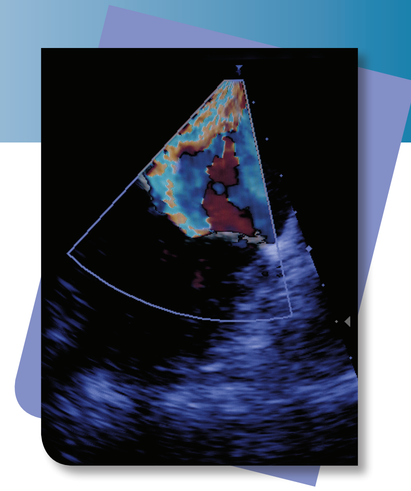
Chapter 50



Echocardiography during Interventional Procedures

Muhamed Saric and Itzhak Kronzon

1. Which of the following is not a contraindication for percutaneous mitral balloon valvuloplasty (PMBV) in rheumatic mitral stenosis?

A. Thrombus in the left atrial appendage
B. Lutembacher syndrome
C. Thrombus in the body of the left atrium
D. Mitral valve score of 14
E. Moderate mitral regurgitation

2. Figure 50.1 and Video 1 demonstrating the right atrial aspect of an atrial septal defect (ASD) were obtained from a 72-year-old female during evaluation for possible percutaneous closure. The dotted yellow line represents the largest ASD diameter (30 mm), while the solid yellow line represents the ASD's aortic rim (7 mm). Other ASD rims were also measured and deemed sufficient for ASD closure.

Additionally, echocardiography demonstrated an enlarged right heart and no significant pulmonary arterial hypertension.

Which of the following is the correct answer?

A. ASD is too large for device closure.
B. ASD anatomy is favorable for device closure.
C. The patient is too old for device closure.
D. The aortic rim of ASD is too small for device closure.
E. The patient does not have a secundum ASD.

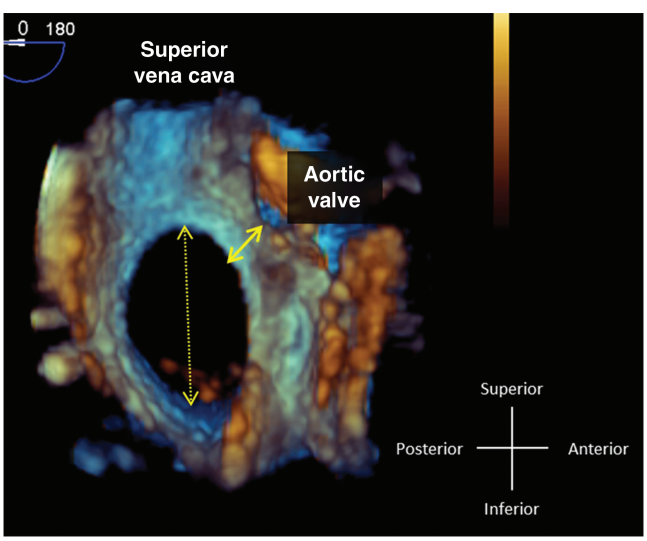


Figure 50.1

3. Figure 50.2 and Video 2 were obtained from a 23-year-old male with an atrial septal defect (ASD) referred for possible percutaneous closure.

Panel A demonstrates the left atrial aspect of an ASD (asterisk); its diameters were measured at 18 × 12 mm.

Panel B and Video 2 demonstrate the left ventricular side of the patient's mitral valve.

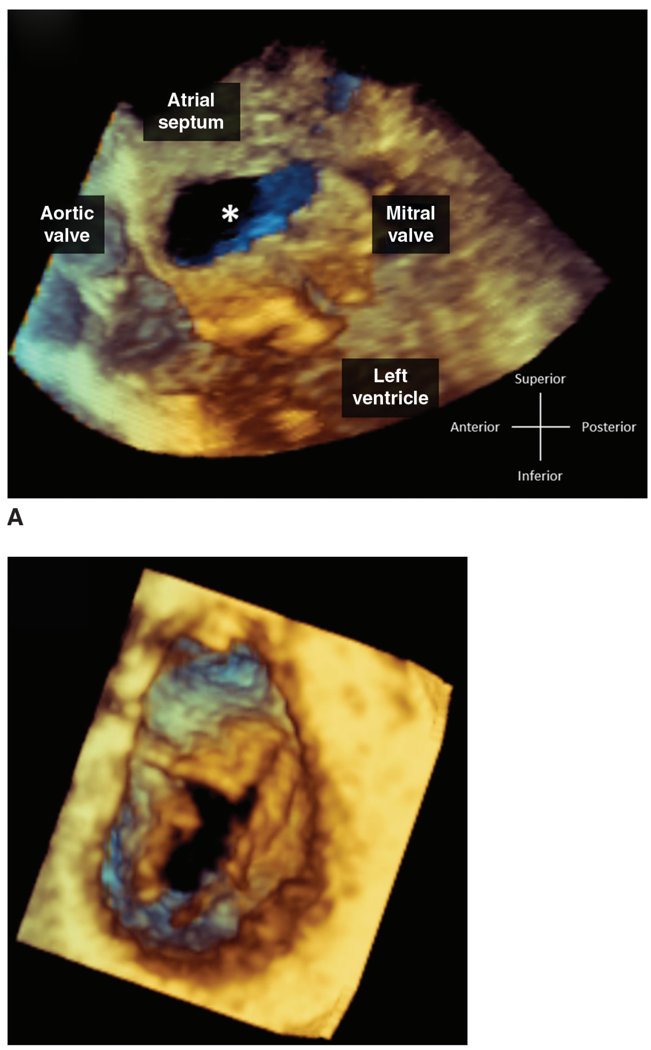


Figure 50.2

Echocardiography also demonstrated moderate mitral regurgitation, enlarged right heart, no pulmonic stenosis, and a peak systolic gradient of the tricuspid regurgitant jet of 25 mm Hg. Right atrial pressure was estimated at 3 mm Hg.

You recommend cancelation of percutaneous ASD closure in this patient because:

A. ASD is too small.
B. The patient has pulmonary hypertension.
C. The secundum ASD is not amenable to percutaneous closure.
D. The right heart is dilated.
E. There is mitral valve pathology.

4. FIGURE 50.3 was obtained by 3D transesophageal echocardiography and demonstrates the left atrial aspect of the mitral valve in the so-called surgical view.

What structure is marked by the arrow?

A. Left atrial appendage
B. Atrial septal defect
C. Right pulmonary artery
D. Aortic root
E. Left upper pulmonary vein

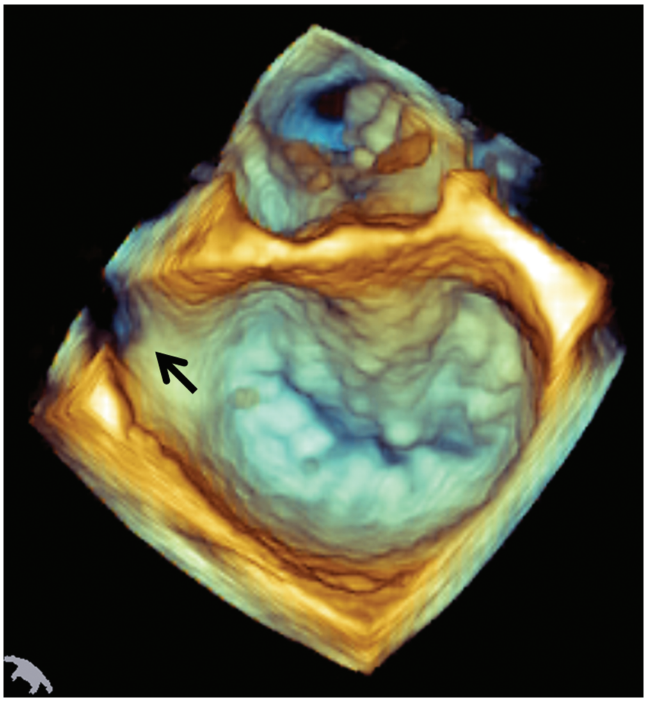


FIGURE 50.3

5. FIGURE 50.4 was obtained by transesophageal echocardiography (TEE) in a 67-year-old male with atrial fibrillation and two embolic strokes who underwent percutaneous exclusion of the left atrial appendage (LAA) using an LAA occluder (black arrow in Panel A and yellow arrow in Panel B).

Panel A demonstrates the 3D TEE appearance of the LAA occluder (black arrow) seen from the left atrial side. Panel B is the color Doppler 2D TEE image obtained at 45 degrees; the yellow arrow points to the location of the LAA occluder. The width of the jet shown in Panel B is 6 mm.

Which of the following is the correct statement?

A. The occluder is placed too deep into the LAA.
B. The LAA occluder is not inferior to anticoagulation in preventing further embolic strokes.
C. The patient may stop anticoagulation immediately post–percutaneous LAA occlusion.
D. LAA thrombus is an indication for LAA occluder implantation.
E. There is a large residual leak around the occluder.

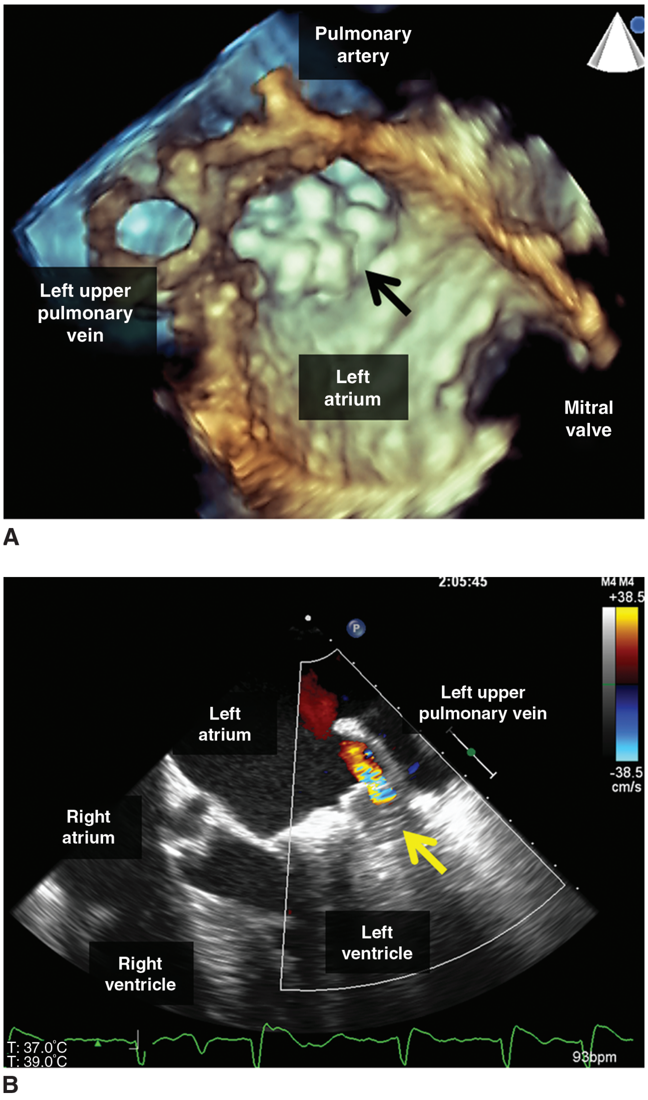


FIGURE 50.4

6. FIGURE 50.5 was obtained by 3D transesophageal echocardiography and demonstrates the left atrial aspect of the mitral valve in the so-called surgical view.

What structure is marked by the arrow?

A. Scallop A1
B. Lateral commissure
C. Scallop P1

D. Scallop A2
E. Accessory scallop

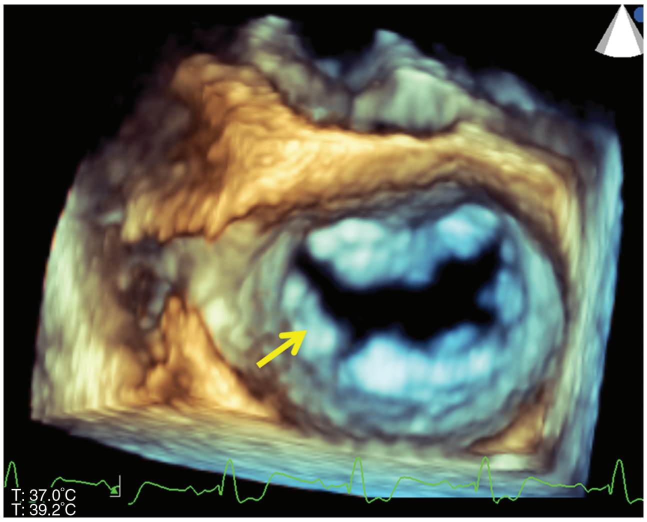


Figure 50.5

7. Figure 50.6 was obtained by 3D transesophageal color Doppler echocardiography and demonstrates the left atrial aspect of the mitral bioprosthetic valve in the so-called surgical view. There is paravalvular leak.

What is the location of the paravalvular leak?

A. 12 o'clock
B. 4 o'clock
C. 10 o'clock
D. 2 o'clock
E. 7 o'clock

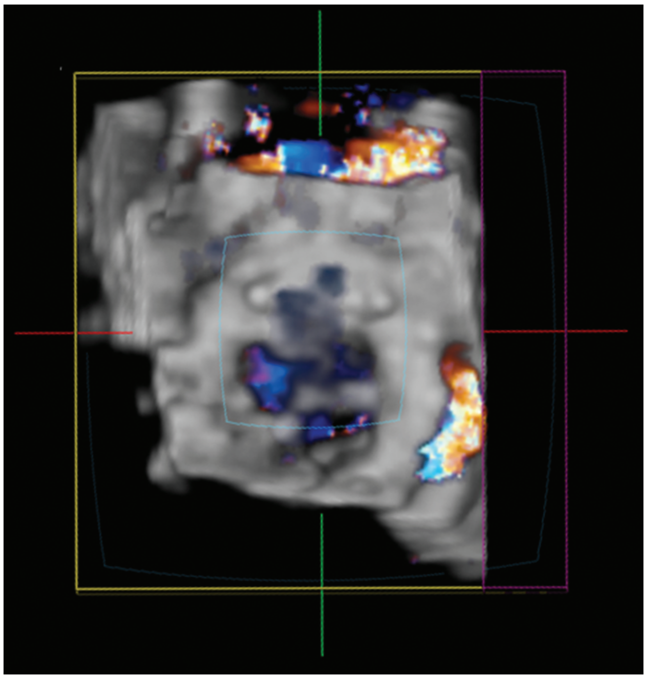


Figure 50.6

8. The pair of images in Figure 50.7 demonstrates the same anatomic structure before (Panel A; peak systole) and after an intervention (Panel B; diastole).

What procedure was performed?

A. Aortic valve balloon valvuloplasty only
B. Surgical aortic valve repair
C. Transcutaneous aortic valve replacement
D. Valve-in-valve implantation to treat bioprosthetic valve regurgitation
E. Type A aortic dissection endovascular graft

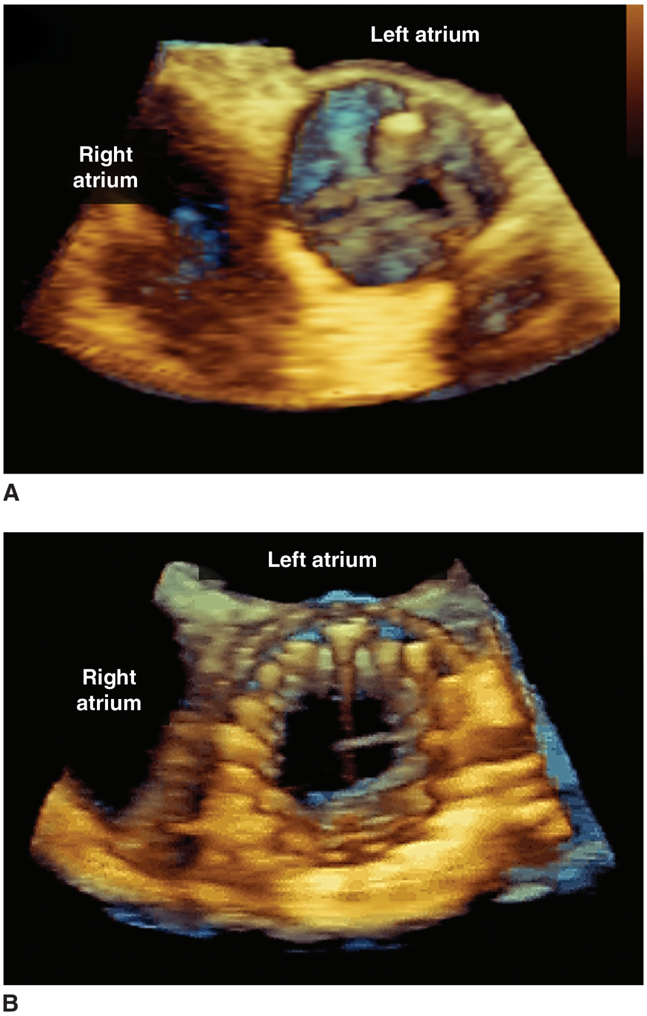
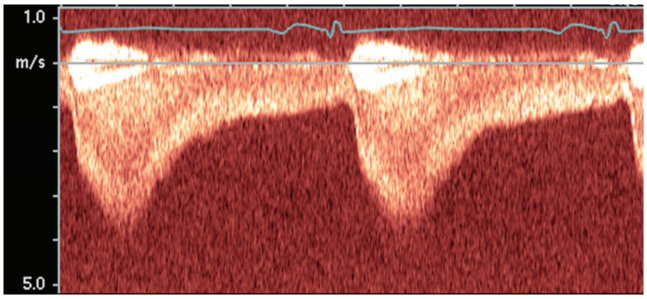


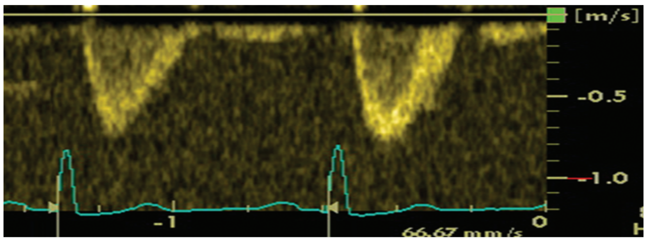
Figure 50.7

9. The pair of images in Figure 50.8 demonstrates spectral Doppler tracings from the same anatomic structure before (Panel A) and after a successful intervention (Panel B). What percutaneous procedure was performed?

A. Patent ductus arteriosus occlusion
B. Endovascular graft for type B aortic dissection
C. Atrial septal defect occlusion
D. Aortic coarctation repair
E. Aortic transection repair



A



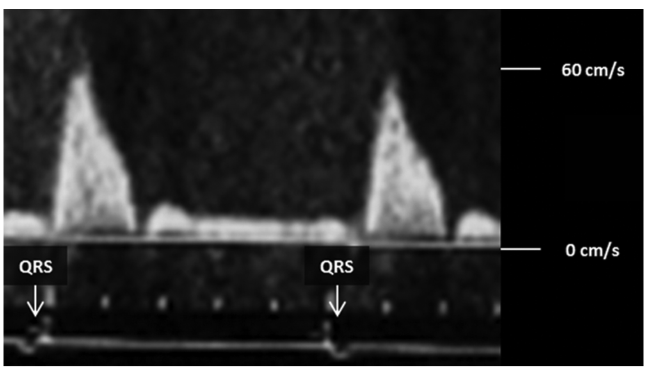
B

Figure 50.8

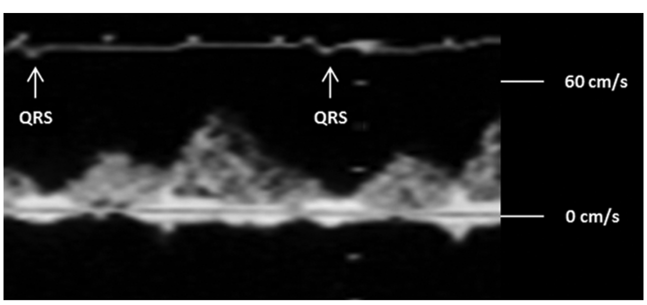
10. Panel A and Panel B of Figure 50.9 demonstrate spectral Doppler tracings from the vascular structure depicted in Panel C. Panel A is obtained before and Panel B after an intervention.

What procedure was performed?

A. Femoral artery pseudoaneurysm closure
B. Internal carotid artery stenting
C. Ligation of dialysis access atrioventricular shunt
D. Coronary artery bypass grafting
E. Balloon angioplasty of the renal artery

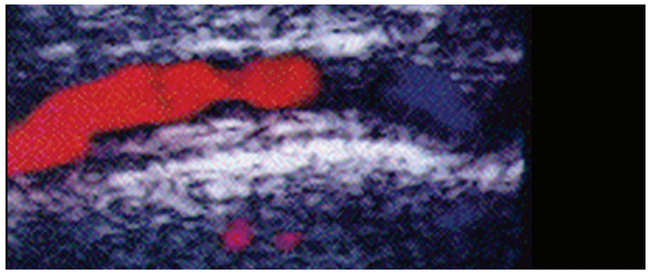


A



B

Figure 50.9



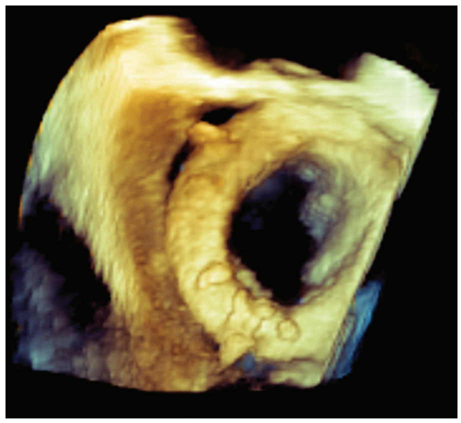
C

Figure 50.9 (*Continued*)

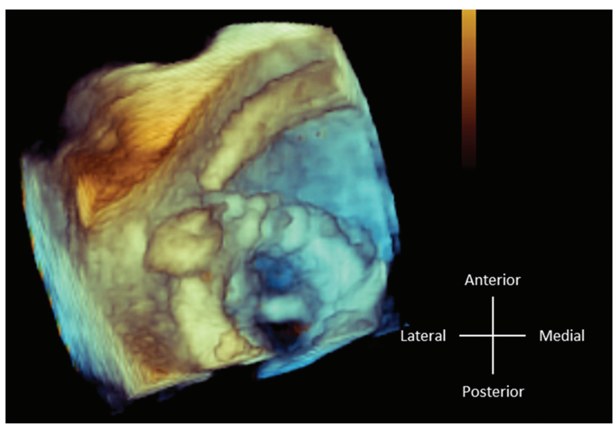
11. The pair of images in Figure 50.10 demonstrates the surgical view of the mitral valve before (Panel A) and after an intervention (Panel B).

What procedure was performed?

A. Mitral balloon valvuloplasty
B. Mitral valve clipping
C. The bioprosthetic valve replaced with mechanical one
D. Device closure of the left atrial appendage
E. Closure of the mitral paravalvular leak



A



B

Figure 50.10

12. The pair of images in Figure 50.11 demonstrates the same anatomic structure before (Panels A1 and A2 on the left) and after an intervention (Panels B1 and B2 on the right). Video 3 is obtained prior to the procedure and Video 4 after the procedure.

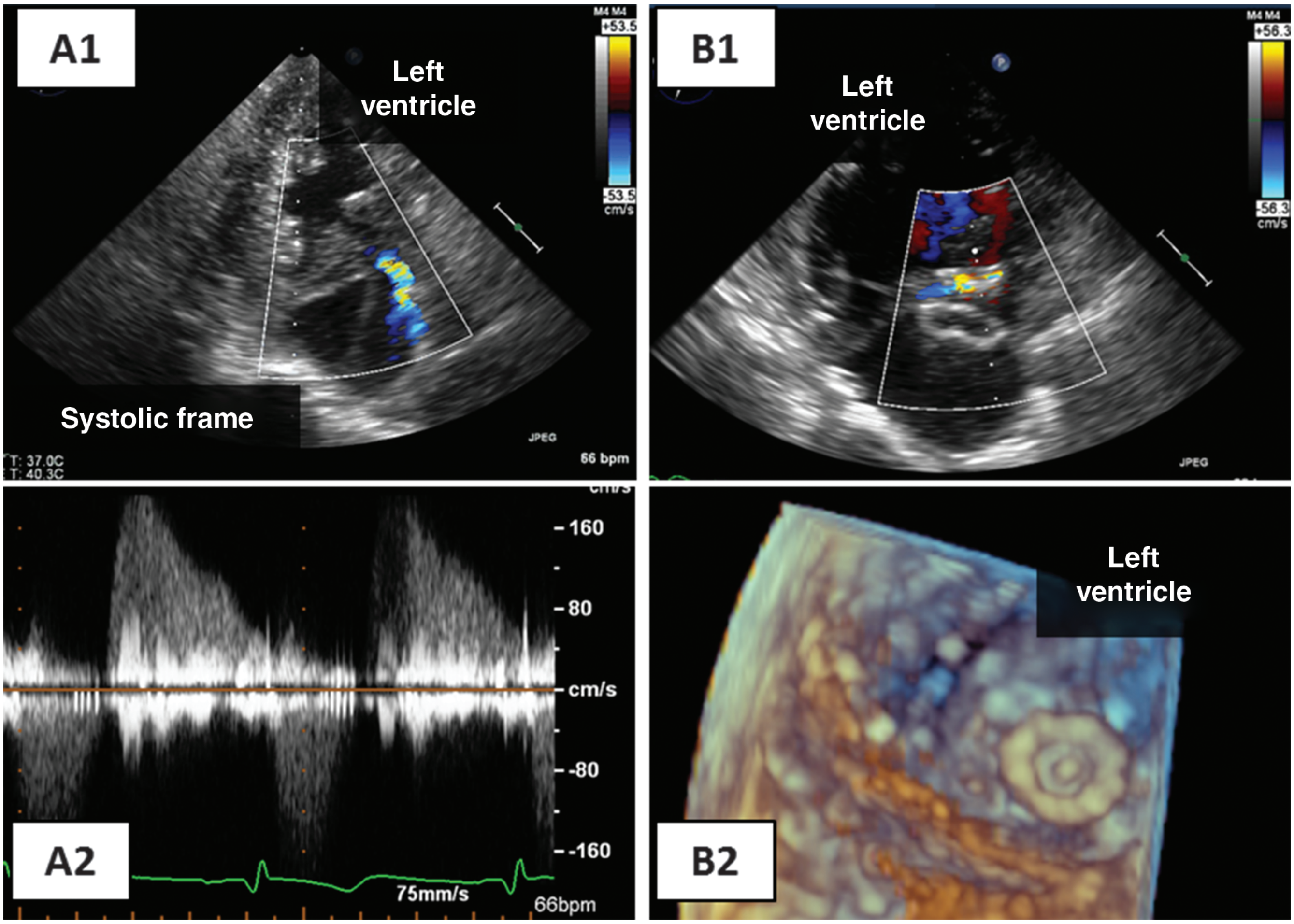
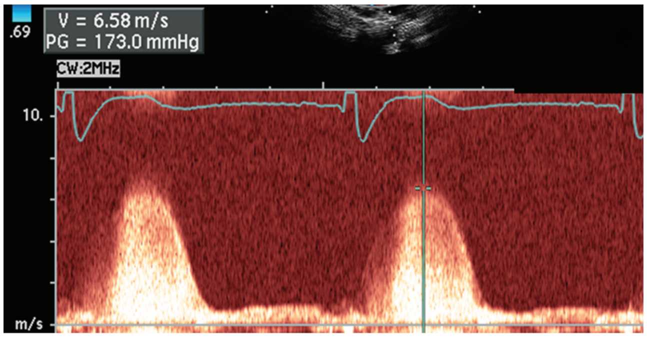


FIGURE 50.11

What procedure was performed?

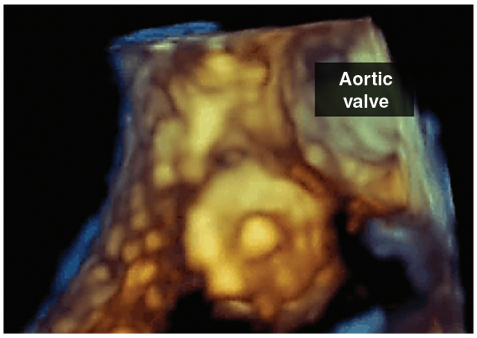
A. Ventricular septal defect closure
B. Left ventricular pseudoaneurysm closure
C. Insertion of the left ventricular assist device cannula
D. Transapical mitral commissurotomy
E. Ventricular septal ablation

13. The pair of images in FIGURE 50.12 demonstrates the same anatomic structure before (Panel A) and after an intervention (Panel B). VIDEO 5 demonstrates the lesion prior to the intervention.



A

FIGURE 50.12



B

FIGURE 50.12 (*Continued*)

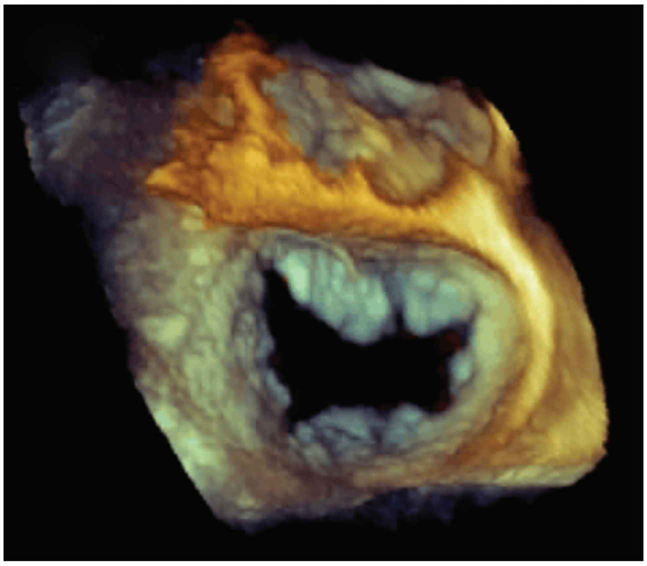
What procedure was performed?

A. Ventricular septal ablation
B. Insertion of the left ventricular assist device cannula
C. Left ventricular pseudoaneurysm closure
D. Ventricular septal defect closure
E. Transcutaneous aortic valve replacement

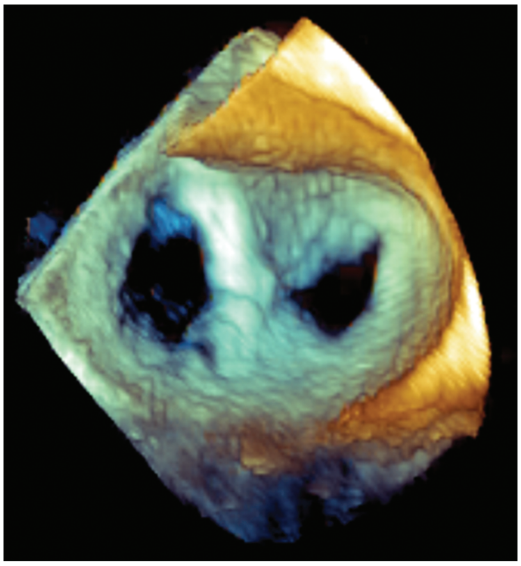
14. The pair of images in FIGURE 50.13 demonstrates the same anatomic structure before (Panel A) and after an intervention (Panel B). Both panels represent diastolic frames.

What procedure was performed?

A. Mitral valve clipping
B. Mitral balloon valvuloplasty
C. Atrial septal defect closure
D. Mechanical valve replaced with bioprosthetic one
E. Closure of the mitral paravalvular leak



A



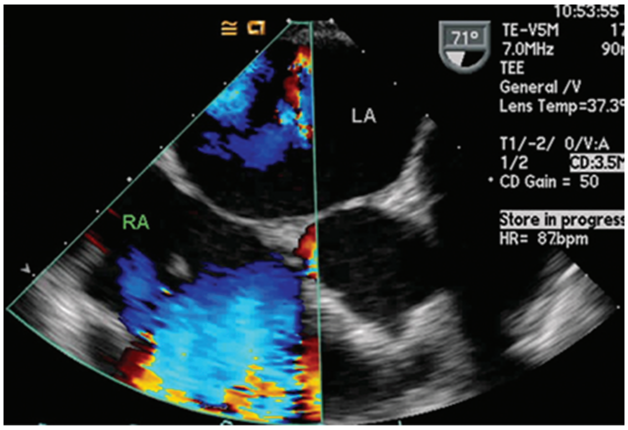
B

FIGURE 50.13

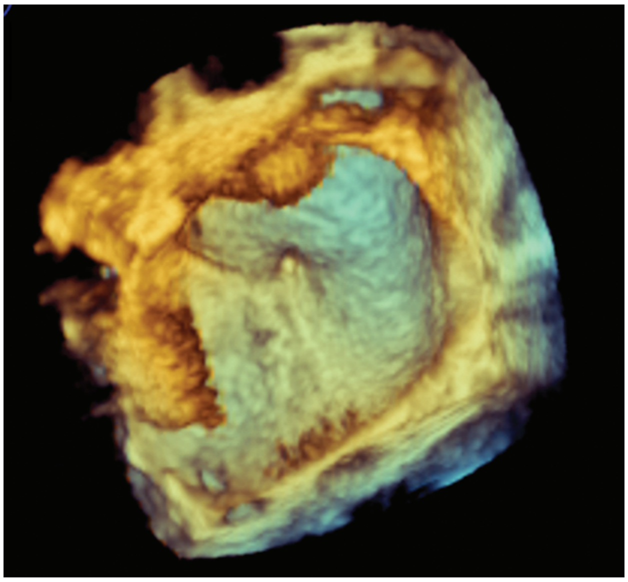
15. The pair of images in FIGURE 50.14 demonstrates a finding before (Panel A), during (Panel B), and after an intervention (Panel C). VIDEO 6 corresponds to Panel A and VIDEO 7.

Which of the following is the most likely explanation for the interval change?

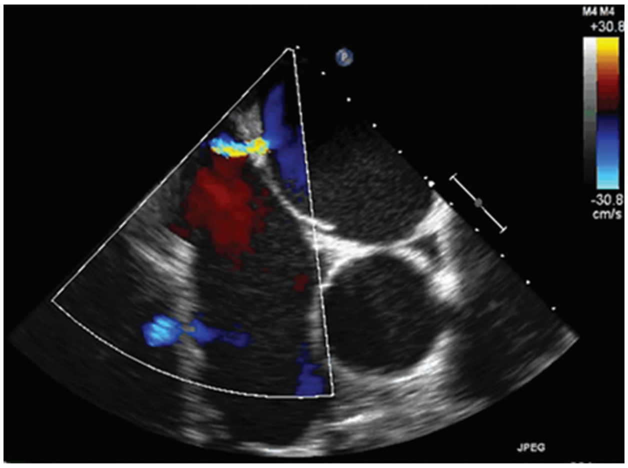
A. New primum atrial septal defect
B. Right atrial free wall perforation
C. Coronary sinus fistula
D. Transseptal puncture
E. Superior vena cava–type sinus venosus atrial septal defect



A



B



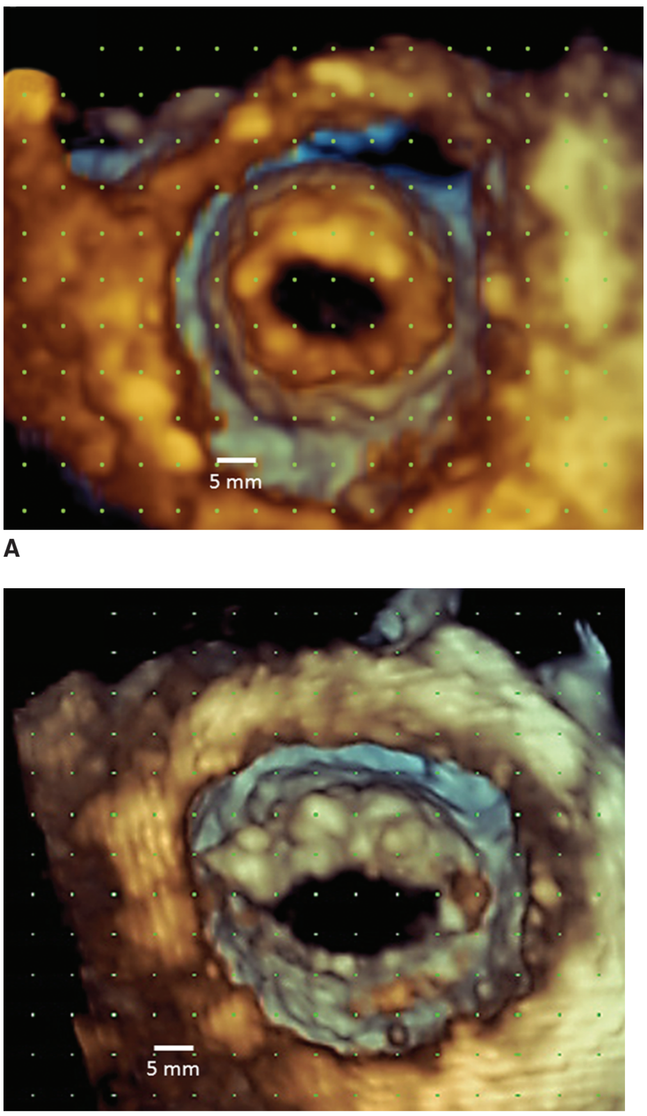
C

FIGURE 50.14

16. The pair of images in Figure 50.15 demonstrates the same anatomic structure before (Panel A) and after an intervention (Panel B). In each panel, the distance between dots on the grid is 5 mm.

Which procedure was performed?

A. Mitral valve clipping
B. Alfieri stitch
C. Mitral balloon valvuloplasty
D. Atrial septostomy
E. Closure of the mitral paravalvular leak



A

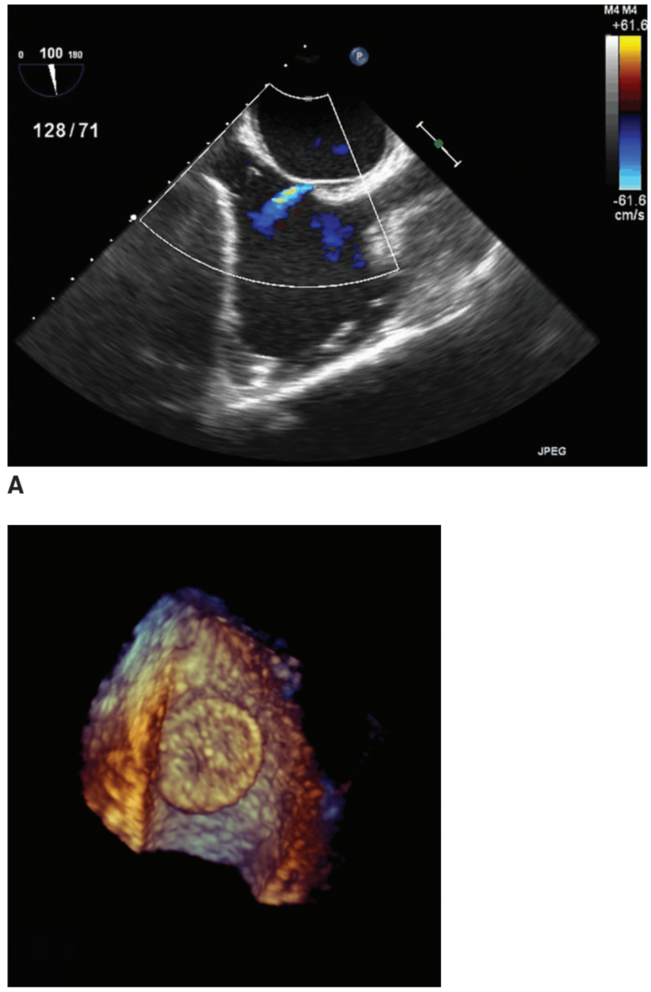
B

Figure 50.15

17. The pair of images in Figure 50.16 demonstrates the same anatomic structure before (Panel A, Video 8) and after an intervention (Panel B).

Which defect was treated during the procedure?

A. Sinus venosus atrial septal defect
B. Patent foramen ovale
C. Primum atrial septal defect
D. Secundum atrial septal defect
E. Unroofed coronary sinus



A

B

Figure 50.16

Answer 1: **B.** In the absence of contraindications, PMBV is recommended for symptomatic patients with moderate or severe mitral stenosis. In asymptomatic patients with moderate or severe mitral stenosis, PMBV is indicated when the pulmonary artery systolic pressure is >50 mm Hg at rest or >60 mm Hg with exercise or when there is new-onset atrial fibrillation.

PMBV may also be considered in a symptomatic patient with mild mitral stenosis (valve area >1.5 cm^2) when pulmonary artery systolic pressure is >60 mm Hg, pulmonary artery wedge pressure >25 mm Hg, or mean mitral valve gradient >15 mm Hg during exercise.

Contraindications for PMBV include unfavorable mitral valve score (>10 on a scale of 0 to 16), left heart thrombus, and moderate to severe mitral regurgitation. Thus, answers A, C, D, and E are incorrect.

Mitral valve score is based on mitral leaflet thickness, calcifications, and mobility as well as the thickness of the subvalvular apparatus. Each of the four categories is graded on a scale of 0 (normal) to 4 (severely abnormal). A normal mitral valve, thus, has a score of 0. The most unfavorable score is 16. PMBV is contraindicated when mitral score is >10. Significant thickening, calcifications, and immobility of mitral leaflets as well as significant thickening of the mitral subvalvular apparatus predispose mitral valve to leaflet tear, a known complication of PMBV that may lead to significant de novo mitral regurgitation.

Thrombus in the left atrium or left appendage is a contraindication for PMBV as catheters and other hardware used in PMBV can disrupt the thrombus and cause stroke or other forms of systemic thromboembolism.

Since de novo mitral regurgitation is a possible complication of PMBV, preexisting moderate or severe mitral regurgitation is a contraindication for PMBV. A combination of preexisting and de novo mitral regurgitation resulting from PMBV may lead to severe acute mitral regurgitation and cardiogenic shock, which may necessitate urgent mitral valve surgery.

Lutembacher syndrome, named after the French physician René Lutembacher (1884 to 1968), is a combination of atrial septal defect and mitral stenosis. Originally, Lutembacher syndrome referred to cases of congenital mitral stenosis with atrial septal defect; however, the term has since also been applied to atrial septal defect cases with acquired (rheumatic) mitral stenosis. The presence of an atrial septal defect (ASD) per se is not a contraindication for PMBV. On the contrary, percutaneous ASD closure can be performed concurrently with PMBV in appropriate patients. Thus, the correct answer is B.

Q1 However, in the presence of atrial septal defect, the pressure half-time method may lead to overestimation of the mitral valve area as discussed in chapters dealing with the assessment of mitral stenosis.

Suggested Reading

Bonow RO, Carabello BA, Chatterjee K, et al. 2008 focused update incorporated into the ACC/AHA 2006 guidelines for the management of patients with valvular heart disease: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to revise the 1998 guidelines for the management of patients with valvular heart disease). Endorsed by the Society of Cardiovascular Anesthesiologists, Society for Cardiovascular Angiography and Interventions, and Society of Thoracic Surgeons. *J Am Coll Cardiol* 2008;52(13):e1–e142.

Inoue K, Owaki T, Nakamura T, et al. Clinical application of transvenous mitral commissurotomy by a new balloon catheter. *J Thorac Cardiovasc Surg* 1984;87(3):394–402.

Joseph G, Abhaichand Rajpal K, Kumar KP. Definitive percutaneous treatment of Lutembacher's syndrome. *Catheter Cardiovasc Interv* 1999;48(2):199–204.

Q2 Kronzon I, Saric M, Lang RM. Chapter 9: Mitral stenosis. In: Lang R, Goldstein SA, Kronzon I, et al., eds. *Dynamic Echocardiography: A Case-Based Approach*. 1st ed. Springer, 2010:38–45.

Lutembacher R. De la sténose mitrale avec communication interauriculaire. *Archives des maladies du coeur et des vaisseaux* 1916;9:237–260.

Wilkins GT, Weyman AE, Abascal VM, et al. Percutaneous balloon dilatation of the mitral valve: an analysis of echocardiographic variables related to outcome and the mechanism of dilation. *Br Heart J* 1988;60:299–308.

***Answer 2:* B.** In the United States, ASD occluders are currently approved only for secundum ASDs. The patient has findings typical of a secundum ASD.

Contraindications for device closure of a secundum ASD include ASD diameter of >38 mm and insufficiency of the aortic rim (<3 mm) or other ASD rims (<5 mm). In addition, device closure should not be performed

- In patients with preexisting intracardiac thrombus (since thrombus can be dislodged by catheters and other hardware used in percutaneous ASD closure)
- In patients who have contraindications to antiplatelet therapy (since antiplatelet therapy is given for several weeks post–device implantation)

The patient's age is not a contraindication for device closure of ASD.

Since the patient has a secundum ASD with a diameter of 30 mm and a sufficient aortic rim, her ASD is amenable to percutaneous ASD closure. Thus, the correct answer is B.

Suggested Reading

Dehghani H, Boyle AJ. Percutaneous device closure of secundum atrial septal defect in older adults. *Am J Cardiovasc Dis* 2012;2(2):133–142.

Saric M, Perk G, Purgess J, et al. Imaging atrial septal defects by real-time 3D transesophageal echocardiography: step-by-step approach. *J Am Soc Echocardiogr* 2010;23(11):1128–1135.

Warnes CA, Williams RG, Bashore TM, et al. ACC/AHA 2008 guidelines for the management of adults with Congenital Heart Disease: Executive Summary: a report of the American College of Cardiology/American Heart Association task force on practice guidelines. *Circulation* 2008;118:2395–2451.

***Answer 3:* E.** In the United States, percutaneous ASD occluders are currently approved only for secundum ASDs.

The patient has findings typical of a primum ASD, which is located in the portion of the interatrial septum adjacent to the atrioventricular (tricuspid and mitral) valves as shown in Panel A. Primum ASD is typically part of the endocardial cushion defect spectrum and may be associated with cleft mitral valve and partial or complete atrioventricular canal defect. This patient has a cleft mitral valve as shown in Panel B.

Because of their location and associated mitral valve pathology, primum ASDs are not amenable to percutaneous closure, and appropriate patients with such defects should be referred for surgical closure of ASD (as well as repair of associated anomalies). Given the primum ASD and cleft mitral valve, the correct answer is E.

Patient has normal pulmonary artery systolic pressure. In this patient, the right ventricular systolic pressure can be calculated as the sum of the peak systolic gradient of the tricuspid regurgitant jet (25 mm Hg) and the right atrial pressure (3 mm Hg). Since the patient does not have pulmonic stenosis, pulmonary artery systolic pressure is the same as the right ventricular systolic pressure, that is, 28 mm Hg.

Right heart dilatation is a hallmark of all ASDs with significant left-to-right shunt; right heart dilatation is an indication rather than a contraindication for ASD closure.

Suggested Reading

Perk G, Ruiz C, Saric M, et al. Real-time three-dimensional transesophageal echocardiography in transcutaneous, catheter-based procedures for repair of structural heart diseases. *Curr Cardiovasc Imaging Rep* 2009;2(5):363–374.

Warnes CA, Williams RG, Bashore TM, et al. ACC/AHA 2008 guidelines for the management of adults with Congenital Heart Disease: Executive Summary: a report of the American College of Cardiology/American Heart Association task force on practice guidelines. *Circulation* 2008;118:2395–2451.

***Answer 4:* A.** The so-called surgical view of the mitral valve shows the mitral valve the way surgeons see the valve (see Fig. 50.17). In this view, using the clockface analogy, the aortic valve is located at 12 o'clock, the left atrial appendage at 9 o'clock, and the interatrial septum at 3 o'clock.

The 3D image structure marked by arrow in this patient is the left atrial appendage. Thus, the correct answer is A.

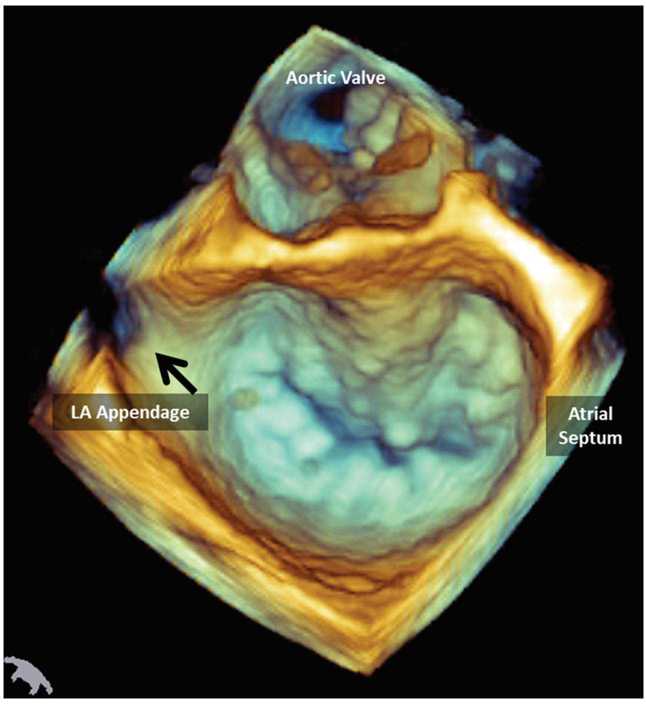


Figure 50.17

Suggested Reading

Q3

Garcia Fernandez MA, Perk G, Saric M, et al. Chapter 12: Real-time three-dimensional transesophageal echocardiography for guidance of catheter based interventions. In: Badano LP, Lang RM, Zamorano JL, eds. *Textbook of Real-Time Three-Dimensional Echocardiography*. 1st ed. Springer, 2011:121–134.

Perk G, Ruiz C, Saric M, et al. Real-time three-dimensional transesophageal echocardiography in transcutaneous, catheter-based procedures for repair of structural heart diseases. *Curr Cardiovasc Imaging Rep* 2009;2(5):363–374.

***Answer 5:* E.** Panel A demonstrates a Watchman device placed into the LA appendage at appropriate depth; the device is neither too deep nor too superficial relative to the LA appendage ostium. Thus, answer A is incorrect.

Percutaneous exclusion of the LA appendage (LAA) using the so-called Watchman device has been shown in a randomized clinical trial to be noninferior to chronic warfarin treatment in prevention of systemic thromboembolism in patients with atrial fibrillation (1). Thus, percutaneous LAA exclusion might provide an alternative strategy to chronic warfarin therapy for stroke prophylaxis in patients with nonvalvular atrial fibrillation. Thus, answer B is incorrect.

Adult patients with nonvalvular atrial fibrillation were eligible for inclusion in this multicenter, randomized noninferiority trial if they had at least one of the following: previous stroke or transient ischemic attack, congestive heart failure, or diabetes, hypertension, or were 75 years or older.

After implantation of the Watchman device, all patients are expected to take warfarin therapy for 6 weeks, clopidogrel for 6 months, and aspirin for life. Thus, answer C is incorrect.

LAA thrombus is a contraindication of implantation of an LAA exclusion device as the thrombus may be dislodged during the procedure and cause an acute thromboembolic event. Thus, answer D is incorrect.

Other exclusion criteria for Watchman device placement include contraindications to warfarin, comorbidities other than atrial fibrillation that require chronic warfarin use, LAA thrombus, a patent foramen ovale with atrial septal aneurysm and right-to-left shunt, mobile aortic atheroma, and symptomatic carotid artery disease.

Unfortunately, there is a large (>5 mm) residual peridevice leak seen in Panel B. Thus, the correct answer is E. This patient would be expected to continue warfarin therapy as there was incomplete exclusion of the LA appendage.

Reference

1. Holmes DR, Reddy VY, Turi ZG, et al.; PROTECT AF Investigators. *Percutaneous closure of the left atrial appendage versus warfarin therapy for prevention of stroke in patients with atrial fibrillation: a randomised non-inferiority trial. Lancet* 2009;374(9689):534–542.

Suggested Reading

Garcia Fernandez MA, Perk G, Saric M, et al. Chapter 12: Real-time three-dimensional transesophageal echocardiography for guidance of catheter based interventions. In: Badano LP, Lang RM, Zamorano JL, eds. *Textbook of Real-Time Three-Dimensional Echocardiography*. 1st ed. Springer, 2011:121–134.

Perk G, Biner S, Kronzon I, et al. Catheter-based left atrial appendage occlusion procedure—role of echocardiography. *Eur Heart J Cardiovasc Imaging* 2012;13(2):132–138.

Perk G, Ruiz C, Saric M, et al. Real-time three-dimensional transesophageal echocardiography in transcutaneous, catheter-based procedures for repair of structural heart diseases. *Curr Cardiovasc Imaging Rep* 2009;2(5):363–374.

***Answer 6:* C.** The so-called surgical view of the mitral valve (see Fig. 50.18) shows the mitral valve the way surgeons see the valve. In this view using the clockface analogy, the aortic valve is located at 12 o'clock, the left atrial appendage at 9 o'clock, and the interatrial septum at 3 o'clock.

The mitral leaflet adjacent to the aortic valve is the anterior mitral leaflet; the other leaflet is the posterior mitral leaflet. The lateral commissure is located at approximately 10 o'clock and the medical commissure at approximately 2 o'clock.

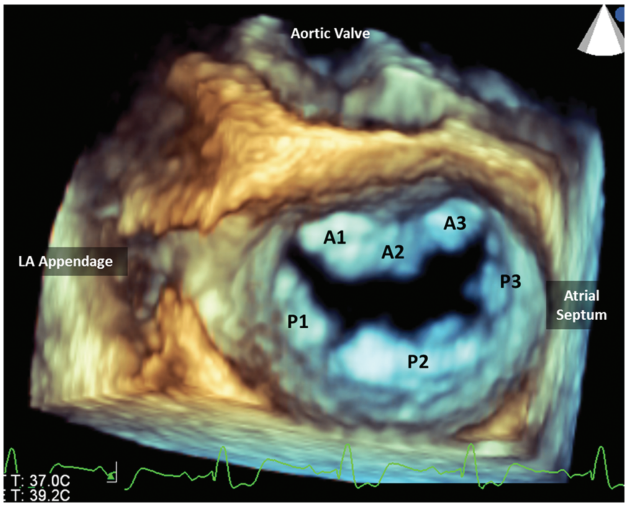


Figure 50.18

Each leaflet typically consists of three scallops, which are numbered in this view from left to right as 1, 2, and 3. Thus, scallop 1 of the either mitral leaflet is located laterally (adjacent to the left atrial appendage), while scallop 3 is located medially (close to the interatrial septum).

The arrow points to the P1 scallop of the posterior mitral leaflet. Thus, the correct answer is C.

Suggested Reading

Garcia Fernandez MA, Perk G, Saric M, et al. Chapter 12: Real-time three-dimensional transesophageal echocardiography for guidance of catheter based interventions. In: Badano LP, Lang RM, Zamorano JL, eds. *Textbook of Real-Time Three-Dimensional Echocardiography*. 1st ed. Springer, 2011:121–134.

Perk G, Ruiz C, Saric M, et al. Real-time three-dimensional transesophageal echocardiography in transcutaneous, catheter-based procedures for repair of structural heart diseases. *Curr Cardiovasc Imaging Rep* 2009;2(5):363–374.

***Answer 7:* B.** The so-called surgical view of the mitral valve shows the mitral valve the way surgeons see the valve. In this view using the clockface analogy, the aortic valve is located at 12 o'clock, the left atrial appendage at 9 o'clock, and the interatrial septum at 3 o'clock.

In this patient, the paravalvular leak is located at approximately 4 o'clock. Thus, the correct answer is B.

Suggested Reading

Garcia Fernandez MA, Perk G, Saric M, et al. Chapter 12: Real-time three-dimensional transesophageal echocardiography for guidance of catheter based interventions. In: Badano LP, Lang RM, Zamorano JL, eds. *Textbook of Real-Time Three-Dimensional Echocardiography*. 1st ed. Springer, 2011:121–134.

Perk G, Ruiz C, Saric M, et al. Real-time three-dimensional transesophageal echocardiography in transcutaneous, catheter-based procedures for repair of structural heart diseases. *Curr Cardiovasc Imaging Rep* 2009;2(5):363–374.

***Answer 8:* C.** Panel A demonstrates severe senile calcific aortic stenosis of a trileaflet valve. Panel on B shows a 3D TEE appearance of transcutaneous aortic valve replacement with a CoreValve. Both are viewed from the ascending aorta side of the valve.

In the United States, two percutaneous aortic valves are being used: Medtronic CoreValve and Edwards Sapien valve. The CoreValve consists of a nitinol wire mesh and bioprosthetic aortic valve leaflets. In Panel B, a crown of CoreValve nitinol wires is seen along the inside perimeter of the ascending aorta; the thin line inside the lumen represents bioprosthetic leaflets. Thus, the correct answer is C.

Prior to transcutaneous aortic valve replacement, aortic balloon valvuloplasty is performed. Immediately thereafter, transcutaneous prosthetic aortic valve is implanted. Thus, answer A is incorrect.

Panel B does not have an appearance of either a surgically implanted bioprosthetic or a mechanical prosthesis. Thus, answer B is incorrect.

Surgically implanted aortic bioprostheses typically have three struts. No struts are seen in Panel A, which demonstrates a native aortic valve. Furthermore, valve-in-valve implantation is not a currently approved indication for the use of transcutaneous aortic valves. Thus, answer D is incorrect.

Panel B may bear some resemblance to an ascending aortic endograft. However, Panel A demonstrates no aortic dissection; instead, it shows severe native aortic stenosis. Thus, answer E is incorrect.

Suggested Reading

Garcia Fernandez MA, Perk G, Saric M, et al. Chapter 12: Real-time three-dimensional transesophageal echocardiography for guidance of catheter based interventions. In: Badano LP, Lang RM, Zamorano JL, eds. *Textbook of Real-Time Three-Dimensional Echocardiography*. 1st ed. Springer, 2011:121–134.

Perk G, Ruiz C, Saric M, et al. Real-time three-dimensional transesophageal echocardiography in transcutaneous, catheter-based procedures for repair of structural heart diseases. *Curr Cardiovasc Imaging Rep* 2009;2(5):363–374.

***Answer 9:* D.** Panel A demonstrates typically spectral Doppler tracings of a patient with severe coarctation of the aorta. Note the very high peak systolic velocity (almost 4 m/s) as well as the abnormal persistence of antegrade flow during diastole. After percutaneous balloon dilation of the aortic coarctation, the spectral Doppler flow in the descending thoracic aorta normalizes. Note the normal peak systolic velocity (in this patient less than 1 m/s) as well as the normal absence of holodiastolic antegrade flow. Thus, the correct answer is D.

Panel A may bear some resemblance to systolic and diastolic antegrade flow across a patent ductus arteriosus. However, a successful percutaneous closure of PDA would result in a complete cessation of flow across the PDA, which is not the case in Panel B. Thus, answer A is incorrect.

Prior to intervention, neither type B aortic dissection nor the atrial septal defect is characterized by such high systolic and diastolic flow velocities shown in Panel A. Thus, neither answer B nor D is correct.

Aortic transection, which typically results from a deceleration injury, is a medical emergency. It requires immediate surgical rather than percutaneous intervention. Thus, answer E is incorrect.

Suggested Reading

Garcia Fernandez MA, Perk G, Saric M, et al. Chapter 12: Real-time three-dimensional transesophageal echocardiography for guidance of catheter based interventions. In: Badano LP, Lang RM, Zamorano JL, eds. *Textbook of Real-Time Three-Dimensional Echocardiography*. 1st ed. Springer, 2011:121–134.

Perk G, Ruiz C, Saric M, et al. Real-time three-dimensional transesophageal echocardiography in transcutaneous, catheter-based procedures for repair of structural heart diseases. *Curr Cardiovasc Imaging Rep* 2009;2(5):363–374.

Q4 Saric M, Kronzon I. Chapter 110: Coarctation of the aorta. In: Lang R, Goldstein SA, Kronzon I, et al., eds. *Dynamic Echocardiography: A Case-Based Approach*. 1st ed. Springer, 2010:459–461.

***Answer 10:* D.** Panel C demonstrates a color Doppler recording from the left internal mammary artery (LIMA). The flow velocity pattern of a native (nongrafted) LIMA is shown in Panel A. Native (nongrafted) LIMA demonstrates the typical high-resistance flow of an artery that supplies skeletal muscles; note that antegrade flow occurs primarily in systole and that there is very little antegrade runoff during diastole.

Panel B demonstrates a change of flow velocity pattern after LIMA is grafted to the left descending coronary artery during coronary artery bypass surgery. LIMA now assumes the flow velocity pattern that is typically seen in the left coronary artery: (a) Significant antegrade flow occurs in both systole and diastole, and (b) diastolic flow is more prominent than the systolic one. Thus, the correct answer is D.

Femoral pseudoaneurysm has a characteristic to-and-fro flow (antegrade in systole, retrograde in diastole). Since this is not seen in Panel A, answer A is incorrect.

Post–successful stenting, internal carotid artery flow velocity pattern would have normalized, that is, it would have assumed a low-resistance flow velocity pattern characterized by a combination of a predominantly systolic antegrade flow and a significant antegrade runoff during diastole. Since this is not seen in Panel B, answer B is incorrect.

Dialysis access shunt, being an atrioventricular shunt, would have demonstrated high-velocity antegrade flow during both systole and diastole at baseline. Since this is not seen in Panel A, answer C is incorrect.

Post–successful balloon angioplasty, renal artery flow velocity pattern would have normalized, that is, it would have assumed a low-resistance flow velocity pattern characterized by a combination of predominantly systolic antegrade flow and a significant antegrade runoff during diastole. Since this is not seen in Panel B, answer E is incorrect.

Suggested Reading

Kasliwal R, Mittal S, Shrivastava S, et al. Echocardiography in minimally invasive direct coronary artery bypass. *Echocardiography* 1999;16(6):603–610.

***Answer 11:* E.** Both Panel A and Panel B demonstrate the left atrial aspect of a bioprosthetic mitral valve in the so-called surgical view. In this view using the clockface analogy, the aortic valve is located at 12 o'clock, the left atrial appendage at 9 o'clock, and the interatrial septum at 3 o'clock.

Panel A demonstrates a paravalvular dehiscence at approximately 11 o'clock. The dehiscence (seen on color Doppler as a paravalvular mitral regurgitant leak) is closed percutaneously with a vascular plug seen in Panel B lateral to the mitral bioprosthetic sewing ring at 11 o'clock. In Panel B, the catheter used to deliver the plug is still seen. The catheter was subsequently removed, and the procedure was completed. Thus, the correct answer is E.

Percutaneous mitral balloon valvuloplasty of a stenosed bioprosthetic valve is done infrequently. Had that been the procedure, Panel B would have shown a valvuloplasty balloon inside the sewing ring of the mitral bioprosthesis. Thus, answer A is incorrect.

Mitral valve clipping is a percutaneous procedure used to treat native (not prosthetic) mitral valve regurgitation. It resembles the surgical Alfieri stitch; the clip is typically placed between A2 and P2 scallops of the native mitral valve. Thus, answer B is incorrect.

Both Panel A and Panel B show the typical sewing ring of mitral bioprosthetic ring. Since there is no change in the appearance of the mitral prosthesis from Panel A to Panel B, answer C is incorrect.

Device closure of the left atrial appendage is accomplished by a percutaneous placement of a plug in the ostium of the left atrial appendage. In Panel A and B, the native left atrial appendage with no plug is seen at approximately 9 o'clock. Thus, answer E is incorrect.

Suggested Reading

Garcia Fernandez MA, Perk G, Saric M, et al. Chapter 12: Real-time three-dimensional transesophageal echocardiography for guidance of catheter based interventions. In: Badano LP, Lang RM, Zamorano JL, eds. *Textbook of Real-Time Three-Dimensional Echocardiography*. 1st ed. Springer, 2011:121–134.

Perk G, Biner S, Kronzon I, et al. Catheter-based left atrial appendage occlusion procedure – role of echocardiography. *Eur Heart J Cardiovasc Imaging* 2012;13(2):132–138.

***Answer 12:* B.** Panel A1 demonstrates a systolic color flow that leaves the left ventricle during systole. Panel A2 further characterizes the flow and demonstrates the to-and-fro pattern characteristic of a pseudoaneurysm (the flow exits the left ventricle into the pseudoaneurysm during systole and returns into the left ventricle from the pseudoaneurysm during diastole). VIDEO 1 demonstrates the to-and-fro flow on color Doppler imaging.

Based on Panels A1 and A2, as well as VIDEO 3, one can establish the diagnosis of left ventricular pseudoaneurysm in this patient with recent infarction of the anterior wall. Panels B1 and B2, as well as VIDEO 4, demonstrate that the left ventricular pseudoaneurysm was closed percutaneously with a closure device. Thus, the correct answer is B.

Ventricular septal defect (VSD) would have had a different flow velocity pattern in Panel A2. Typical VSD does not show a to-and-fro flow velocity pattern. Instead, in an uncomplicated VSD, the flow from the left ventricle to the right ventricle occurs almost exclusively during systole albeit a small amount of flow into the right ventricle occurs during diastole as well. Thus, answer A is incorrect.

Panel B2 demonstrates a closure device. An inflow cannula of a left ventricular assist device is typically placed in the left ventricular apex and would have demonstrated a central lumen in Panel B2. Thus, answer C is incorrect.

Mitral valve is not seen in any of the attached still images or the videos. Thus, answer D is incorrect.

During ventricular septal ablation, alcohol is injected into a septal coronary artery branch. Panel A2 is not consistent with a coronary artery flow (flow in the coronary arteries is antegrade in systole and diastole). Thus, answer E is incorrect.

Suggested Reading

Dudiy Y, Jelnin V, Einhorn BN, et al. Percutaneous closure of left ventricular pseudoaneurysm. *Circ Cardiovasc Interv* 2011;4(4):322–326.

Garcia Fernandez MA, Perk G, Saric M, et al. Chapter 12: Real-time three-dimensional transesophageal echocardiography for guidance of catheter based interventions. In: Badano LP, Lang RM, Zamorano JL, eds. *Textbook of Real-Time Three-Dimensional Echocardiography*. 1st ed. Springer, 2011:121–134.

Perk G, Ruiz C, Saric M, et al. Real-time three-dimensional transesophageal echocardiography in transcutaneous, catheter-based procedures for repair of structural heart diseases. *Curr Cardiovasc Imaging Rep* 2009;2(5):363–374.

***Answer 13:* D.** Panel A demonstrates the typical spectral Doppler flow velocity pattern of uncomplicated VSD. Note that the flow from the left ventricle to the right ventricle occurs almost exclusively during systole albeit a small amount of flow into the right ventricle occurs during diastole as well. The VSD was subsequently closed with a percutaneous closure device. The left ventricular side of the VSD closure device is seen in Panel B. Thus, answer D is incorrect.

During ventricular septal ablation, alcohol is injected into a septal coronary artery branch. Panel A2 is not consistent with a coronary artery flow (flow in the coronary arteries is antegrade in systole and diastole). Thus, answer A is incorrect.

An inflow cannula of a left ventricular assist device is (a) typically placed in the left ventricular apex and (b) would have demonstrated a central lumen in Panel B. Since neither is the case, answer B is incorrect.

Flow velocity pattern in Panel A is not consistent with a left ventricular pseudoaneurysm. Pseudoaneurysms have a characteristic to-and-fro flow pattern (flow leaves the left ventricle into the pseudoaneurysm during systole and returns from the pseudoaneurysm into the left ventricle during diastole). Thus, answer C is incorrect.

Aortic stenosis is characterized by an elevated systolic gradient. However, the systolic antegrade flow in aortic stenosis is not holosystolic but rather occurs only during the ejection phase. In contrast, the systolic flow in Panel A is holosystolic. In other words, the onset of aortic stenosis flow occurs after QRS on the ECG; the flow of VSD starts at QRS on the ECG. Furthermore, Panel B demonstrates a device adjacent to and not in the aortic valve. Thus, answer E is incorrect.

Suggested Reading

Garcia Fernandez MA, Perk G, Saric M, et al. Chapter 12: Real-time three-dimensional transesophageal echocardiography for guidance of catheter based interventions. In: Badano LP, Lang RM, Zamorano JL, eds. *Textbook of Real-Time Three-Dimensional Echocardiography*. 1st ed. Springer, 2011:121–134.

Perk G, Ruiz C, Saric M, et al. Real-time three-dimensional transesophageal echocardiography in transcutaneous, catheter-based procedures for repair of structural heart diseases. *Curr Cardiovasc Imaging Rep* 2009;2(5):363–374.

Saric M, Kronzon I. Chapter 107: Ventricular septal defect and Eisenmenger syndrome. In: Lang R, Goldstein SA, Kronzon I, et al., eds. *Dynamic Echocardiography: A Case-Based Approach*. 1st ed. Springer, 2010:446–450. Q5

***Answer 14:* A.** Both Panels A and B demonstrate the left atrial aspect of a native mitral valve in the so-called surgical view. In this view using the clockface analogy, the aortic valve is located at 12 o'clock, the left atrial appendage at 9 o'clock, and the interatrial septum at 3 o'clock.

Panel B demonstrates the characteristic appearance of a mitral valve clip between A2 and P2 scallops. This percutaneous procedure is equivalent to the surgical Alfieri stitch and is used to treat severe degenerative or functional mitral regurgitation. Thus, the correct answer is A.

Percutaneous mitral balloon valvuloplasty is the treatment of choice for rheumatic mitral stenosis. Panel A does not demonstrate mitral stenosis. Furthermore, the mitral valve would have still had one diastolic orifice postvalvuloplasty. In contrast, Panel B demonstrates two separate diastolic orifices; this is a typical finding post–mitral clipping. Thus, answer B is incorrect.

The atrial septum is well seen at 3 o'clock in Panel B. No device associated with the atrial septum is seen. Thus, answer C is incorrect.

Both Panels A and B demonstrate a native (nonprosthetic) mitral valve. Thus, neither answer D nor answer E is correct.

Suggested Reading

Garcia Fernandez MA, Perk G, Saric M, et al. Chapter 12: Real-time three-dimensional transesophageal echocardiography for guidance of catheter based interventions. In: Badano LP, Lang RM, Zamorano JL, eds. *Textbook of Real-Time Three-Dimensional Echocardiography*. 1st ed. Springer, 2011:121–134.

Perk G, Ruiz C, Saric M, et al. Real-time three-dimensional transesophageal echocardiography in transcutaneous, catheter-based procedures for repair of structural heart diseases. *Curr Cardiovasc Imaging Rep* 2009;2(5):363–374.

***Answer 15:* D.** Panel A and Video 6 demonstrate an intact interatrial septum on 2D TEE color Doppler. Panel B shows the left atrial aspect of the interatrial septum on 3D TEE during transseptal puncture. Panel C and Video 7 demonstrate a small iatrogenic atrial septal defect (ASD) in the posterior portion of the atrial septum, a residual of the transseptal puncture.

Transseptal puncture is an obligatory step in many percutaneous procedures involving the left heart (such as percutaneous mitral balloon valvuloplasty, left atrial appendage occlusion, and paravalvular mitral prosthetic leak closure). In this patient, a deflated balloon used in mitral valvuloplasty was delivered first transvenously into the right atrium and then across the previously created transseptal puncture into the left atrium and across the mitral valve. After removal of all transseptal catheters, it is not unusual to see a small residual iatrogenic atrial septal defect. Thus, the correct answer is D.

The location of the ASD in the posterior portion of the atrial septum seen in Panel B is not consistent with a primum ASD. Primum ASDs are located near the atrioventricular (mitral and tricuspid) valves. Thus, answer A is incorrect.

Panel B demonstrates puncture of the interatrial septum and not of the right atrial free wall. Thus, answer B is incorrect.

The location of the ASD in the posterior portion of the atrial septum seen in Panel B is not consistent with the anatomic location of either the coronary sinus or the superior vena cava. Thus, neither answer D nor answer E is correct.

Suggested Reading

Garcia Fernandez MA, Perk G, Saric M, et al. Chapter 12: Real-time three-dimensional transesophageal echocardiography for guidance of catheter based interventions. In: Badano LP, Lang RM, Zamorano JL, eds. *Textbook of Real-Time Three-Dimensional Echocardiography*. 1st ed. Springer, 2011:121–134.

Perk G, Ruiz C, Saric M, et al. Real-time three-dimensional transesophageal echocardiography in transcutaneous, catheter-based procedures for repair of structural heart diseases. *Curr Cardiovasc Imaging Rep* 2009;2(5):363–374.

Saric M, Perk G, Purgess J, et al. Imaging atrial septal defects by real-time 3D transesophageal echocardiography: step-by-step approach. *J Am Soc Echocardiogr* 2010;23(11):1128–1135.

***Answer 16:* C.** Both panels show the 3D transesophageal echocardiographic appearance of a rheumatic mitral valve from the left ventricular perspective. Panel A demonstrates severe rheumatic mitral stenosis with a valve area of approximately 0.6 cm^2. Post–mitral balloon valvuloplasty, the mitral valve area in Panel B doubled to approximately 1.2 cm^2. Thus, the correct answer is C.

In mitral valve clipping or after Alfieri stitch, the mitral orifice is divided into two or more holes due to placement of either a clip or a stitch typically between A2 and P2 scallops of the mitral valve. Since in both Panel A and Panel B there is single mitral orifice, neither answer A nor answer B is correct.

Atrial septostomy is a creation of a de novo large atrial septal defect to treat cyanotic congenital heart disease such as the D-transposition of the great arteries. Historically, atrial septostomy was the very first percutaneous procedure for the treatment of structural heart disease. It was introduced in 1966 by the American physician William Rashkind (1922 to 1986) at the Children's Hospital of Philadelphia. Neither Panel A nor Panel B has the appearance of an atrial septal defect. Thus, answer D is incorrect.

Both Panel A and Panel B show native mitral valve. Paravalvular leaks occur with prosthetic mitral valves. Thus, answer E is incorrect.

Suggested Reading

Bonow RO, Carabello BA, Chatterjee K, et al. 2008 focused update incorporated into the ACC/AHA 2006 guidelines for the management of patients with valvular heart disease: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to revise the 1998 guidelines for the management of patients with valvular heart disease). Endorsed by the Society of Cardiovascular Anesthesiologists, Society for Cardiovascular Angiography and Interventions, and Society of Thoracic Surgeons. *J Am Coll Cardiol* 2008;52(13):e1–e142.

Garcia Fernandez MA, Perk G, Saric M, et al. Chapter 12: Real-time three-dimensional transesophageal echocardiography for guidance of catheter based interventions. In: Badano LP, Lang RM, Zamorano JL, eds. *Textbook of Real-Time Three-Dimensional Echocardiography*. 1st ed. Springer, 2011:121–134.

Inoue K, Owaki T, Nakamura T, et al. Clinical application of transvenous mitral commissurotomy by a new balloon catheter. *J Thorac Cardiovasc Surg* 1984;87(3):394–402.

Perk G, Ruiz C, Saric M, et al. Real-time three-dimensional transesophageal echocardiography in transcutaneous, catheter-based procedures for repair of structural heart diseases. *Curr Cardiovasc Imaging Rep* 2009;2(5):363–374.

Rashkind WJ, Miller WW. Creation of an atrial septal defect without thoracotomy. A palliative approach to complete transposition of the great arteries. *JAMA* 1966;196(11):991–992.

Wilkins GT, Weyman AE, Abascal VM, et al. Percutaneous balloon dilatation of the mitral valve: an analysis of echocardiographic variables related to outcome and the mechanism of dilation. *Br Heart J* 1988;60:299–308.

***Answer 17:* B.** Panel A represents a 2D transesophageal echocardiographic image obtained in the bicaval view with the superior vena cava on the right, the inferior vena cava on the left, the left atrium on the top, and the right atrium on the bottom of the image. Color Doppler demonstrates a small shunt across the patent foramen ovale (PFO), which in this patient is in the left-to-right direction. In general, flow across PFO can be predominantly unidirectional (left to right or right to left) or bidirectional depending on pressure differences between the two atria. Panel B shows the right atrial aspect of a PFO closure device. Thus, the correct answer is B.

All the remaining answers are related to non-PFO types of atrial septal defect. Panel A demonstrates the typical appearance of PFO, a small defect between the two layers of the atrial septum. Thus, the other answers are incorrect.

Suggested Reading

Garcia Fernandez MA, Perk G, Saric M, et al. Chapter 12: Real-time three-dimensional transesophageal echocardiography for guidance of catheter based interventions. In: Badano LP, Lang RM, Zamorano JL, eds. *Textbook of Real-Time Three-Dimensional Echocardiography*. 1st ed. Springer, 2011:121–134.

Perk G, Ruiz C, Saric M, et al. Real-time three-dimensional transesophageal echocardiography in transcutaneous, catheter-based procedures for repair of structural heart diseases. *Curr Cardiovasc Imaging Rep* 2009;2(5):363–374.

Saric M, Perk G, Purgess J, et al. Imaging atrial septal defects by real-time 3D transesophageal echocardiography: step-by-step approach. *J Am Soc Echocardiogr* 2010;23(11):1128–1135.

Queries

[Q1] Please check if edit to sentence starting "However, in the presence of…" is okay.
[Q2] Please provide the publisher location for reference "Kronzon et al. (2010)".
[Q3] Please provide the publisher location for reference "Garcia Fernandez et al. (2010)" throughout the chapter.
[Q4] Please provide the publisher location for reference "Saric and Kronzon (2010)".
[Q5] Please provide the publisher location for reference "Saric and Kronzon (2010)."