Left Ventricular Volume and Evaluation of Heart Murmurs

Dr. Jahan Eftekar
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1. You are examining a female patient with an audible systolic murmur. To confirm your clinical suspicion you asked her to firmly grip your hand. This maneuver reduced the murmur intensity. Which of the following conditions is she most likely suffering from?
   A. Mitral regurgitation
   B. Mitral stenosis
   C. Ventricular septal defect
   D. Aortic regurgitation
   E. Aortic stenosis

   **Important Basic Concepts**
   - Increased blood flow through the affected valve increases the intensity of murmur
   - Modulating preload and afterload will increase or decrease intensity of murmurs
   - Maneuvers Affecting Preload
     - Decreased Preload: Valsalva, standing, hypovolemia, tachycardia, and vasodilators
     - Increased Preload: Squatting, passive leg-raising, increased ECF volume, and bradycardia
   - Maneuvers Affecting Afterload
     - Decreased Afterload: Hypovolemia and vasodilators
     - Increased Afterload: Squatting, hand grip, and alpha-1 agonists and beta-2 blockers
   - Important Murmurs: Mitral regurgitation and stenosis, aortic regurgitation and stenosis, VSD, ASD, and hypertrophic cardiomyopathy

   **Increased Afterload Effects on Murmur Intensity**
   - Defects increasing their Murmur Intensity
     - Aortic Insufficiency
     - Mitral insufficiency
     - Mitral stenosis
     - Ventricular Septal Defect (early stages)
   - Defects decreasing their Murmur Intensity
     - Aortic Stenosis
     - Hypertrophic Cardiomyopathy

2. What is the most common cause of sudden cardiac death?

3. What will happen to the murmur intensity of hypertrophic cardiomyopathy with decreased preload?

   **About Murmur of Hypertrophic Cardiomyopathy**
   - Protrusion of a thick upper ventricular septum reduces left ventricular outlet orifice. Blood flowing through narrow outlet speeds-up and causes a suction effect (or Venturi effect).
   - Suction effect draws the anterior leaflet of the mitral valve towards the septum and further decreases the diameter of the outlet tract.
   - Meanwhile as a result of dragging the mitral leaflet into the ventricle a functional mitral insufficiency is created. Thus, systolic murmur in HCM is due to high flow through a narrow outlet tract plus mitral regurgitation.

   **Note:** Stenosis in HCM is dynamic and it is contrasted with the fixed aortic valve stenosis or mitral insufficiencies.
Venturi Effect and HOCM
- As fluids pass through narrow tracts their velocity increases and their pressure decreases.
- Flow of the fluids through narrow tracts may impose a suction effect on the surrounding areas.
- Increased flow causes an audible murmur.
- In hypertrophic obstructive cardiomyopathy (HOCM) the suction effect of venturi mechanism may drag the anterior leaflet of the mitral into the left ventricle and further narrows the ventricular outlet.
- Analogy: Water pouring at high intensity through a narrow hose.

Murmur Dyads
- HOCM versus Aortic Stenosis
- HOCM versus Mitral prolapse

4. What is the genetic cause of hypertrophic cardiomyopathy?

HOCM vs. Mitral Prolapse

<table>
<thead>
<tr>
<th>HOCM</th>
<th>Mitral Prolapse</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Both conditions present with mitral insufficiency</td>
<td></td>
</tr>
<tr>
<td>• Both conditions cause systolic murmurs</td>
<td></td>
</tr>
<tr>
<td>• Intensity of murmurs in both increases under low preload conditions</td>
<td></td>
</tr>
<tr>
<td>• Intensity of murmurs in both decreases under high preload conditions</td>
<td></td>
</tr>
<tr>
<td>• Insufficiency is dynamic</td>
<td></td>
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<tr>
<td>• High afterload, decreases the intensity of murmur</td>
<td></td>
</tr>
<tr>
<td>• Low afterload increases the intensity of murmur (venturi effect)</td>
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<tr>
<td>• Insufficiency is fixed</td>
<td></td>
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<td>• Low afterload decreases the intensity of murmur</td>
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</tbody>
</table>

5. HOCM causes dynamic outflow obstruction. What is the description of dynamic flow obstruction?

6. What is the effect of isoproterenol administration on left ventricular volume and how does this affect the intensity of murmur in HOCM?

7. What is the effect of atenolol administration on left ventricular volume and how does this affect the intensity of murmur in HOCM?

8. What is the effect of phenylephrine administration on left ventricular volume and how does this affect the intensity of murmur in HOCM?
9. What is the effect of Prazosin administration on left ventricular volume and how does this affect the intensity of murmur in HOCM?

10. What is the effect of amyl nitrite administration on left ventricular volume and how does this affect the intensity of murmur in HOCM?

11. What is the effect of Valsalva maneuver on left ventricular volume and how does this affect the intensity of murmur in HOCM?

12. What is the effect of hand-grip maneuver on left ventricular volume and how does this affect the intensity of murmur in HOCM?

13. Your patient is a 31-year-old woman who is diagnosed with mitral prolapse (MVP). Auscultation of her heart is significant for an audible mid-systolic click. Which of the following options is a more likely auscultation finding if she moves from seating to a standing position?

   A. The click gets closer to S1 and murmur duration gets longer
   B. The click gets closer to S1 and murmur duration gets shorter
   C. The click gets closer to S2 and murmur duration gets longer
   D. The click gets closer to S2 and murmur duration gets shorter
   E. The click’s position and the murmur’s duration will not change

14. Name three important conditions and/or maneuvers that move the click of the MVP closer to the S1 position:

15. Name three conditions and/or maneuvers that move the click of the MVP closer to the S2 position:

   Preload Effects on Click Position in Mitral Prolapse

<table>
<thead>
<tr>
<th>Decreased Preload</th>
<th>Increased Preload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Click gets closer to S1</td>
<td>Click gets closer to S2</td>
</tr>
<tr>
<td>- Standing</td>
<td>- Squatting and hand-grip</td>
</tr>
<tr>
<td>- Valsalva maneuver</td>
<td>- Increased blood volume</td>
</tr>
<tr>
<td>- Amyl nitrite</td>
<td>- Bradycardia</td>
</tr>
<tr>
<td>- Beta-agonists</td>
<td>- Beta-blockers</td>
</tr>
<tr>
<td>- Prazosin (alpha-1 blockers)</td>
<td>- Phenylephrine (alpha-1 agonists)</td>
</tr>
<tr>
<td>- Inspiration (volume of left ventricle decreases)</td>
<td>- Expiration (volume of left ventricle increases)</td>
</tr>
</tbody>
</table>

16. You are observing a 5-year-old child with the history of a mild tetralogy of Fallot. While playing with a few other children in the patient receiving room, the child’s lips turns blue and he stops his play and squats for almost 20 seconds and then resumes his play. You noticed that his lips are no longer cyanotic. What is the most likely physiologic mechanism of reduced cyanosis in this case?

   A. Increased systemic vascular resistance
   B. Decreased systemic vascular resistance
   C. Increased pulmonary vascular resistance
   D. Decreased pulmonary vascular resistance
   E. Dilation of the orifice of the pulmonary valve

17. Why does squatting cause relief of cyanosis in Tetralogy?
18. Patients with VSD are presented with systolic murmur. What is the effect of hand gripping on the intensity of murmur in these patients?

21. Murmur of which valvular defect is similar to the murmur of ASD and how do you distinguish the two from each other?

22. After Valsalva maneuver the intensity of cardiac murmur of a patient is increased. This is most likely indicative of which of the following anomalies?

- A. Tricuspid regurgitation
- B. Atrial septal defect
- C. Mitral valve prolapse
- D. Mitral stenosis
- E. Pulmonic stenosis

**Generalizations**

- Most murmurs decrease their intensities after Valsalva maneuver (i.e. with decreased preload) with the exception of the murmurs of hypertrophic cardiomyopathy (sub-aortic left ventricular outflow obstruction) and mitral valve prolapse (MVP).
- As a general rule increasing preload increases flow to the heart and increases intensity of almost all types of murmurs. In contrast, decreasing preload reduces the intensity of valvular murmurs.
- The only two notable exceptions to this rule for the Boards purposes are mitral valve prolapse and hypertrophic obstructive cardiomyopathy!

23. You are evaluating a patient with cardiac murmur. The patient is instructed to take a few rapid deep breaths of amyl nitrite. You evaluated the quality of his heart murmur about 20 seconds after the maneuver. Results show that there was a significant drop in the intensity of his murmur. Which of the following defects is the most likely cause of this finding?

- A. Late stage VSD
- B. Hypertrophic cardiomyopathy
- C. Aortic stenosis
- D. Mitral stenosis
- E. Mitral regurgitation

Heart murmurs are caused by normal flow through a stenotic valve or by high flow through a normal valve (e.g. flow through pulmonary valve in the ASD).
24. In the last scenario we said that of amyl nitrite administration decreases intensity of murmur in Mitral regurgitation. However, earlier we said that HOCM also causes dynamic mitral regurgitation. What happens to intensity of murmur in HOCM after amyl nitrite administration?

25. What is the effect of increasing afterload on the intensity of mitral insufficiency due to HOCM and rheumatic heart disease?

26. A variety of physiological maneuvers are used to evaluate and differentiate heart murmurs. Squatting is among the commonly used maneuvers. Which of the following physiological findings commonly results from squatting?

A. Increase in venous return to the right heart
B. Increase in venous return to the left heart
C. Increase in peripheral vascular resistance
D. Reflex bradycardia
E. All of the above findings result from squatting
Answers

1. [E] Aortic Stenosis (AS)
2. Hypertrophic cardiomyopathy (HCM)
3. Increases
4. Autosomal dominant. Mutation causes defect in sarcomere units (proteins); mainly beta-myosin units. There is disruption of the contractile units
5. Left ventricular outflow obstruction that depends on the ventricular volume and flow rate during systole.
6. Isoproterenol has beta-1 and beta-2 agonistic function. The beta-1 effect causes positive inotropic. It increases the ejection fraction and drops the ventricular volume. As a result of increased contractility, increased flow through narrow outlet, and ventricular pressure also increases. The rise in left vascular resistance. As a result of increased TPR (afterload) the left ventricular pressure is compressed. This maneuver raises the afterload or systemic pressure and as a result the right-to-left flow. Hence, the murmur is reduced.
7. Atenolol has beta-1 antagonistic function. It causes negative inotropism (contractility). It decreases the ejection fraction and increases the ventricular volume. As a result of increased volume the thickened part of the inter-ventricular septum is pushed away from the outlet area and dynamics of flow returns to normal. Hence, intensity of murmur decreases.
8. Phenylephrine has alpha-1 agonistic function. It increases afterload and decreases the ejection fraction and increases the ventricular volume. As a result of increased volume the thickened part of the inter-ventricular septum is pushed away from the outlet area. Left ventricular outflow tract obstruction and gradient decreases and dynamics of flow returns to normal. Hence, intensity of murmur decreases.
9. Prazosin has alpha-1 blocking effect. It decreases afterload. It increases the ejection fraction and decreases the ventricular volume. As a result of increased flow through a narrow outlet (increased outlet gradient), there is an augmented venturi effect and the murmur intensity increases. Note: Currently Prazosin is NOT used in clinical settings for evaluation of HOCM.
10. Effects are similar to Prazosin. It decreases afterload. It increases the ejection fraction and decreases the ventricular volume. As a result of increased flow through a narrow outlet (increased outlet gradient), there is an augmented venturi effect and the murmur intensity increases.
11. Valsalva decreases preload. It decreases the ventricular volume. The outflow gets more obstructed due to thick inter-ventricular septum. The murmur intensity increases due to passage of blood through a narrowed outlet.
12. Handgrip increases afterload. Ejection fraction goes down and ventricular volume increases. As a result of increased volume the thickened part of the inter-ventricular septum is pushed away from the outlet area. Left ventricular outflow tract obstruction and gradient decreases and dynamics of flow returns to normal. Hence, intensity of HOCM murmur decreases.
13. [A]. The click gets closer to S1 and murmur duration gets longer
15. Conditions that increase the preload. Squatting, increased blood volume and bradycardia.
16. [A]. Increased systemic vascular resistance
17. With prolonged squatting the lower arteries (e.g. femoral) are compressed. This maneuver raises the afterload or systemic vascular resistance. As a result of increased TPR (afterload) the left ventricular pressure also increases. The rise in left ventricular pressure acts as an impediment to free flow of the right ventricular volume through the ventricular septal defect into the left ventricle. This increases the pulmonary flow and allows for more oxygenation of the blood.
18. Hand-gripping increases systemic afterload. Less blood can enter the aorta and more is poured onto the right ventricle. Hence, the murmur gets louder.
19. The patient most likely has Eisenmenger’s syndrome (i.e. late stage VSD). Increased systemic pressure reduces the right-to-left pressure gradient and as a result the right-to-left flow. Hence, the murmur is reduced.
20. Increased flow to the right heart and through the pulmonic valve. So it is best heard in the pulmonic area (upper left sternal border). Note that heart valves are all normal in ASD. The murmur is quite weak and often may not be detectable. Also note that at times there may also be audible (low pitched) murmurs due to higher tricuspid flow murmur in diastole.
21. The systolic murmur produced by an ASD is due to increased flow through the pulmonic valve and it resembles that of pulmonic stenosis. However, the intensity of murmur in ASD is much less pronounced. Additionally ASD is presented with splitting of the S2 heart sound.
22. [C] Mitral valve prolapse
23. [E]. Mitral regurgitation. Amy nitrite is a vasodilator. The maneuver causes an abrupt drop in the total peripheral resistance and decreases the afterload. As a result the intensity of murmur of mitral regurgitation (MR) decreases. MR is a back flow murmur. As a result of drop in the afterload, blood can move forward through the aorta with more ease. This results in more forward and less backward flow. Hence, the intensity of the murmur decreases.
24. Amylnitrite decreases afterload. It increases ejection fraction and decreases the ventricular volume. The outlet tract gets narrower. As a result of flow through the narrow outlet tract (increased outlet gradient) plus venturi (suction) effect that produces a functional mitral insufficiency, the murmur intensity in HOCM increases.
25. Decreases the intensity of murmur in HOCM and increase that in rheumatic mitral insufficiency.
26. [E]. All of them result from squatting. Squatting primarily increases venous return to the right heart and then to the left heart. It increases the systemic blood pressure and as a result it is often accompanied by reflex bradycardia.

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