VALVULAR STENOSIS I

Echo Board Review

QUESTION 1

An 82-year-old man presented with symptoms of exertional dyspnea. The aortic valve was severely calcified, with an outflow tract diameter of 2.4 cm and a velocity time integral of 12 cm (Fig. 11–23). Aortic jet velocity and VTI were 3.9 m/s and 86 cm from the apical window and 3.96 m/s and 94 cm from the suprasternal notch approach (Fig. 11–24). VTIs were calculated as the area under the Doppler curve by tracing the outer edge of the curve.

Based on these data, perform the following calculations:

Transaortic stroke volume: ____________
Cardiac output: ____________
Continuity equation aortic valve area: ____________
____
Velocity ratio: ____________
Overall, the degree of aortic stenosis is: ____________
____

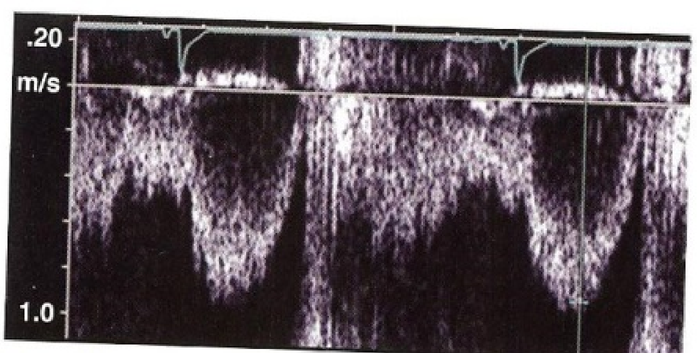


Figure 11–23

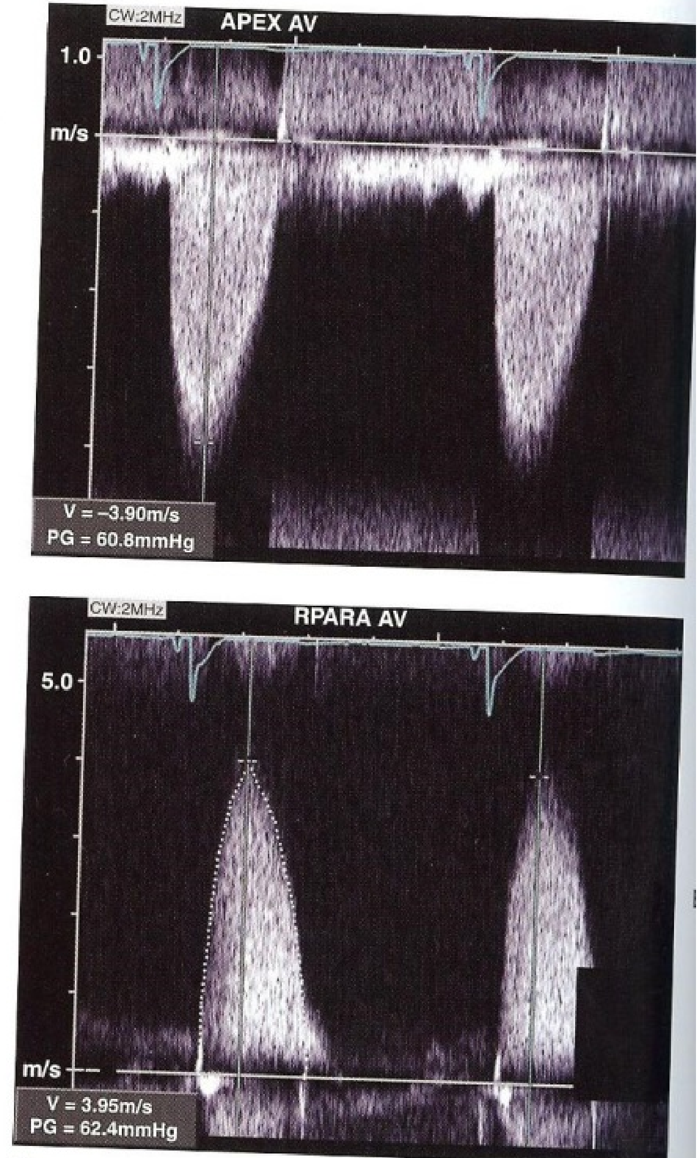


Figure 11–24

ANSWER 1

The first step is to calculate the outflow tract cross-sectional area:

$$CSA_{LVOT} = \pi(\ LVOT_D\ /2)^2 = 3.14(2.4/2)^2 = 4.5\ cm^2$$

$$\text{Transaortic stroke volume (SV)} = CSA_{LVOT} \times VTI_{LVOT} = 4.5\ cm^2 \times 12\ cm = 54\ cm^3 = 54\ ml$$

Heart rate is calculated as 60 seconds/minute divided by the R-R interval in seconds. In this case, the R-R interval is 0.9 second (see the ECG and time markers at the standard 0.2 second intervals), so heart rate is 67 beats per minute.

$$\text{Cardiac output is SV} \times \text{heart rate (66 beats per minute [bpm])} = 3564\ ml = 3.56\ L/min$$

The aortic jet is examined from both apical and high right parasternal windows, with the highest jet velocity representing the most parallel intercept angle between the jet and ultrasound beam. The highest velocity signal is used to measure the VTI.

Continuity equation aortic valve area is

$$AVA = SV/VTI_{AS\text{-}Jet} = 54\ cm^3/94\ cm = 0.6\ cm^2$$

The velocity ratio is

$$V_{LVOT}/V_{max} = 0.9/4.0 = 0.23$$

These findings are all consistent with severe aortic stenosis.

QUESTION 2

A 42-year-old woman being evaluated for liver transplantation has a CWD LV outflow velocity of 3.8 m/s. The aortic valve M-mode is shown in Figure 11–25.

The most likely diagnosis is:

A. Bicuspid aortic valve
B. Hypertrophic cardiomyopathy
C. Subaortic membrane
D. Mitral regurgitation jet mistaken for LV outflow

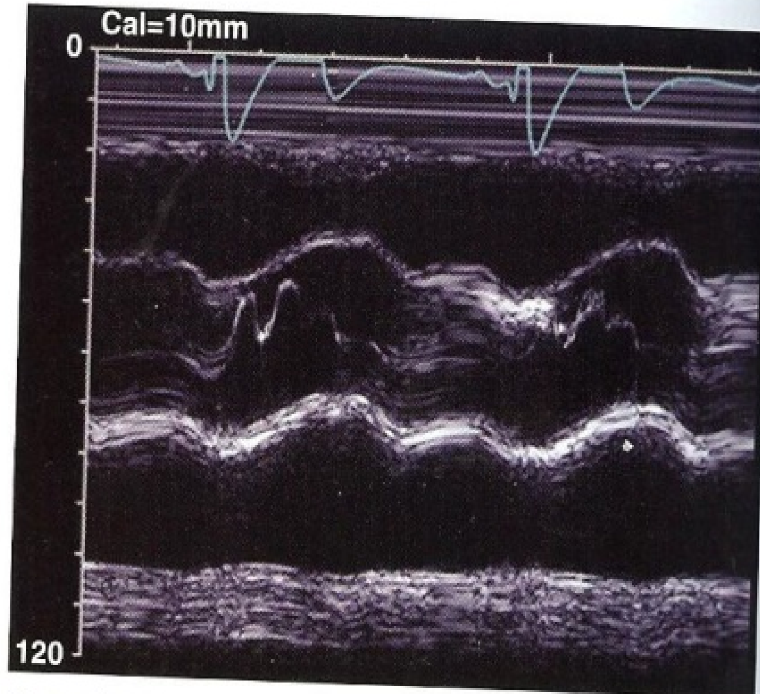


Figure 11–25

ANSWER 2: C

This M-mode recording shows early systolic closure of the aortic valve, but the leaflets then open fully in late systole, as is typical with a fixed subaortic obstruction, such as a subaortic membrane. With a bicuspid valve, leaflet closure is eccentric and opening is normal unless there is superimposed calcification. With dynamic subaortic obstruction caused by hypertrophic cardiomyopathy, the leaflets close in mid (not early) systole, followed by coarse fluttering of the leaflets in late systole. If a high velocity jet is found with a normal aortic valve, the possibility of having mistaken the mitral regurgitant jet for the aortic stenosis jet should be considered. The mitral regurgitant jet is longer in duration than LV outflow and has a velocity of faster than 5 m/s if blood pressure is greater than 100 mm Hg.

QUESTION 3

2D images of the aortic valve in a 56-year-old man referred for evaluation of a murmur are shown in Figures 11–26*A* and B.

The most likely diagnosis is:

A. Rheumatic valve disease
B. Calcific valve disease
C. Bicuspid valve
D. Subaortic membrane
E. Normal valve

A

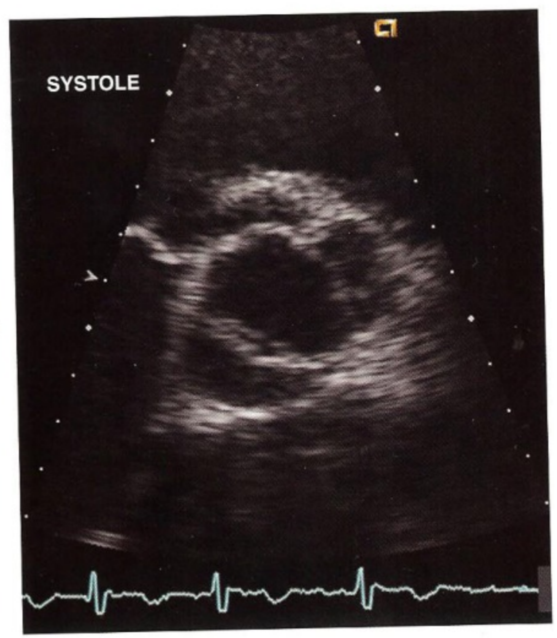


Figure 11–26

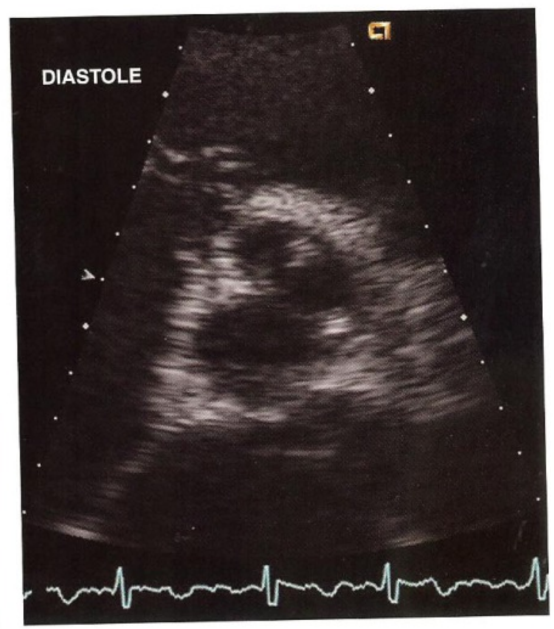
ANSWER 3: C

These images show a bicuspid aortic valve. In diastole, there appear to be three leaflets, because there is a raphe in the anterior leaflet (the fused right and left coronary cusps). The systolic image is diagnostic, showing only two leaflets with only two points of attachment to the aorta (commissures). Often, frame-by-frame analysis of a zoomed short axis view of the valve is needed to make this diagnosis. In a short axis view, with rheumatic aortic disease there is commissural fusion. With calcific disease of either a bicuspid or trileaflet valve, there is calcification in the base of the leaflets. With a subaortic membrane, the aortic valve may appear normal or may be mildly sclerotic due to the impact of the high velocity jet. With a normal trileaflet valve, all three leaflets can be seen in systole.

QUESTION 4

During evaluation of a 76-year-old man with calcific aortic stenosis, you are having difficulty obtaining a left ventricular outflow tract (LVOT) diameter measurement from the parasternal window. You have already adjusted the depth and used zoom mode to maximize the frame rate and readjusted the gain setting to optimize the blood–tissue interface. You also tried repositioning the patient and had him hold his breath at end exhalation. At this point, the next best step is to:

A. Use a default value of 2.0 cm for outflow tract diameter
B. Calculate the LVOT–to–aortic jet velocity ratio instead of valve area
C. Recommend transesophageal echocardiography
D. Refer for cardiac catheterization
E. Measure LVOT diameter in the apical long axis view



B

ANSWER 4: B

LVOT diameter can be accurately measured in more than 95% of patients if care is taken in optimizing patient position and instrument settings. LVOT diameter varies widely and is not accurately predicted by body size in adults, although it tends to be smaller in women, so using a "default" value is not appropriate. The ratio of outflow tract to aortic jet velocity does not require an LVOT diameter measurement and is a useful measure of stenosis severity. Transesophageal imaging might provide better images of the valve itself and might be considered if the velocity ratio and other data do not provide sufficient information of clinical decision making. Transesophageal images allow better evaluation of valve anatomy and may allow direct planimetry of valve area in some cases but rarely provide accurate velocity data because of the intercept angle from this approach. Cardiac catheterization is reserved for cases when the aortic jet velocity also is nondiagnostic or if clinical data are discrepant with the echocardiographic findings. LVOT diameter measurements from an apical view are likely to be imprecise because of the lateral beam width at this depth from this approach.

QUESTION 5

An 84-year-old man presented with heart failure symptoms. Coronary angiography was normal, but echocardiography showed an LV ejection fraction of 24%. In addition, the aortic valve was moderately calcified, with a maximum jet velocity of 2.4 m/s, an LV outflow tract diameter of 2.4 cm, an LV outflow tract velocity of 0.6 m/s, and a continuity equation valve area of 1.0 cm^2. A dobutamine stress echocardiogram was requested and the Doppler flows shown in Figure 11–27 were obtained:

These findings are most consistent with:

A. Severe aortic stenosis
B. Primary myocardial dysfunction
C. Lack of contractile reserve
D. Inadequate test

ANSWER 5: B

From the data shown, the maximum aortic velocities can be directly measured. Mean gradient was estimated using the formula Mean gradient $= 2.4v^2$. Stroke volume was calculated as LV outflow tract CSA times the VTI of flow. Valve area was calculated with the continuity equation. This study shows:

	Rest	Dobutamine
Stroke volume	45 ml	68 ml
Aortic velocity	2.4 m/s	2.7 m/s
Mean gradient	14 mm Hg	17 mm Hg
Aortic valve area	1.0 cm^2	1.4 cm^2

This is an adequate test because there was an increase in aortic jet velocity. There is a normal contractile response to dobutamine with an increase in stroke volume. There also was an improvement in the biplane ejection fraction from 24% to 30%. The increase in valve area with dobutamine indicates the valve leaflets are flexible and that severe stenosis is not present. Thus this patient has a primary cardiomyopathy with the incidental finding of moderate aortic valve stenosis. The stenosis appears more severe at rest because the valve leaflets only open to an area of 1.0 cm^2 because of the combination of moderately calcified leaflets and inadequate force to open the leaflets in systole.

QUESTION 6

A 23-year-old man was referred to echocardiography for evaluation of hypertension. Parasternal short axis views showed a bicuspid aortic valve. The long axis view is shown in Figure 11–28.

Which of the following Doppler data is essential in this patient?

A. Doppler tissue imaging at the mitral annulus
B. Pulmonary vein Doppler velocities
C. Doppler descending aortic velocities
D. Mitral regurgitant jet dP/dt measurement
E. Tricuspid regurgitant jet

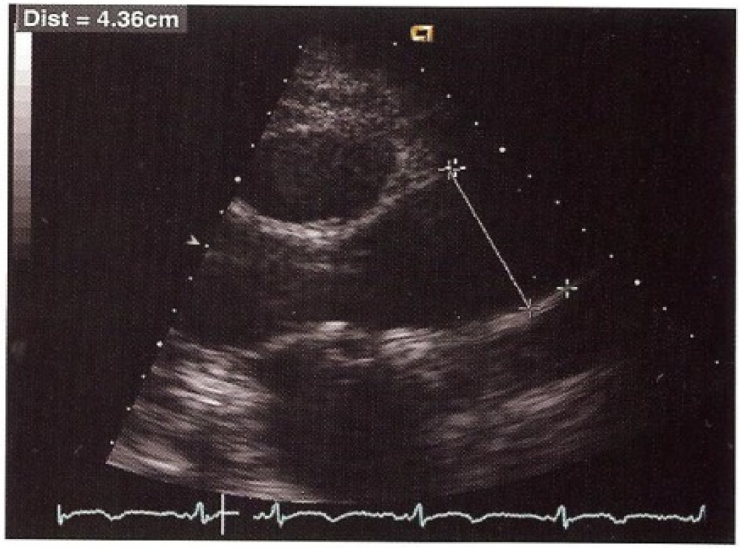


Figure 11–28

ANSWER 6: C

A bicuspid aortic valve is associated with an aortic coarctation in 10% of cases, so it is essential to evaluate descending aortic flow signals in this patient, especially given the history of hypertension. Conversely, more than 50% of patients with an aortic coarctation have a bicuspid valve. The finding of a dilated ascending aorta is also associated with a bicuspid aortic valve and is not related to the severity of valve dysfunction. These patients are at increased risk of aortic dissection. Doppler tissue imaging and pulmonary venous inflow patterns would be helpful for evaluation of ventricular diastolic dysfunction but are not essential in this patient. The mitral regurgitant jet dP/dt would be helpful if ventricular systolic dysfunction was present. The tricuspid regurgitant jet would allow estimation of pulmonary pressures but is likely to be normal in this patient.

QUESTION 7

A 23-year-old woman is referred for possible balloon mitral valvuloplasty for rheumatic mitral stenosis. Parasternal long and short axis views in diastole are shown in Figure 11–29.

Calculate the mitral valve morphology score: ____________________

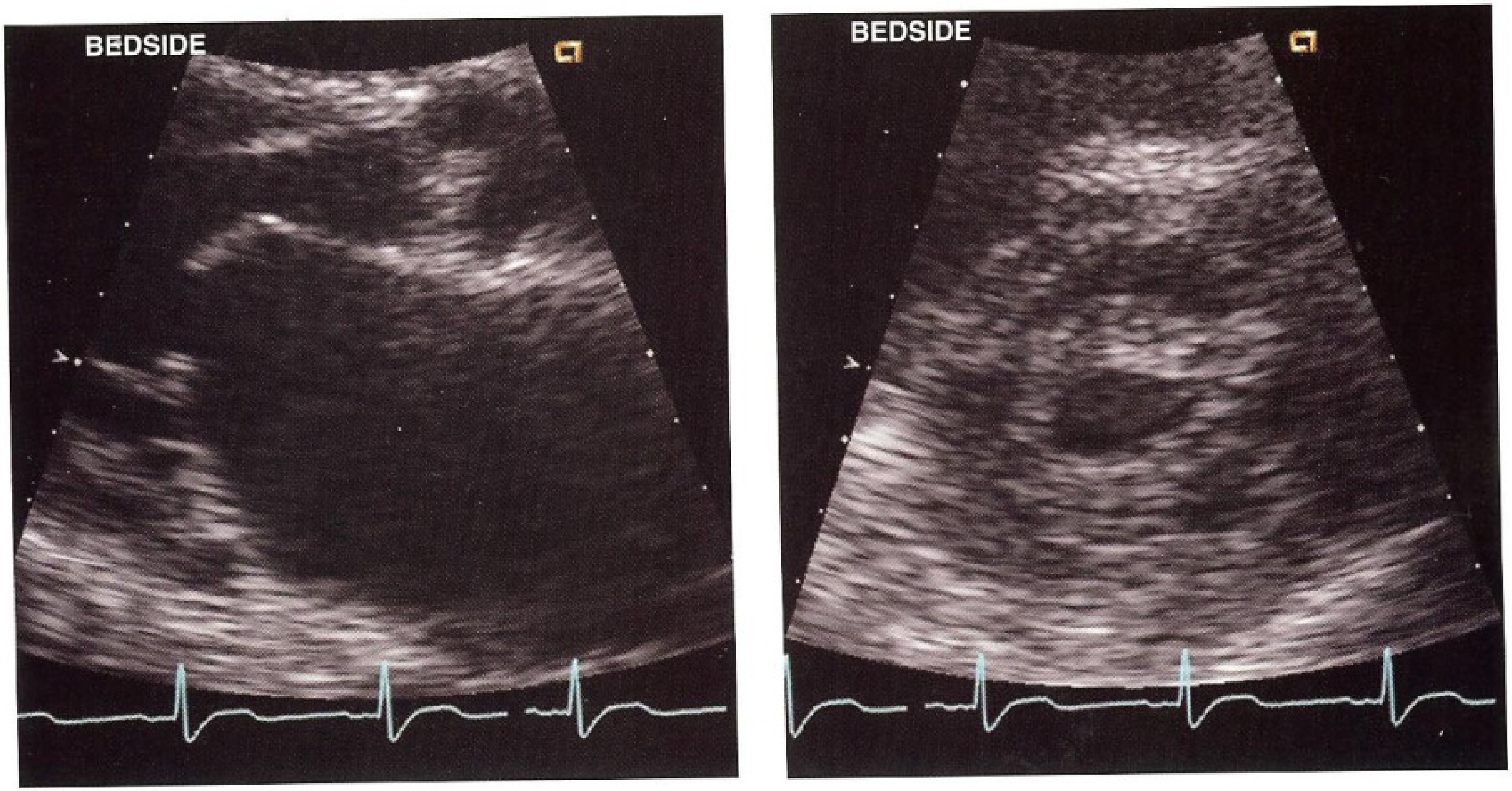


Figure 11–29

ANSWER 7

A score of 1 (mild) to 4 (severe) is assigned to each of four characteristics of the valve: reduction in leaflet mobility, leaflet thickening, calcification, and subvalvular (chordal) involvement. In this patient, classical rheumatic changes are present, with commissural fusion resulting in diastolic doming of the leaflets with little separation of the leaflet tips. However, the base and mid-portion of the leaflet move relatively normally, consistent with a score of 1 for leaflet mobility. Thickening is very mild and restricted to the leaflet tips (score 1), and there is minimal valve calcification (score 1). The chordae do not appear to be thickened (score 1) but might be better evaluated in an apical view. The total Wilkins morphology score thus is 4, indicating a favorable morphology for a valvotomy and a low likelihood of procedural complications. Using the French classification, this is a group I valve, thin pliable leaflets with normal chordal length.

QUESTION 8

The Doppler velocity curve across the mitral valve in the same patient as shown in Question 7 is shown in Figure 11–30.

Measure the pressure half time:______________

Calculate valve area: ______________

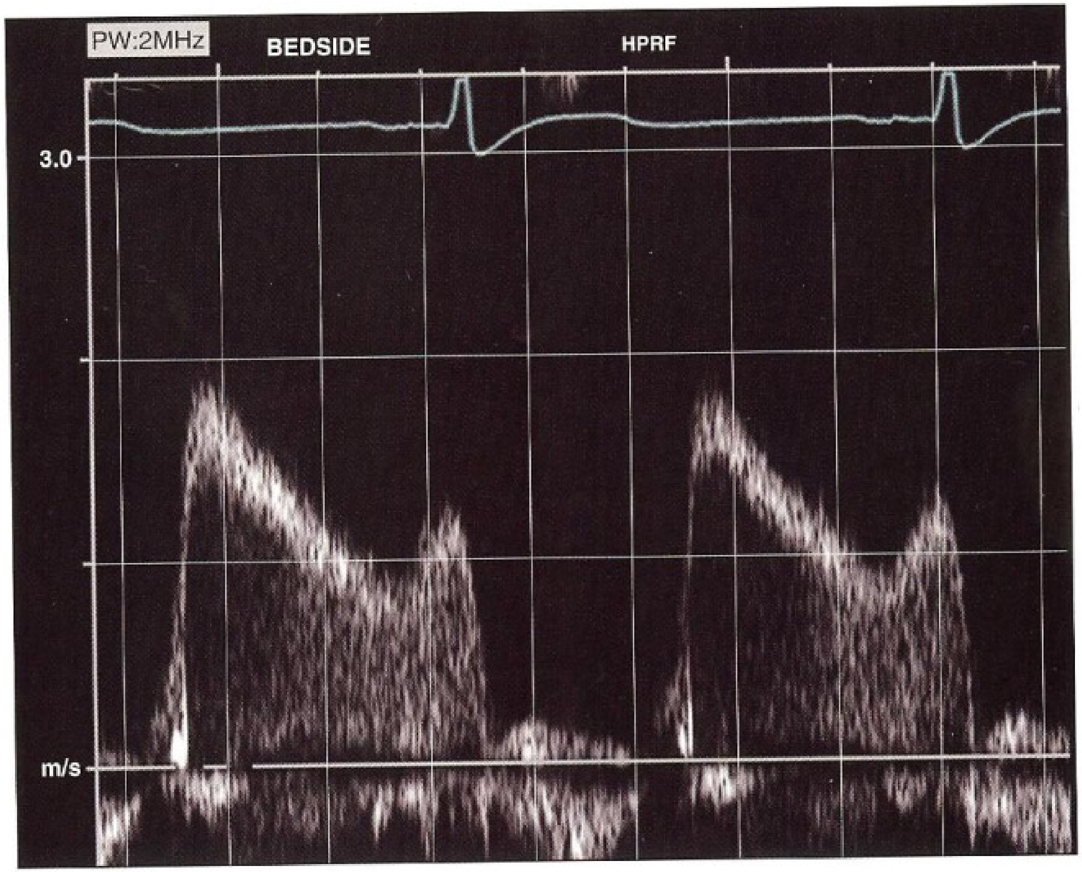


Figure 11–30

ANSWER 8

The pressure half time is the time interval between the peak pressure gradient and ½ the peak gradient. The peak velocity in early diastole (1.8 m/s) corresponds to the peak pressure gradient. A line is drawn from the peak velocity along the diastolic deceleration slope of the flow signal. The velocity corresponding to ½ the peak gradient is calculated ($V_{T½}$) using the simplified Bernoulli equation for the pressure gradient at each velocity. Thus:

$$4\,(V_{T½})^2 = 4(V_{max})^2/2$$

and solving for $V_{T½}$:

$$V_{T½} = V_{max}/\sqrt{2} = V_{max}/1.4$$

With an ultrasound system or a computer analysis system, the pressure half time is displayed from the line placed on the diastolic deceleration slope. By hand, a vertical line is drawn at the peak velocity, and the point on this line corresponding to ½ the peak gradient (1.3 m/s) and the time interval between these two lines is measured in milliseconds (175 msec). Valve area is calculated by dividing the empiric constant 220 by the pressure half time, so valve area in this case is 1.3 cm^2.

QUESTION 9

An apical Doppler signal across the mitral valve in a patient with mitral stenosis is recorded (Fig. 11–31). The patient is in a steep left lateral decubitus position on a stretcher with an apical cutout.

The best approach to measuring the pressure half time in this patient is to:

A. Use the CWD recording instead.
B. Place a line from the peak velocity to the end-diastolic velocity.
C. Place the line along the mid-diastolic section of the velocity curve.
D. Use a higher transducer frequency for the Doppler recording.
E. Use a lower transducer frequency for the Doppler recording.

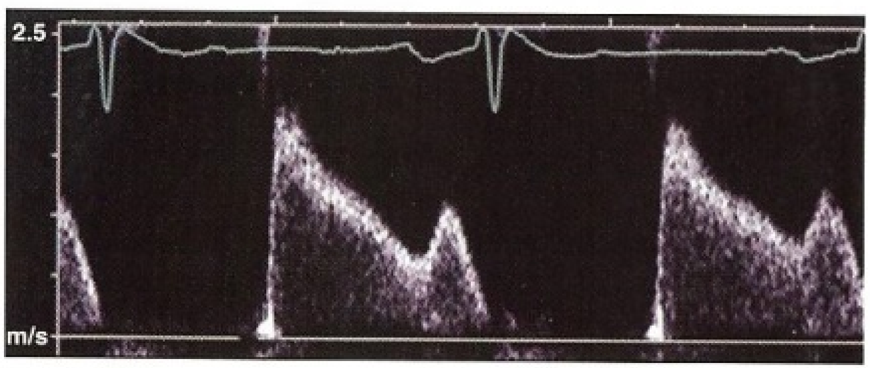


Figure 11–31

ANSWER 9: C

This Doppler recording shows a deceleration slope that is not linear, with a steep slope in early and mid-diastole, followed by a flatter slope in late diastole, possibly related to pulmonary venous inflow contributing to the transmitral flow curve. If efforts to obtain a more parallel intercept angle do not improve the signal, the best approach is to draw the line along the mid-diastolic slope, ignoring the end-diastolic signal, and using the intersection of this line with the onset of flow as the peak velocity. The CWD signal will have the same slope as the pulsed Doppler signal and is measured the same way. Changing the transducer frequency will not affect the slope of the diastolic velocity deceleration.

QUESTION 10

The Doppler recording in Figure 11–32 shows:

A. Severe mitral stenosis
B. Severe mitral regurgitation
C. Severe aortic stenosis
D. Severe aortic regurgitation

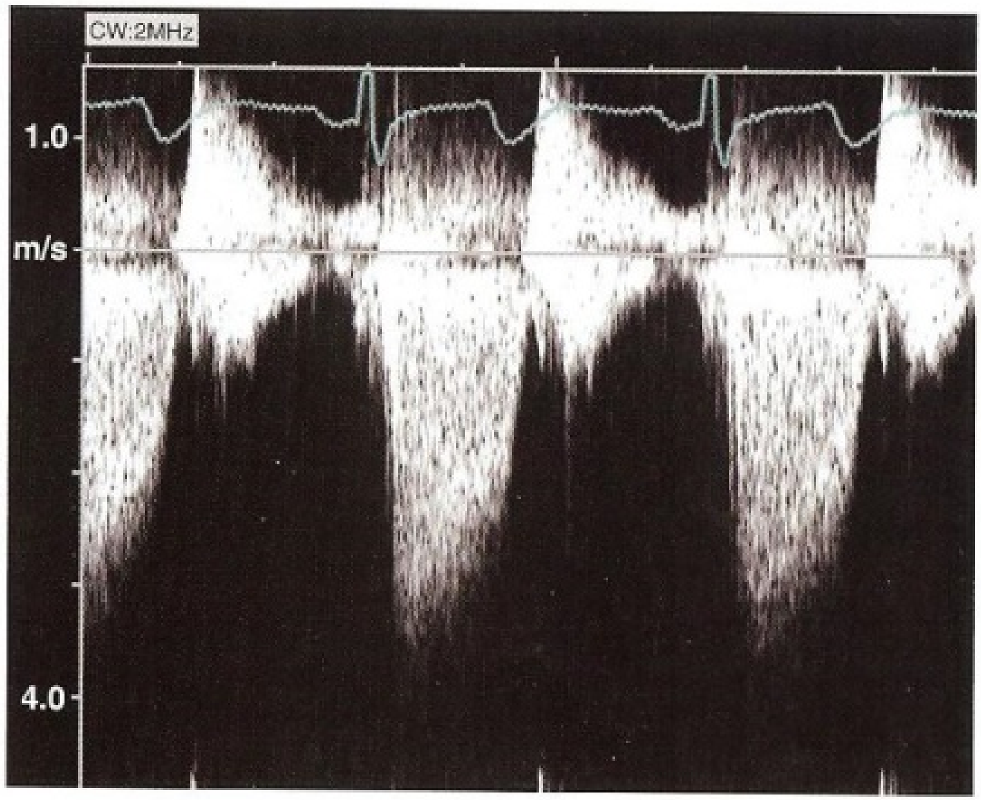


Figure 11–32

ANSWER 10: B

This CWD velocity signal recorded from an apical window shows a diastolic signal of LV inflow. Although the antegrade mitral velocity is high, the deceleration slope is steep, consistent with a high antegrade volume flow rate, without significant stenosis. In systole, the mitral regurgitant signal is as dense as antegrade flow, consistent with severe mitral regurgitation. The relatively low velocity suggests a low systolic blood pressure and high left atrial pressure. With aortic stenosis, the systolic ejection period is shorter than for mitral regurgitation, and there is a gap between the end of forward mitral flow and the onset of aortic flow (isovolumic contraction) and between the end of aortic flow and the onset of mitral flow (isovolumic relaxation). With aortic regurgitation, the diastolic velocity reflects the aortic–to–left ventricular diastolic pressure difference, which is typically greater than 50 mm Hg, or a velocity of faster than 3.5 m/s, which is much higher than transmitral velocities, even when mitral stenosis is present. The aortic regurgitant flow is longer in duration than antegrade mitral flow as aortic regurgitation continues from aortic valve closure to valve opening.

QUESTION 11

A patient with rheumatic mitral stenosis underwent treadmill stress testing, with the Doppler recordings at baseline (*A*) and immediately post-exercise (*B*) shown in Figure 11–33.

This data is most consistent with:

A. Normal exercise response
B. Exercise-induced mitral regurgitation
C. Dynamic outflow obstruction
D. Primary pulmonary hypertension
E. Severe mitral stenosis

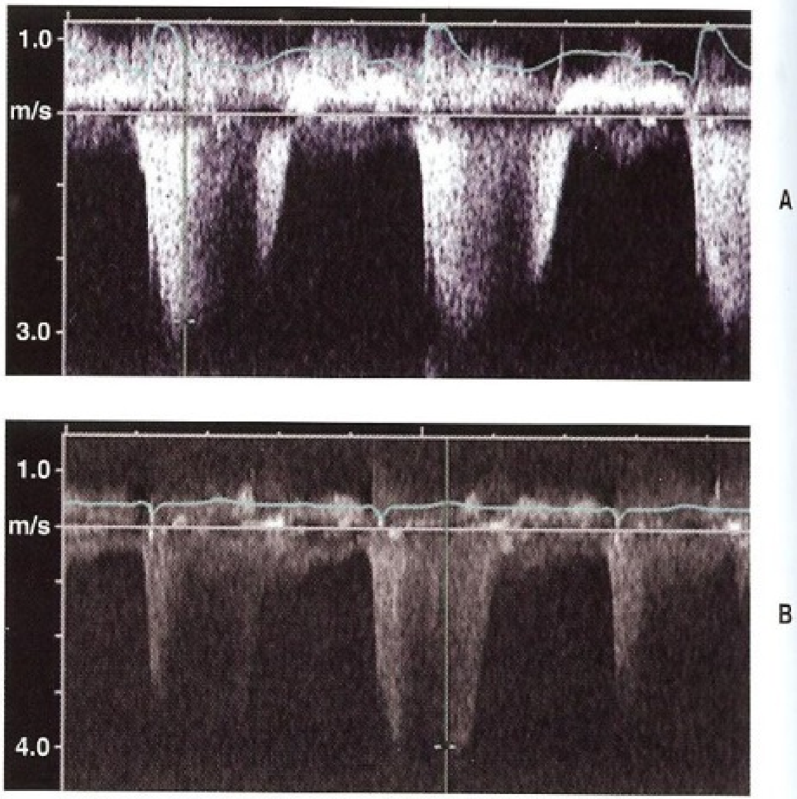


Figure 11–33

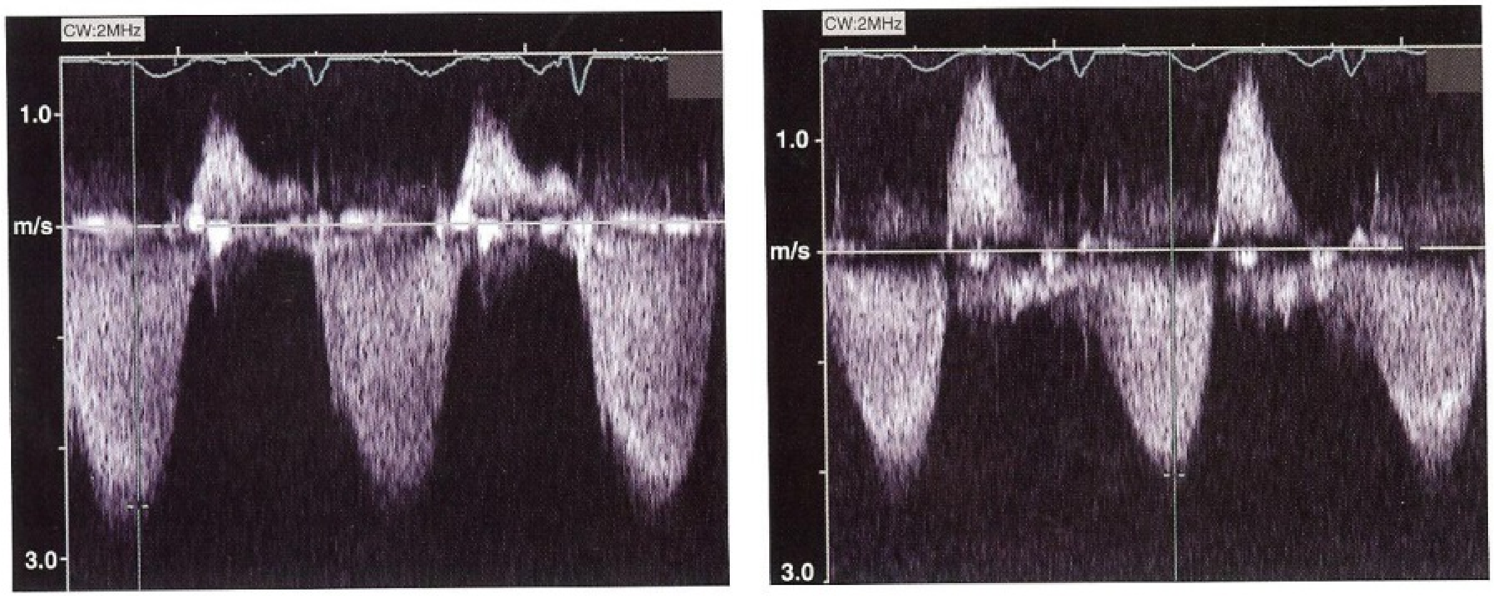
ANSWER 11: E

These Doppler recordings show tricuspid regurgitation at rest and post-exercise. The resting tricuspid regurgitant (TR) jet of 2.8 m/s indicates an RV to RA systolic pressure gradient of 31 mm Hg. Assuming an RA pressure of 5 mm Hg, estimated resting pulmonary artery (PA) pressure is 36 mm Hg. The post-exercise TR jet of 3.6 m/s is consistent with a pressure difference of 52 mm Hg and a PA systolic pressure of 57 mm Hg (moderate pulmonary hypertension). The primary goal in exercise testing with mitral stenosis is to evaluate the rise in PA pressure with exercise. A small increase is normal, but an exercise PA systolic pressure of more than 50 mm Hg suggests a significant rise in LA pressure, caused by a severely stenotic mitral valve, and is an indication for intervention. Exercise testing also is helpful for detection of exercise-induced mitral regurgitation with myxomatous or ischemic mitral regurgitation. The mitral regurgitant jet would be of higher velocity than the TR jet, as MR reflects the LV-to-LA pressure gradient in systole (typically more than 100 mm Hg or faster than 5 m/s). Exercise to evaluate outflow obstruction may be helpful in patients with hypertrophic cardiomyopathy with a typical late-peaking systolic velocity curve.

QUESTION 12

A 26-year-old man with a history of repaired tetralogy of Fallot is referred for echocardiography. The request form notes that a systolic murmur is present. The CWD recordings obtained in this patient are shown in Figure 11–34. What is the most likely diagnosis?

A. Residual ventricular septal defect
B. Severe pulmonic regurgitation
C. Severe pulmonic stenosis
D. Severe pulmonary hypertension
E. Severe tricuspid regurgitation



A

B

Figure 11–34

ANSWER 12: B

Figure 11–34*A* shows tricuspid regurgitation, Figure 11–34*B* shows antegrade and retrograde pulmonic flow. This patient has severe pulmonic regurgitation, as shown by the dense diastolic regurgitant signal with a steep deceleration slope for the pulmonic valve velocity recording. The antegrade velocity across the pulmonic valve (*right*, Fig. 11–34*B*) with a velocity of 2.0 m/s indicates a maximum pressure gradient of only 16 mm Hg. The tricuspid regurgitant jet velocity of 2.5 m/s (*left*, Fig. 11–34*A*) reflects an RV to RA systolic pressure difference of 25 mm Hg (or RV systolic pressure of 30 mm Hg if RA pressure is 5 mm Hg). The TR velocity reflects the pressure difference; the density of the signal reflects the volume of TR. Because the density of the signal is slightly less intense than antegrade tricuspid flow, regurgitation is moderate, but not severe. Pulmonary pressures are normal, based on subtracting the systolic gradient across the pulmonic valve from the systolic RV pressure (30 − 16 = 14 mm Hg).