Pressure-Volume Loop: Ventricular Physiology and Pathology

Question-Pause-Answer Drills

From Triology Book:
Physiology and Pharmacology with Relevant Pathology

Integrated Cardiac Hemodynamics
Basics of Pressure-Volume Loops
Aortic Stenosis,
Aortic Regurgitation
Mitral Stenosis
Mitral Regurgitation
The pressure-volume loop represents events in the left ventricle in one heartbeat. Although it is commonly construed for the left ventricle it may also be applicable to the right ventricle.

- The horizontal lines represent the ventricular volume and the vertical lines, the intra-ventricular pressure.

  Volume expands horizontally, and pressure rises vertically!

1. What does the line marked “H” represent? ____________________________

2. What do the lines “G” and “E” respectively represent? ____________________________

3. Which segment of the loop happens in systole and which one in diastole? ____________________________

4. Mitral valve closes after the left ventricular pressure exceeds the atrial pressure. It is audible as the first heart sound or S1. At what point on P-V loop this happens? ____________________________

5. Aortic valve opening happens after the left ventricular pressure exceeds the aortic pressure; at what point of the P-V loop this happens? ____________________________

6. At what point of the P-V loop the S2 (second heart sound) is audible? ____________________________

7. What is “afterload”, and at what point on P-V loop you expect it to attain the highest magnitude? ____________________________

8. What is the other physiological term commonly used in cardiac physiology to describe the “afterload”? ____________________________

9. If all relevant parameters stay constant; what will happen to the cardiac output if the afterload is increased? ____________________________

10. What is preload? ____________________________

11. What is the other physiological term commonly used in cardiac physiology to describe the “preload”? ____________________________
12. **Using the above diagram; what is the rough value for “preload”?**

13. **Using the above diagram; what is the rough value for “afterload”?**

14. **Using the above diagram; what is the “stroke volume”?**

15. **Name three conditions that greatly increase the afterload?**

16. **Why in aortic regurgitation, the afterload is increased?**

17. **What will happen to afterload in mitral regurgitation?**

18. **Quantitatively, the precise calculation of the preload involves three parameters; end-diastolic pressure, ventricular end diastolic radius and thickness of the ventricle. For the sake of simplicity, the volume and pressure are often used interchangeably because they almost have the same effect on the radius. What is the precise formula used to measure preload based on Law of Laplace?**

19. **Ventricular Hypertrophy Reduces the Tension**

   Hypertrophy of ventricular wall shares the generated wall tension among more muscle fibers and in a sense reduces the per sarcomere tension. Recall the following formula:
   \[
   \text{Wall Stress} = \left( \text{Pressure} \times \text{Radius} \right) / \left( 2 \times \text{Thickness} \right)
   \]
   \[
   \text{Stress} = \text{Tension in wall}
   \]

20. **What will happen to preload in mitral insufficiency?**

21. **Which of the three arterial indices better represent the afterload: mean, diastolic or systolic pressure?**

22. **Which of the two represents afterload during ejection of the ventricle; intraventricular pressure or aortic pressure?**
23. The filling pressure of the ventricle is often named “preload” because this is the load on the muscle fibers before:

______________________________________________________________________________

24. What is the most important factor in determining the stroke volume?

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25. What is the second most important factor in determining the stroke volume?

______________________________________________________________________________

26. Based on the Laplace law what factors in diastole progressively increase the ventricular muscle tension?

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27. Can we use the term “afterload” for aortic pressure during the phase that the aortic valve is closed?

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28. Above diagram shows the relationship of Frank-Starling curves to afterload and stroke volume. The centrally located curve marked “B” is for normal heart. Which of the two curves; A or C, represents increased and which one decreased afterload conditions?

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29. Using the Frank-Starling diagram above and assuming that the curve B represents normal heart and C and A, increased and decreased afterload conditions; what do you expect to be the effect of increased afterload on the preload?

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30. In the previous question we said that increased afterload will increase the preload. What is the reason for this phenomenon?

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31. Stroke volume (SV) is derived by subtracting end-systolic (ESV) from end diastolic volume (EDV). That is, SV=EDV-ESV. In patients with heart failure, vasodilators such alpha-1 antagonists (e.g. prazosin), would help to increase the stroke volume. Which of the two parameters, ESV or EDV is primarily affected by the administration of the vasodilators in heart failure?

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______________________________________________________________________________

32. Vasodilators drop the afterload and preload (see above question). If both parameters are reduced, then why the stroke volume increases (instead of staying constant)?

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33. Would you expect the afterload to increase or decrease in ventricular dilation?

______________________________________________________________________________

______________________________________________________________________________

Mnemonic for Increased Pre and Afterload

34. Would you expect the afterload to increase or decrease in ventricular hypertrophy?

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______________________________________________________________________________

35. Stroke volume is affected by preload. What are the two clinical indicators of the level of preload?

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______________________________________________________________________________
36. What is the normal value of Central Venous Pressure (CVP) and what preload-related information can you drive from it?

_____________________________________

37. What is the normal value of Pulmonary Capillary Wedge Pressure (PCWP) and what preload-related information can you drive from it?

_____________________________________

38. What would be the effect of over-hydration, right-sided heart failure and increased venous return on CVP?

_____________________________________

39. What would be the effect of left heart failure, mitral stenosis and cardiac compression on PCWP?

_____________________________________

40. Stroke volume is the amount of blood ejected in one cardiac cycle and it is about 50-100 ml. What is Stroke Index (A.K.A. Stroke Volume Index)?

_____________________________________

41. Stroke volume in addition to preload and afterload is affected by contractility. What is the physiological definition of contractility?

_____________________________________

42. What are the major factors that affect contractility?

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43. Using the above diagram what will happen to stroke volume if contractility is decreased and end-diastolic pressure is kept constant?

_____________________________________

44. What would be a reasonable explanation for the fact that hypercapnia and acidosis reduce contractility and as a result drop the stroke volume?

_____________________________________

45. It is apparent that contractility of the cardiac muscle depends on entry of calcium into the myocytes. How does calcium cause muscle contraction?

_____________________________________

46. What is meant by calcium-induced calcium release?

_____________________________________

47. Sarcomere length and tension, based on the Frank-Starling concept, is the mechanism by which the heart regulates the force of contraction. How does the concept of calcium-induced contraction fit into this schema?

_____________________________________

48. During exercise the heart rate increases. Increased heart rate decreases the diastolic filling phase and the end-diastolic volume. What would be a reasonable explanation for preservation of stroke volume during exercise despite a decrease in filling phase?

_____________________________________

49. A patient is presented with low cardiac output despite normal preload and afterload. What are a few conditions that would cause this finding?

_____________________________________

50. A 55-year-old man’s heart has zero cardiac output, zero preload and zero afterload. Assuming that the man is alive, what would be a reasonable explanation for these findings?

_____________________________________

51. What is Left Ventricular Stroke Work Index (LVSWI) and what does it clinically indicate?

_____________________________________

52. What is the best term to describe the pressure at which ejection begins?

_____________________________________

53. In the following diagram the P-V loop “A” is drawn for normal heart. The line “C” is the end-systolic P-V line and the curve “D” is the so called “elastance curve/line” of the ventricle. In terms of the 3 major factors that affect the stroke volume; namely, preload, afterload and contractility, what has caused the P-V-loop “B”?

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54. What is the term used to describe the line “C” in the above diagram, and what common attribute will cause the points of aortic valve closure (end of systole) of two ventricular pressure-loops fall on this line?

_____________________________________

55. Which of the two loops has a higher stroke volume and what would you conclude from the above diagram?

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56. What is the afterload line and what is the significance of having two P-V-loops with parallel afterload lines?

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57. In the following diagram in terms of the 3 major factors that affect the stroke volume; namely, preload, afterload and contractility, what has caused the P-V-loop “B”, and what is the striking cardiac output related finding between the two loops?

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58. Using above diagram as a reference, what do you think would constitute as a good index to determine the afterload on P-V loops?

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59. In the following diagram in terms of the factors affecting stroke volume what has caused the loop “B”, what is the effect on stroke volume and what constitutes a good index to determine the increase or decrease of this factor?

_____________________________________

Note: The loop A for normal heart.
Afterload is not a simple quantity. For instance, total peripheral resistance will raise the aortic and mean arterial pressure, and they are all correlated with increased afterload. 

Questions:

1. The line “H” represents the ventricular filling phase.
2. The lines “G” and “E” respectively represent the isovolumetric relaxation and contraction!
3. From point “C” to “A”, the ventricle is in systole; while from “A” to “C” it is in diastole. You may like to draw a line from point “C” to “A” and divide the loop into two triangular halves, and then write “Systole” within the right, and “diastole”, within the left-side triangle.
4. Mitral closure causes the S1 sound and happens at point “C”!
5. Aortic opening happens at the point “D”!
6. The second sound “S2” is due to the closure of the aortic valve and happens at point “A”, when the aortic pressure exceeds the ventricular pressure.
7. Afterload is the load against which the ventricle has to pump. It is the ventricular tension that is required to develop in the chamber’s wall for proper contraction. It is also described as the pressure that must be generated in order to eject the blood out of the chamber. It is peaked at the point “A”.
8. The term used to often describe the afterload is “end-systolic pressure”!

Note: Mean arterial pressure is also correlated

9. The ventricular pressure must exceed aortic (systemic) pressure to open the aortic valve. Hence, as afterload increases the cardiac output decreases!
10. Preload is the volume of blood in the ventricle at the end of diastole and immediately after atrial contraction and filling of the ventricle. It is the pressure that stretches the ventricle.
11. The other term for preload is “end-diastolic volume”
12. The preload, or end-diastolic volume, is the load or volume right before systole (at point “C”). It is about 130 ml.
13. The afterload or end-systolic volume is volume of the ventricles after systole and it is about 50 ml (point A)
14. Stroke volume is the amount ejected in each beat. It is end-diastolic volume minus end systolic volume. That is, 130 – 50 = 80 ml
15. Three conditions increasing afterload are: (1) Aortic stenosis (2) Increased blood pressure or total peripheral resistance as result of hypertension; and (3) Aortic insufficiency.
16. In aortic regurgitation, a percentage or fraction of the blood that is pushed forward or ejected out of the ventricle is returned back into the ventricle. This raises the afterload.
17. In mitral regurgitation the afterload decreases because during systole part of blood is regurgiating back onto the atria and only part onto the aorta. This means that the left ventricle has to work less in order to eject the blood.
18. \[ S = \frac{(EDV \times EDR)}{2T} \]
   EDV= End diastolic volume (or pressure; P)
   EDR= End diastolic ventricular radius (R)
   T= thickness of the wall of ventricle
   S=Amount of Stress
19. Two conditions increasing preload are: (1) Increased venous pressure (tone) and venous return back to the heart and (2) Increased blood volume!
20. Mitral regurgitation results in volume overload of the left ventricle at the end of diastole, i.e. increased preload, as well as a reduction in afterload due to the regurgitant pathway back into the left atrium.
21. Diastolic arterial pressure!

Note that mean arterial pressure also depends on diastolic pressure!

Answers:

22. During ejection phase the afterload is represented by either or both aortic and intraventricular pressures which are practically equal to each other!

Note: The two compartments are joined to each other!
23.. It contracts!
24. End-diastolic filling (ie. maximum diastolic volume or preload) is the most important determinant of stroke volume.
25. The second most important factor affecting stroke volume is aortic pressure (afterload)!
26. During the ventricular filling progressive rise in ventricular pressure (P) and volume (R or radius) increase the tension (T).

Note: \[ T = \frac{P \times r}{2} \]
27. Not precisely!

More precisely the afterload is the aortic pressure during the period that the aortic valve is open; because it is the force that is necessary to overcome opposition to ventricular ejection. Note: Afterload is not a simple quantity. For instance, total peripheral resistance will raise the aortic and mean arterial pressure, and they are all correlated with increased afterload!
28. Increased afterload shifts the Frank-Starling curve down and right (from B to C). In contrast decreased afterload moves the curve up and left (from B to A).
29. Afterload does not have an immediate effect on the preload. It has, however, an indirect effect on the preload. As it is shown in the diagram, increased afterload, not only drops the overall stroke volume (curve C), but for attainment of any level of stroke volume it raises the end-diastolic pressure. The opposite works with decreased afterload conditions (i.e. curve A).
30. Increased afterload (end-systolic) volume adds to venous blood that returns to the ventricle during the subsequent diastole and raises the end-diastolic pressure (preload)!
31. Reducing arterial pressure and TPR, allows for more rapid ventricular ejection and raises the stroke volume. As a result end-systolic volume drops. Since less blood stays in the ventricle at the end of systole, the incoming venous blood during diastole will also get reduced. In other words, decreasing arterial pressure primarily drops the afterload and indirectly the end diastolic pressure (preload).
32. In the presence of vasodilators the reduction in end diastolic volume is less than the end-systolic volume. This will cause an increase in stroke volume. Recall that \[ SV=EDV-ESV \].

Increase! Recall that afterload is the stress (tension) on the ventricular wall at the time of ejection, and it is minimally equal to aortic pressure. Based on the Laplace Law, \[ S = \frac{(P \times r)}{2t} \] where, \( r \) is thickness. Hence, as a result of dilation, \( r \), or radius, increases, and everything staying constant; tension (S) or afterload increases.
34. Decrease! Recall: \( S = \frac{(P \times r)}{2 \times \text{Thickness}} \)
35. The two clinical indicators of preload are Central Venous Pressure (CVP) and Pulmonary Capillary Wedge Pressure (PCWP).
36. Central Venous Pressure (CVP) readings are used to approximate the Right Ventricular End Diastolic Pressure (RVEDP). It ranges from 2 to 6 mmHg and assesses right ventricular function and general fluid status of the body! Note: CVP is also known as Right atrial pressure!
37. Pulmonary Capillary Wedge Pressure (PCWP) provides an estimate for LVEDP (left ventricular end diastolic pressure). It normally ranges from 4-12 mmHg.
38. They all increase the CVP! Note that in contrast, hypovolemia and decreased venous return will drop the CVP.
39. They all increase the PCWP!
40. Stroke index (SI) is the amount of blood ejected in one cardiac cycle relative to body surface area. It is measured in ml per meter square per beat (normal= 35 ml/m2)
41. Force of contraction based on a given preload. It is also defined as the intrinsic ability of a cardiac muscle fiber to contract at a given fiber length.
42. Contractility is affected by carbon dioxide, pH, myocardial infarction and ionotropes.
43. Decreases!
44. Hypercapnia and intracellular acidosis probably interfere with the interaction between calcium and myofilaments.
45. See the following diagram for the answer:

46. Calcium-induced calcium release (CICR) is calcium release from sarcoplasmic reticulum of the heart muscle. This mechanism is qualitatively less apparent in the skeletal muscles. The cardiac myocytic membranes contain voltage-gated (L-type) calcium ion channels that are responsible for the entry of calcium ions into the cytosol after depolarization. Within the myocytes there are sarcoplasmic reticulum organelles that contain high levels of calcium. It is postulated that sarcoplasmic membrane has T-type (fast) calcium channels that permit rapid entry of the calcium into the sarcoplasm. The latter leads to release of the sarcoplasmic reticulum’s calcium stores into the cytoplasm. The high cytoplasmic calcium in turn unmasks the binding of actin and myosin and results in contraction. The process is terminated by rapid reentry (reabsorption) of the calcium via ATP-operated calcium pumps back into the sarcoplasm (see the diagram below).

47. It is postulated that stretching the sarcomeres, would increase the affinity of troponin binding sites for calcium. This phenomenon is also known as length-related activation. Note: Sarcomere is the unit of muscle composed of actin, myosin and other related subunits (troponin, etc.)
48. Exercise (increased adrenergic tone) has positive inotropic effect. Increased inotropy together with reduced end-diastolic volume would maintain the stroke volume.
49. This patient most likely has reduced contractility. Acidosis, high CO2, myocardial infarction and negative inotropes (beta-blockers) may cause this finding.
50. The patient is undergoing heart transplantation procedure and he has received a working heart from a recently deceased organ donor (allograft). His original heart is placed in a jar! Sorry for the humorous question!!
51. LVSWI is the best index (indicator) of contractility. It measures the amount of work the left ventricle does during each contraction and evaluates its pumping function of the left ventricle. For the board purposes it is enough to know that it is calculated using 4 parameters: Stroke volume, Body surface area, Mean arterial pressure and Pulmonary capillary wedge pressure. [Normal: 45-75gm/M/M2/beat]
52. Afterload!
53. Preload (LVEDV) for P-V loop “B” is increased, while afterload and contractility are kept constant!
54. Line “C” is the contractility line. If two aortic closure points fall on this line, it shows that the contractility is kept constant (the same) for both P-V loops!
55. The heart in Loop B has a higher stroke volume. It supports the fact that in the light of constant contractility and afterload, increasing preload will increase the stroke volume.
56. The afterload line is a line that joins the maximum end-diastolic point on x-axis to the end of systole point (aortic closure point). If the afterload lines for two P-V-curves are parallel to each other it shows that they are subjected to the same afterload.
57. The two loops have the same contractility and preload. But the loop B has increased afterload. The striking outcome is closure of the aortic valve at a higher pressure, less volume ejection in systole and as result a drop in stroke volume (evidenced by the smaller width of the loop B)
58. The angle of the line that connects the x-axis point of EDV to the aortic closure point is the best estimate of degree of afterload. A bigger angle designates a higher afterload!
59. Only contractility has increased. As a result SV has increased. Increased or decreased slope of the contractility line determines the increase or decrease of contractility.

8. Northwestern Medical Review
www.northwesternmedicalreview.com
• Aortic stenosis (AS) impairs ventricular emptying due to high outflow resistance.
• A large pressure gradient is required to push the blood through the valve; this raises the peak (or end-systolic pressure or the afterload).
• The shaded P-V loop represents mild to severe aortic stenosis. Compared to normal heart, the ventricular pressure rises sharply in systole; meanwhile less volume is ejected into the aorta.

1. What happens to stroke volume in AS and what portion of the shaded diagram represents it?

2. What will happen to end-systolic ventricular volume (afterload) in AS?

3. Do you expect the velocity of fiber–shortening increase or decrease in AS or any condition that increases the afterload?

4. What is the expected end diastolic volume in AS, and how does this affect the force of contraction?

5. What is the key adaptive (structural cardiac remodeling) response to AS?

6. What is the expected systemic blood pressure in AS?

7. What is an important clinical finding in AS?

8. Do you expect patients with aortic stenosis to have wide or narrow pulse pressures?

9. Northwestern Medical Review
www.northwesternmedicalreview.com
Pressure-Volume Loop: Mitral Stenosis

- Mitral stenosis impairs left ventricular filling
- End-diastolic volume (preload) drops. See arrow marked “B” in the above diagram.
- Stroke-volume (width of the loop), via Frank-Starling, and as a result cardiac output drops.
- There is a slight decrease in end-systolic volume (See arrow “A” in the above diagram) but there is more decrease in end-diastolic volume. That is magnitude of “B” is more than “A”. Hence, end-diastolic volume drops more than end-systolic volume.
- Note that the changes cited above are short-term responses and do not include compensatory reactions of the body.

9. What is the most common primary structural consequence of the mitral stenosis?

10. Normal mitral valve area is about 4 to 6 cm²; what is considered a serious stenosis?

11. What are the sequential pathophysiologic findings in patients with mitral valve area less than 1 cm² (i.e. serious stenosis)?

12. Atrial fibrillation is a common consequence of mitral stenosis that may potentially cause mural thrombosis. What is mural thrombosis?

13. Would you primarily expect a dilated or concentric hypertrophy in the left atrium as result of moderate mitral stenosis?

14. What would you expect the heart rate to be in a patient with mitral stenosis?

15. What is the major risk factor for mural thrombi in mitral stenosis?

16. Rheumatic heart disease is the major worldwide cause of mitral stenosis. About how many years after rheumatic heart disease patients are presented with symptoms of the disease such as dyspnea?

Note: Rheumatic heart disease used to be the number 1 cause in the USA!

17. Without valvuloplasty and valve replacement, what is the mortality rate of mitral stenosis and about how many years after the onset of symptoms it happens?

18. Would you expect to see mitral stenosis more in males or females?
19. What are the compensatory mechanisms that are triggered in response to mitral stenosis?

20. What are the compensatory mechanisms that are triggered in response to aortic stenosis?

21. What will happen to preload in mitral stenosis?

22. What will happen to stroke volume in mitral stenosis?

23. What will happen to aortic pressure in mitral stenosis?

24. What are the top two clinical findings in symptomatic mitral stenosis?

25. Which of the two would you expect to see in long-term symptomatic mitral stenotic patients; left or right ventricular hypertrophy?

Answers: Aortic and Mitral Stenosis

Aortic Stenosis
1. The stroke volume is represented by the width of the loop and it is decreased in AS.
2. End-systolic ventricular volume increases in AS!
3. Increased afterload slows the velocity of myocytic shortening. Because the period of time available for ejection is fixed at about 200 msec, a decrease in fiber shortening velocity drops the volume ejection and as a result more blood remains in the ventricle after systole.
4. As a result of increase in end-systolic volume the excess residual blood is added to the incoming venous blood and raises the EDV. This raises the preload and as a result (via Starling Law) the force of contraction.
5. Concentric ventricular hypertrophy!
6. As a result of fall in stroke volume, the arterial pressure drops substantially in AS.
7. Syncope and faintness is a common clinical finding in the AS.
8. Pulse pressure is equal to systolic minus diastolic pressure. As a result of low systolic pressure, AS patients have a narrow pulse pressure.

Mitral Stenosis
9. Left atrial hypertrophy!
10. Valvular area less than 1 cm² is considered to be serious mitral stenosis.
11. The rough sequence of pathophysiologic findings are: (A) Increased left atrial pressure; (B) Transmission of left atrial pressure to pulmonary vasculature (increased venous and capillary pressure); (C) Pulmonary hypertension; (D) Extravasation of fluids into alveolar spaces; (E) Pulmonary edema, and as a result dyspnea; (F) Atrial hypertrophy, as a result of constant atrial pressure overload; (G) Right heart failure; (H) Predisposition to atrial fibrillation and mural thrombi.

Note: The order of the events may vary a little in different cases.
12. Mural thrombus is a thrombus (blood clot) that is adhered to the endothelial lining! 
(Note: “Mural” in English literature means “painting on the wall”!)
13. The stenotic mitral primarily causes dilation of the atrial chamber and dilated atrial hypertrophy.
14. The heart rate increases to compensate for the low cardiac output.

As we said before; a major problem in mitral stenosis is the development of atrial fibrillation which occurs in up to 40% of patients. Loss of atrial contraction with the development of Afib decreases cardiac output. Since cardiac output is related to heart rate, Afib with a rapid ventricular response decreases diastolic filling time and further compromises cardiac output. Note that the left ventricular function is often normal in mitral stenosis.

15. Atrial fibrillation!
16. About 20 years!
17. The mortality rate is about 85% and it happens about 20 years after the onset of the symptoms.
18. Females! Two-thirds of the patients are females!

Mitral stenosis is a Ms. Disease!

19. A few expected compensatory physiological responses to MS are: increased rennin-angiotensin and aldosterone, systemic vasoconstriction, increased blood volume, increased heart rate, increased ionotropy of the heart and hypertrophy.

20. Physiological compensations of aortic stenosis are for most part similar to mitral stenosis.
21. Preload (end-diastolic volume) decreases!
22. As a result of drop in preload, stroke volume decreases but not as much as the AS!
23. As a result of drop in stroke volume, aortic pressure drops; but a lot less than AS because past the mitral everything works fine!
24. Dyspnea is the most common and one of the early findings in MS. The other is atrial fibrillation that causes mural thromboembolism. Note that in MS. the main problem is the rise in the atrial pressure and as a result difficulty in pulmonary venous drainage into the left atrium that leads to dyspnea and to pulmonary hypertension.
25. Right ventricular hypertrophy. Pulmonary hypertension leads to cor-pulmonale and right-sided hypertrophy. Therefore symptoms of mitral stenosis are mainly right-sided failure symptoms.

11. Northwestern Medical Review
www.northwesternmedicalreview.com
• In mitral regurgitation during systole, blood not only is forced into the aorta but it back regurgitates into the left atrium.
• The left atrial pressure and volume increase during systole.
• Because of the presence of the constantly-open mitral valve, there are no isovolumetric phases (Note the curved-out pattern of the two vertical axes in the above diagram.)
• Note: Blood tends to regurgitate back onto the left atrium as soon as the left ventricular pressure exceeds the left atrial pressure in systole.
• As a result of reduction in total outflow resistance, the afterload or end systolic volume decreases (Note: the left perimeter of the loop falls to left side of the normal loop. That is, the end systolic volume becomes less than normal conditions).
• In contrast, left ventricular end-diastolic volume and as a result pressure increase. This raises the preload and as a result the ventricular stroke volume (the width of the curve). But note that the stroke volume is distributed both forwardly into the aorta and backwardly into the atrium. As a result the overall ejection onto the aorta decreases.

1. What is the most common cause of mitral regurgitation in the USA?
________________________________________________________________________

2. Which of the two; men or women are more commonly presented with mitral regurgitation and why?
________________________________________________________________________
________________________________________________________________________

3. Mitral prolapse; often non-symptomatic, is classified as a mitral insufficiency condition and it is by far more common in females. On the other hand, mitral regurgitation; often symptomatic is more common in males. What would be a reasonable explanation for this finding?
________________________________________________________________________
________________________________________________________________________

Mitral regurgitation is a Mr. Disease!

4. Aortic stenosis is more common in the elderly women as a result of age-related calcification of the valve. However, prevalence of the disease in young-age is more common in males and it is associated with bicuspid (instead of tricuspid) aortic valves. What would be a reasonable explanation for this finding?
________________________________________________________________________

Aristotle is a man!
5. The so-called “secondary mitral insufficiency” is due to dilatation of the left ventricle and as a result failure of the valve to completely obliterate the atrioventricular passageway. Name a few causes of secondary mitral insufficiency?

_____________________________________

6. What will happen to the isovolumetric phases in mitral insufficiency?

_____________________________________

7. What would be the expected tension in the left ventricular wall in mitral insufficiency?

_____________________________________

8. Which of the two would you expect in mitral insufficiency; eccentric or concentric ventricular hypertrophy?

_____________________________________

9. What would you expect in mitral regurgitation eccentric or concentric atrial hypertrophy?

_____________________________________

10. What is the hallmark of mitral insufficiency?

_____________________________________
In aortic regurgitation during diastole blood flows back from the aorta into the left ventricle.

As such the filling of the ventricle immediately begins after systole (see left side of the shaded area).

Like mitral regurgitation, there are no true isovolumetric relaxation and contraction phases.

As the mitral valve opens, not only blood flows from left atrium but also from the aorta onto the left ventricle. Note that aortic pressure is greater than left ventricular pressure in diastole.

As a result, end-diastolic volume greatly increases.

At the early part of systole and as long as the aortic pressure is higher than the ventricle, still blood flows onto the ventricle. As such there is further increase in volume of left ventricle in early systole.

The increased end-diastolic volume via Frank-Starling mechanism is translated into increased force of contraction and higher pressure and stroke volume.

Note that in the absence of systolic failure the end systolic volume would be very close to normal volume!

11. What type of ventricular hypertrophy is primarily expected in aortic insufficiency?
   ________________________________

12. What is regurgitant fraction?
   ________________________________

13. What do you expect to be the diastolic aortic pressure in AI and why?
   ________________________________

14. What is the expected pulse pressure in AI and why?
   ________________________________

15. What will happen to effective forward flow in AI and why?
   ________________________________

16. A patient with AI is presented with audible 4th heart sound; what does this indicate?
   ________________________________

17. Is aortic insufficiency more common in males or females?
   ________________________________
18. To what extent age-related factors affect the prevalence of the AI?

19. What is the hallmark physical finding of aortic insufficiency?

20. What would be the suggested treatment in AI patients with hypertension?

21. What are the compensatory mechanisms that are triggered in response to aortic regurgitation?

22. In a patient with aortic regurgitation who is not yet presented with heart failure, what would be the expected end-systolic volume?

**Mnemonic for Interpretation of P-V Loop Diagrams**

In stenotic conditions, the left and right side of the loop are straight. In regurgitation conditions (aortic and mitral) they are curved (convex out).

23. The diagram below shows the relationship between left ventricular pressure and volume in the normal heart, and two conditions labeled “A” and “B”. Which of the two represents a hypertrophied and which one a failing (high compliant) ventricle?

24. What is the most common cardiomyopathy?

25. What are the most common causes of dilated (Congestive) cardiomyopathy?

26. A common denoting feature of patients suffering from systemic sclerosis, amyloidosis, hemochromatosis, Löffler’s syndrome, carcinoid syndrome, and sarcoidosis is failure of diastolic cardiac filling. Which of the two curves/lines “A” or “B” in the former diagram is associated with these conditions?

27. What is the term that properly describes cardiomyopathy as a result of former conditions?

28. What clinical condition is the top differential for restrictive cardiomyopathy?

29. What is constrictive pericarditis?
Answers:

Mitrail Regurgitation

1. Over 50% of the cases in the USA are due to myxomatous degeneration of the valve.
2. X-linked myxomatous valvular disease is characterized by mitral valve dystrophy and degeneration of the aortic valve. It mainly affects males and, to a degree of severity, the females.
3. The disease must have an x-linked recessive pattern. Presence of a normal gene will somehow mask the effect of the defective gene. As such defects in females are milder.
4. Congenital bicuspid aortic valve is inherited in an x-linked fashion. Also it has more tendencies for calcification!
5. Any causes of the dilated (congestive) cardiomyopathy and volume overload may potentially cause secondary mitral insufficiency. To name a few; aortic insufficiency, alcoholism, vitamin B1 deficiency and doxorubicin therapy!
6. In the pressure-volume loop that there are no true isovolumetric contraction and relaxation phases because of the presence of a hole between ventricle and atrium.
7. Mitral insufficiency causes volume overload of the left ventricle. The outflow is divided between the high pressure and low compliance aortic and arterial blood, and low pressure/high compliance left atrium. Despite increase workload, most of the output is poured onto the left atrium that has a high compliance. For this reason the ventricular wall tension is only minimally increased.
8. Mitral insufficiency is mainly a volume overload problem and causes eccentric hypertrophy with dilated chamber.
9. Eccentric atrial hypertrophy and dilation!
10. Marked left atrial pressure elevation during systole.

Aortic Regurgitation

11. Eccentric (dilated) hypertrophy!
12. Regurgitant fraction is the fraction of ejected blood into the aorta that returns back into the ventricle during diastole.
13. Regurgitant back flow drops the diastolic aortic pressure!
14. Pulse pressure is the difference between systolic and diastolic pressure. As a result of drop in systolic diastolic pressure, the pulse pressure increases in AI.
15. Effective forward flow through the aorta decreases as a result of the regurgitant flow.
16. The fourth sound requires a hypertrophied ventricle. So the patient must have left ventricular hypertrophy in response to the AI.
17. AI is more common in males. 75% of the patients with pure aortic insufficiency are males.
18. In contrast to aortic stenosis that is old-age related; aortic insufficiency is not related to aging.
19. The hallmark of aortic insufficiency is high pitched decrescendo diastolic murmur in the second intercostal space at the left sternal border.
20. ACE inhibitors, nifedipine and hydralazine are helpful because they decrease the afterload.
21. Systemic vasoconstriction, volume expansion, increased heart rate and dilated hypertrophy.
22. End-systolic volume may only increase very minimally. (see the diagram at the beginning of the topic)
23. “B” is an example of hypertrophied (low-compliant and stiff ventricle) and “A”, a failing heart (e.g. dilated cardiomyopathy)!
24. Dilated cardiomyopathy!
25. See the diagram below!

26. B!
27. Restrictive cardiomyopathy!
28. Constrictive pericarditis!
29. Constrictive pericarditis is due to a thickened, fibrotic pericardium that forms a non-compliant shell around the heart and impedes diastolic filling. Any pericarditis may potentially cause constriction. A few common causes: Coxsackie virus, Tuberculosis, Staph aureus, myocardial infarction, surgical procedures, trauma to chest wall, SLE, and scleroderma.
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