VALVULAR STENOSIS

ECHO BOARD REVIEW
QUESTION 1

A 31-year-old man with a history of palpitations and a murmur is referred for echocardiography. The initial parasternal long-axis view is shown (Figure 11-23).

![Figure 11-23.](image)

The most likely diagnosis is:

A. Mitral valve prolapse
B. Subaortic stenosis
C. Bicuspid aortic valve
D. Ventricular septal defect
E. Calcific aortic stenosis
ANSWER 1: C

In this diastolic image (Figure 11-31) in a parasternal long-axis view, a bicuspid valve is evident by the anteriorly displaced aortic valve closure plane relative to the midpoint of the aortic root. The diagnosis of bicuspid aortic valve should be confirmed in systolic short-axis view (see below) showing the two leaflets and two commissures. In diastole, the aortic valve may appear trileaflet if there is a ridge of tissue, or raphe, where the leaflets would normally separate; this can be difficult to distinguish from a closed commissure on a diastolic image. In this patient, the anterior mitral valve leaflet appears normal and mitral prolapse would not be evident on a diastolic image in any case. There is no defect in the proximal ventricular septum to suggest a ventricular septal defect and there is no narrowing or membrane seen in the left ventricular outflow tract.

Figure 11-31.
QUESTION 2

A 52-year-old male patient is referred for evaluation of exertional dyspnea. He has a history of congenital aortic stenosis and had undergone corrective surgery as a child. TTE demonstrates an ejection fraction (EF) of 68% without regional wall motion abnormalities. The aortic valve is heavily calcified with minimal systolic motion. These Doppler signals are obtained (Figure 11-24 A and B).

![Doppler signals](image)

Figure 11-24 A and B.

The most appropriate next step in patient management is:

A. Transesophageal echocardiography
B. Dobutamine stress echocardiography
C. Coronary angiography
D. Repeat transthoracic echocardiography
stress echocardiography may be helpful to differentiate low-gradient severe aortic stenosis, but systolic function is preserved in this case. Coronary angiography might be appropriate if aortic stenosis is not severe, because coronary disease is an alternate explanation for his symptoms, but should be considered only after complete evaluation of the aortic valve.

For the repeat study, Doppler interrogation of the valve from multiple views with careful patient positioning and transducer angulation is needed to record the highest jet velocity. The first Doppler recording (Figure 11-24A) was taken from the apical window. A peak velocity of 3.7 m/s suggested only moderate-range stenosis in the setting of normal forward stroke volume but is a poor-quality signal without a clear Doppler envelope and a poorly defined peak velocity. The second Doppler recording (Figure 11-24B) (peak approximately 2.0 m/s) clearly underestimates the severity of stenosis and was not well aligned with the aortic jet (signal above and below the baseline). With the patient repositioned in a steep left lateral decubitus position, using an apical cutout in the exam table additional imaging provided velocity data from apical, suprasternal, high right parasternal, and substernal views, with careful transducer angulation from each window. The apical CW Doppler signal (Figure 11-24C) was still suboptimal (4.0 m/s), but a higher velocity (≥4.7 m/s) was obtained from a right parasternal window (Figure 11-24D) consistent with severe aortic stenosis.

ANSWER 2: D

The original ECG report describes normal systolic function and evidence of aortic stenosis, with a heavily calcified, immobile valve. However, the Doppler data are poor quality; the apparent maximum velocity does not fit with the rest of the clinical and imaging data. Thus, a repeat transthoracic study is recommended. TEE is helpful for visualization of valve anatomy and allows planimetry of valve area in some cases, but Doppler data for aortic stenosis on TEE are suboptimal because it is difficult to align the Doppler beam with the stenotic jet due to constraints of transducer position in the esophagus. Obviously, the non-invasive transthoracic data should be correctly recorded before proceeding to TEE. Dobutamine
QUESTION 3

A 28-year-old woman who recently moved to the United States presents to establish care with a provider. A murmur is heard on examination and an echocardiogram is ordered (Figure 11-25).

![Echocardiogram Image](image)

Figure 11-25.

The most likely diagnosis is:

A. Rheumatic valve disease
B. Tetralogy of Fallot
C. Bicuspid aortic valve
D. Myxomatous mitral valve disease
E. Ventricular septal defect
This is a transmitral Doppler tracing taken from an apical window with flow directed toward the transducer during diastole. The Doppler pattern is consistent with atrioventricular valve inflow with early filling (E wave) and late filling due to atrial contraction (A wave), and the markedly prolonged diastolic deceleration slope is consistent with obstruction of LV inflow at the valve level. The pressure half-time is 240 ms, consistent with a valve area of 220/240 or 0.9 cm$^2$ (try measuring it yourself on the image). Mitral stenosis is nearly uniformly caused by rheumatic valve disease and has wide geographic variation in prevalence and age at presentation. Mitral regurgitation due to myxomatous mitral valve disease and ventricular septal defect flow would both occur during systole. Regurgitation of a bicuspid aortic valve would occur during diastole but would not show evidence of atrial contraction. Also, peak end-diastolic velocity of an aortic regurgitant jet would be higher velocity than transmitral flow due to the higher transvalvular gradient between the aortic diastolic pressure and LV chamber. A common late complication of surgically treated Tetralogy of Fallot is pulmonic regurgitation. Similar to aortic regurgitation, pulmonic regurgitation would occur during diastole, but would not show evidence of atrial contraction, and the shape and magnitude of the velocity curve would reflect the pulmonary artery to RV diastolic pressure difference.
QUESTION 4

A 78-year-old woman presents with aortic stenosis. On physical examination her vital signs reveal a blood pressure of 144/80 mm Hg and heart rate of 56 bpm. On TTE, the aortic valve is severely calcified, with:

<table>
<thead>
<tr>
<th>LV outflow tract diameter</th>
<th>2.4 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>LV outflow tract peak velocity</td>
<td>0.9 m/s</td>
</tr>
<tr>
<td>LVOT velocity-time integral</td>
<td>12 cm</td>
</tr>
<tr>
<td>Aortic valve velocity</td>
<td>4.0 m/s</td>
</tr>
<tr>
<td>Aortic valve velocity-time integral</td>
<td>94 cm</td>
</tr>
</tbody>
</table>

Based on this data, do the following calculations:
Transaortic stroke volume
Cardiac output
Continuity equation aortic valve area
Aortic velocity ratio
Overall, the degree of aortic stenosis is
ANSWER 4

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

$$CSA_{LVOT} = \pi \left( \frac{LVOT_d}{2} \right)^2 = 3.14 \left( \frac{2.4}{2} \right)^2 = 4.5 \text{ cm}^2$$

Transaortic stroke volume (SV) = CSA$_{LVOT}$ x VTI$_{LVOT}$
$$= 4.5 \text{ cm}^2 \times 12 \text{ cm} = 54 \text{ cm}^3 = 54 \text{ ml}$$

Cardiac output is:
$$SV \times \text{heart rate (56 bpm)} = 3024 \text{ mL} = 3.02 \text{ L/min}$$

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

The velocity ratio is:
$$V_{LVOT} / V_{\text{max}} = 0.9 / 4.0 = 0.23$$

These findings are all consistent with severe aortic stenosis, defined as an aortic velocity greater than 4.0 m/s and valve area less than 1.0 cm$^2$. 
QUESTION 5

A 58-year-old woman is referred for echocardiography for new onset atrial fibrillation. She lives in a rural area and has not seen care providers regularly due to lack of insurance. The following image is obtained (Figure 11–26).

![Echocardiogram Image]

Figure 11–26.

The most likely cause of the abnormalities seen here is:

A. Endocarditis
B. Calcific valve disease
C. A systemic inflammatory disease
D. Rheumatic disease
E. Congenital bicuspid aortic valve
ANSWER 5: D

This parasternal short-axis image shows a trileaflet aortic valve with thickening along the leaflet edges and commisural fusion diagnostic for rheumatic aortic valve disease. The left atrium is severely enlarged and spontaneous contrast is seen, suggesting there also is severe mitral stenosis. Atrial fibrillation can be a presenting symptom with rheumatic valve disease. In the United States, many patients initially present at age 50 to 60 years, with about 80% of cases occurring in women. In immigrants from countries with a higher prevalence of rheumatic fever, valve disease presents at a younger age. Endocarditis results in valve vegetations, leaflet destruction, and abscess formation, not commisural fusion. Calcific aortic valve disease affects the body of the leaflet, not the leaflet edges or commissures. Systemic inflammatory diseases can affect the posterior aortic wall and aortic valve but typically cause aortic regurgitation, rather than stenosis, and would be unlikely to cause this degree of left atrial enlargement.
QUESTION 6

A 76-year-old man with coronary artery disease presents with exertional dyspnea. A recent angiogram shows chronic occlusion of his right coronary artery and no new coronary lesions. Echocardiography demonstrates a heavily calcified aortic valve, an EF of 40%, and regional wall motion abnormalities in the inferior wall and apex. The following data were obtained from a dobutamine stress echocardiogram at an infusion rate of 7.5 mcg/kg/m:

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Dobutamine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ejection fraction (%)</td>
<td>40</td>
<td>55</td>
</tr>
<tr>
<td>LVOT velocity (m/s)</td>
<td>0.7</td>
<td>0.8</td>
</tr>
<tr>
<td>Aortic maximum velocity (m/s)</td>
<td>3.5</td>
<td>4.2</td>
</tr>
<tr>
<td>Mean aortic gradient (mm Hg)</td>
<td>27</td>
<td>41</td>
</tr>
<tr>
<td>Aortic valve area (cm²)</td>
<td>0.8</td>
<td>0.8</td>
</tr>
</tbody>
</table>

These findings are most consistent with:

A. Lack contractile reserve  
B. Severe aortic stenosis  
C. Moderate aortic stenosis  
D. Inadequate test
ANSWER 6: B

This patient has low output, low gradient aortic stenosis. The baseline data are either consistent with severe aortic stenosis in the setting of LV dysfunction or may be due to only moderate aortic stenosis with reduced leaflet opening secondary to the low trans-aortic flow rate. Dobutamine stress echocardiography is helpful in distinguishing between these diagnoses; with severe aortic stenosis, valve replacement is indicated, whereas with moderate stenosis, medical therapy is more appropriate. In this patient, there is a normal contractile response to dobutamine with an increase in stroke volume and an increase in ejection fraction from 40% to 55%. Despite the concurrent increase in both stroke volume and aortic jet velocity, the calculated aortic valve area remained the same at 0.8 cm², indicating that the aortic stenosis is severe and is the result of a "fixed" obstruction. The definition of severe aortic stenosis on dobutamine stress echocardiography is a valve area less than 1.0 cm² with an increase in stroke volume greater than 20% or an aortic velocity greater than 4.0 m/s at any flow rate. With a primary cardiomyopathy and moderate aortic stenosis, inadequate forward stroke volume to fully open the leaflets in systole may lead to smaller aortic valve orifice area calculations at rest. However, with dobutamine infusion, the increase in forward stroke volume results in greater leaflet opening and a larger valve area calculation. A lack of contractile reserve would lead to no change in cardiac output (ejection fraction) or stroke volume with dobutamine, not the situation in this case. The appropriate augmentation in cardiac output suggests this test was diagnostic (adequate).
QUESTION 7

A 36-year-old woman with known rheumatic valve disease is referred for mitral valvotomy. Echocardiographic factors to consider in determining candidacy for percutaneous valvotomy include all of the following except:

A. Mitral valve leaflet thickening
B. Systolic anterior motion (SAM) of the chords
C. Mitral valve calcification
D. Mitral valve leaflet mobility
E. Chordal apparatus thickening
Systolic anterior motion (SAM) of the chords is not a characteristic feature of mitral stenosis. SAM occurs with dynamic subaortic obstruction, as can occur with hypertrophic cardiomyopathy, often resulting in late systolic mitral regurgitation. SAM also can be seen with mitral valve prolapse and in some normal individuals, without associated outflow obstruction in either of these situations. Optimal results with percutaneous mitral valvotomy occur with fracturing of the fused commissures, allowing a larger orifice area. The features of mitral valve anatomy predictive of outcomes with percutaneous mitral valvotomy are described by a scoring system with four echocardiographic criteria: leaflet mobility, leaflet thickening, subvalvar (chordal) thickening, and mitral valve calcification. A score between 1 and 4 points is assigned to each criteria (more severe involvement = 4) and then summed. A score greater than 8 points is consistent with more leaflet thickening and calcification or more involvement of the subvalvular apparatus; these patients tend to have less optimal results because abnormal leaflet morphology remains after the procedure. Severe commisural calcification also is a poor prognostic sign because it increases the likelihood of a leaflet tear during the procedure, producing significant mitral regurgitation. Best results are seen in patients with a score less than 8 points and little commissural calcium.
Doppler recordings recorded in a young woman with a systolic murmur and dyspnea are shown below (Figure 11-27). The diameter of the inferior vena cava (IVC) measured 1.8 cm with normal inspiratory collapse.

Figure 11-27.

Calculate the pulmonary arterial systolic pressure.
Doppler signal A can be identified as the tricuspid regurgitant jet, taken from the apical 4-chamber view, based on a long ejection time with a Doppler signal that starts at the onset of the QRS signal. The peak velocity is elevated at 3.3 m/s, consistent with an RV-to-RA systolic pressure difference of 44 mm Hg. With a normal-caliber IVC and normal inspiratory collapse, right atrial pressure is about 5 mm Hg. Adding the estimated RA pressure to the RV-to-RA pressure difference, then, provides an estimated RV systolic pressure of 49 mm Hg. However, estimation of the pulmonary arterial systolic pressure from the tricuspid regurgitant jet assumes that there is no intervening pressure gradient between the pulmonary circulation and the RV. In this case, there is also pulmonic stenosis as shown in tracing B, recorded from the parasternal short-axis view. The pulmonic valve Doppler signal is differentiated from the tricuspid regurgitant signal by the relative delay in onset, accounted for by isovolumic contraction. The peak velocity of the pulmonic stenosis jet is 2.8 m/s, which corresponds to a pressure gradient of 32 mm Hg across the pulmonic valve, or between the RV and pulmonary artery in systole. This pressure gradient must be subtracted from the RV systolic pressure to obtain the estimated pulmonary systolic pressure (49 - 32 = 17 mm Hg), which is normal.
A 36-year-old woman undergoing chronic dialysis therapy for end-stage renal disease presents for clinical follow-up. She denies cardiopulmonary symptoms, palpitations, or fever. Her exercise tolerance is unchanged from baseline. A TTE is ordered and the following image is obtained (Figure 11-28). The transmural mean gradient is 3 mm Hg and there is mild mitral regurgitation.

These findings are most consistent with:

A. Rheumatic valve disease
B. Acute bacterial endocarditis
C. Mitral annular calcification
D. Left atrial myxoma
E. Persistent left superior vena cava
This parasternal long-axis image shows severe calcification of the posterior mitral valve annulus. There is a minimal transmitral pressure gradient without significant mitral regurgitation. Mitral annular calcification develops from progressive calcium deposition along and beneath the mitral valve annulus with relative sparing of the posterior mitral valve leaflet, appearing with an irregular, lumpy appearance. The mitral valve leaflets and chordae tendineae are generally not involved. In advanced cases of mitral annular calcification, there is encroachment on the mitral valve leaflets. There may be a mild inflow gradient or mild associated mitral regurgitation, but mitral annular calcification rarely requires surgery. Rheumatic mitral valve disease involves leaflet thickening and scarring along commissural lines with restriction of diastolic opening or "doming" of the anterior leaflet, which is not seen in this case. In addition, most of the calcific burden for rheumatic valve disease is seen at the leaflet tips rather than at the base of the valve or valve annulus. Bacterial endocarditis typically involves the atrial side of the leaflets and is associated with mitral regurgitation due to leaflet destruction or poor coaptation. A myxoma is a benign cardiac mass that typically originates from the atrial septum with an echodensity similar to tissue. A persistent left superior vena cava results in a dilated coronary sinus, which is seen as an echolucent area posterior to the mitral annulus in the long-axis view.
QUESTION 10

A 60-year-old woman with tricuspid valve stenosis is admitted to the hospital with dyspnea and pedal edema. The transtricuspid Doppler tracing is shown below (Figure 11-29).

Figure 11-29.

In this case, the severity of stenosis is best assessed by measuring:

A. Average peak gradient, 3 cardiac cycles
B. Mean gradient, longest Doppler signal
C. Average mean gradient, 3 cardiac cycles
D. Peak late gradient, highest Doppler signal
ANSWER 10: C

Tricuspid valve stenosis is nearly uniformly caused by rheumatic valve disease. The patient is in atrial fibrillation with variability in the R–to–R interval. With a shorter cardiac cycle, less time is spent in diastole, and diastolic LV filling is completed in a shorter interval. For these shorter cardiac cycles, the peak early inflow velocity is higher than in Doppler signals with a longer cardiac cycle duration. Because mean gradient averages the instantaneous gradients over the flow duration, the mean gradient will be higher on shorter cycle lengths and lower on long cycle lengths. In clinical practice, when significant variation in heart rate is present, any measurements of peak and mean gradients are averaged over several cardiac cycles. For mitral or tricuspid stenosis, mean gradients are more representative of stenosis severity than peak gradients.
QUESTION 11

An asymptomatic patient with rheumatic mitral stenosis is seen for routine follow-up. The diastolic flow curve shows an increased velocity and flat diastolic slope with a maximum velocity of 2.0 m/s.

The time interval between maximum velocity and various points on the diastolic flow curve are measured as follows:

<table>
<thead>
<tr>
<th>Velocity (m/s)</th>
<th>Time (msec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.8</td>
<td>190</td>
</tr>
<tr>
<td>1.4</td>
<td>225</td>
</tr>
<tr>
<td>1.0</td>
<td>250</td>
</tr>
<tr>
<td>0.6</td>
<td>275</td>
</tr>
</tbody>
</table>

Calculate the mitral valve area: ____________
ANSWER 11: 1.0 cm²

The pressure half-time ($T\frac{1}{2}$) is defined as the time required for the pressure gradient across an obstruction to decrease to half of its maximal value. Velocity is squared in the Bernoulli equation to calculate pressure gradient, so to calculate the velocity on the curve where the gradient is $\frac{1}{2}$ the maximum gradient, maximum velocity is divided by 1.4 (because 1.4 is the square root of 2). In this case, 2.0 m/s divided by 1.4 equals 1.4 m/s so the $T\frac{1}{2}$ is 225 ms. Then mitral valve area is calculated by the equation $\frac{220}{T\frac{1}{2}}$, in this case $\frac{220}{225} = 0.98$ cm². Valve area calculations are only accurate to one decimal point so this calculation should be rounded up and reported at 1.0 cm², consistent with severe mitral stenosis.
QUESTION 12

The following image (Figure 11–30) is consistent with:

A. Mitral stenosis
B. Aortic stenosis
C. Tricuspid stenosis
D. Pulmonic stenosis
ANSWER 12: B

This is an M-mode tracing through the aortic valve. Aortic valve motion is shown against time on the horizontal axis. The anterior and posterior aortic valve annulus is seen throughout the cardiac cycle with slight motion corresponding to systole and diastole. Within the annulus is a bright, calcified aortic valve best seen during diastole. During systole, there is little valve motion, consistent with aortic stenosis.