    - Crescendo-decrescendo?
    - Holosystolic?
    - Does it have a click before?
    - Does it radiate?
  - Diastolic?
    - Decrescendo?
    - Does it have a snap?
  - Continuous?
    - *Easiest- It is always associated with PDA*
- Still stuck? **Do specific maneuvers** to increase or decrease the intensity
- Still stuck? Perform an **echocardiogram**

F. Murmur Maneuvers

36:26

1. Inspiration

- ↑Right Side murmurs due to ↑R sided Venous return
- ↓Left side murmurs due to ↓L sided Venous return

Expiration

- ↑Left Side murmurs due to ↑L sided Venous return
- ↓Right side murmurs due to ↓ R sided Venous return

2. Leaning Forward

- Brings the aortic valve closer to the chest wall
- This technique ↑Aortic Murmurs such as aortic stenosis and aortic regurgitation

Lateral Decubitus

- Brings the mitral valve closer to the chest wall
- This technique ↑Mitral Valve murmurs such as mitral valve stenosis and regurgitation

3. ↑Venous Return

- Squatting or leg raise → ↑Venous Return to the heart
  - ↑All Murmurs EXCEPT:
    - Hypertrophic cardiomyopathy
      - ↓intensity of murmur
    - Mitral valve prolapse
      - Brings the click later and makes the murmur shorter

↓Venous Return

- Valsalva maneuver or standing → Valsalva maneuver increases the intrathoracic pressure
  - ↓All murmurs EXCEPT:
    - Hypertrophic cardiomyopathy
      - ↑Intensity of HCM
    - Mitral valve prolapse
      - Cause the click to come earlier and the murmur longer

4. ↑Afterload

- Handgrips → **↑Intensity of aortic regurgitation and mitral valve regurgitation murmur**
  - In **aortic regurgitation** → ↑Pressure inside the aorta will shoot more blood back to the LV across the dysfunctional aortic valve.
  - In **mitral regurgitation** → Provides more volume of blood in LV secondary to the previous cycle, causing ↓SV, but now, during this current cardiac cycle, the LV has a larger volume of blood to push across the dysfunctional mitral valve and back into the atrium.

- Handgrips → **↓Intensity of aortic stenosis, MVP, and HCM murmur**
  - In **Aortic Stenosis** → ↑Afterload makes it harder for blood to leave LV through the stenotic aortic valve and out into the aorta → ↓Flow across the semilunar valve → ↓Aortic stenosis murmur
  - In **MVP** → ↑Afterload causes a delay in LV ejection from a heavily filled ventricle→↑Time required to eject blood from LV into the aorta and close Mitral valves; thus, if there is evidence of MVP, there will be a delay in the ejection click and shorter regurgitation murmur associated with the MVP
  - In **HCM** → ↑Afterload leads to ↓SV from LV → Leading then during the next cardiac cycle to this overfilled ventricle leads to the stretching of the LV and reduction in the LVOTO → ↓HCM murmur

↓Afterload

- Amyl nitrate (vasodilator) → **↓Intensity of aortic regurgitation and mitral valve regurgitation murmur**
  - In **aortic regurgitation**→↓Pressure inside the aorta will lead to less blood shooting back to the LV across the dysfunctional aortic valve.
  - In **mitral regurgitation** → Provides much less volume of blood in LV secondary to the previous cycle, causing ↑ SV, but now, during this current cardiac cycle, the LV has a smaller volume of blood to push across the dysfunctional mitral valve and back into the atrium.

- Amyl nitrate (vasodilator) → **↑Intensity of aortic stenosis, MVP, and HCM murmur**
  - In **Aortic Stenosis** → ↓Afterload makes it easier for blood to leave LV through the stenotic aortic valve and out into the aorta → ↑Flow across the semilunar valve → ↑Aortic stenosis murmur.
  - In **MVP** → ↓Afterload causes NO delay in LV ejection from a normally filled ventricle →↓Time required to eject blood from LV into the aorta and close Mitral valves; thus, if there is evidence of MVP, there will be a very early ejection click and longer regurgitation murmur associated with the MVP.
  - In **HCM**→ ↓Afterload leads to ↑SV from LV → Leading then during the next cardiac cycle to this underfilled ventricle leads to less stretching of the LV and enlargement in the LVOTO → ↑HCM murmur.

Maneuver	Effects on Murmur
Inspiration (↑ RA venous return)	↑ R side murmurs ↓ L side murmurs
Leaning Forward (bring AV close to chest wall)	↑ Aortic Murmurs (ex: AS/AR)
↑ Venous Return (Squat/Leg raise)	↑ All Murmurs Exception: MVP, HCM (↓ Murmur)
↑ Afterload (handgrips)	↑ AR/MR Murmur ↓ AS, MVP, HCM Murmur

Maneuver	Effects on Murmur
Expiration (↑ LA venous return)	↑ L side murmurs ↓ R side murmurs
Lateral decubitus (bring MV close chest wall)	↑ Mitral Murmurs (ex: MS/MR)
↓ Venous Return (Valsalva/Stand)	↓ All Murmurs Exception: MVP, HCM (↑ Murmur)
↓ Afterload (amyl nitrate)	↓ AR/MR Murmur ↑ AS, MVP, HCM Murmur