Echo of Prosthetic Valves

October 20, 2009

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Feigenbaum's Text; 6th ed, 2005, Ch. 14, Prosthetic Valves.
ACC/AHA Guidelines Valve Disease Update 2008.

Types of Prosthetic Valves

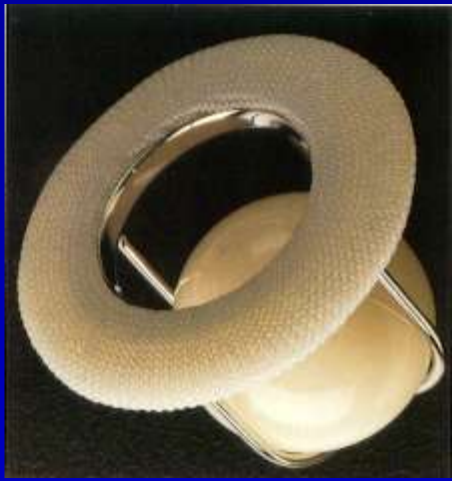
- Mechanical
- Bioprosthetic
- Valve repairs
  - Annuloplasty rings

Mechanical Valves

- Caged ball
  - Starr-Edwards
- Single disc
  - Bjork-Shiley
  - Medtronic-Hall
  - Omnicarbon
  - Lillehei-Kaster
- Bileaflet disc
  - St. Jude Medical
  - CarboMedics
  - Duramedics Jyros

Mechanical Prosthetic Valves

- More durability but more anticoagulation is required and risk of bleeding is higher
- Preferred for >10-15 year life expectancy
- Types:
  - Ball in cage (Starr-Edwards)
  - Tilting disc (Bjork-Shiley; Medtronic Hall)
  - Bileaflet (St. Jude)



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Tissue Valves

- Porcine
  - Carpentier-Edwards
  - Hancock
- Bovine
  - Hancock
- Pericardial
  - Carpentier-Edwards
  - Ionescu-Shiley
  - Hancock
- Stentless
  - St. Jude Toronto
  - Medtronic Freestyle
  - Biocor
  - Edwards Prima
- Homografts

Biological Prosthetic Valves

- Less thromboembolism, less anticoagulation but less durable and more reoperation
- Options
  - Autograft (pulmonic to aortic .. Ross procedure)
  - Autologous or autogenous pericardial (crafted at surgery)
  - Homograft (allograft – human)
  - Heterograft or xenograft is sterilized and nonviable thus bioprosthesis, bovine pericardial, porcine valve (degeneration is more likely after 5 yr for MVR and after 8 yr for AVR, if regurg is noted, echo q 3-6 mo)

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Prosthetic Valves

- Complications: infection, bleeding, thrombosis, embolism, regurgitation due to perivalvular or valvular leak, degeneration (rarely hemolytic anemia)
- Valve selection
  - Repair is preferable to replacement if feasible
  - Lifestyle preferences of patient are often overriding consideration
  - Mechanical for long life span, renal dialysis, or already requiring anticoagulation
  - Biologic for avoiding anticoagulation
    - AVR if >65 yo
    - MVR if >65 yo and no risk factors for thromboembolism

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Aortic Valve Surgery

- AVR with mechanical or bioprosthetic
- AVR with homograft
- AVR with PV autograft (Ross)
- AV repair
- LV to descending Ao Shunt

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Class I Indications for TTE in Patients with Known or Suspected Endocarditis

- For diagnosis looking for vegetations with or without positive blood cultures
- For management looking for degree of valve dysfunction
- For management looking for complications (abscess, perforation, shunt)
- For reassessment in high risk (virulent org, persistent fever or pos cultures, deterioration, new murmur)

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Class II Indications for TTE in Patients with Known or Suspected Endocarditis

- For diagnosis in prosthetic valve in pt with persistent fever but neg blood cultures or murmur (IIa)
- For management, re-evaluation of prosthetic valve endocarditis during antibiotic therapy in the absence of clinical deterioration (IIb)

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Class I Indications for TEE in Endocarditis

- For management to assess the severity of valvular lesions in symptomatic patients, if transthoracic echocardiography is nondiagnostic.
- For diagnosis in patients with valvular heart disease and positive blood cultures, if transthoracic echocardiography is nondiagnostic.
- For management looking for complications (abscess, perforation, shunt)
- TEE as first-line diagnostic study to diagnose prosthetic valve endocarditis and assess for complications.

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Indications for Echo for Thrombosis of Prosthetic Valves

- TTE in suspected prosthetic valve thrombosis to assess hemodynamic severity (I)
- TEE or fluoroscopy in suspected valve thrombosis to assess valve motion and clot burden (I)

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Indications for Echo in Follow-up

- TTE after valve intervention, either in hospital or at 2-4 weeks after discharge (I)
- TTE in patients with bioprosthetic valves may be considered annually after the first 5 years in the absence of a change in clinical status (IIb)
- Routine annual echocardiograms are not indicated in the absence of a change in clinical status in patients with mechanical heart valves or during the first 5 years after valve replacement with a bioprosthetic valve (III)

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Indications for Echo in Patients with Prosthetic Valves

- Postintervention baseline study for valve function (early) and ventricular remodeling (late)
- Routine re-evaluation study after baseline studies of patients with mild to moderate ventricular dysfunction without change in signs or symptoms (IIa)
- Routine re-evaluation at the time of increased failure rate of a bioprosthesis without clinical evidence of prosthetic dysfunction (IIb)
- Routine re-evaluation, or nonintervenable patients (III)

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Interpretive tip

- Bioprosthetic aortic valve may resemble normal valve – careful examination:
  - sewing ring and struts are more echogenic than normal and tend to shadow the leaflets
  - Distinguishing a normally functioning stentless valve from a native aortic valve can be impossible

Feigenbaum's Text; 6th ed, 2005, Ch. 14, Prosthetic Valves.

Interpretive tip

- Bileaflet (St. Jude) mechanical aortic valve may show high velocity (and high localized gradient) through central orifice that is not representative of the more important net gradient (there is pressure recovery)

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Interpretive tip

- Regurgitation is normal in virtually all mechanical prostheses
  - Closure backflow is flow that causes the leaflet to shut and then ceases
  - Leakage backflow occurs when leaflets are closed, to “provide a washing mechanism” and is with symmetric narrow jets directed obliquely from the edges
  - Distinguish leakage backflow from pathologic regurgitation by severity and pattern

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Interpretive tip

- Leakage backflow appearance
  - St. Jude: one central and 2 peripheral jets
  - Medtronic-Hall: one central jet
  - Generally jet area < 2cm2 and <2.5 cm long

Feigenbaum's Text; 6th ed, 2005, Ch. 14, Prosthetic Valves.

Interpretive tip

- Continuity equation works well in prosthetic valves
- Pressure half-time in MV and TV replacements are useful, but pressure half-time generally <u>over</u>estimates the valve area in MV prosthesis

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Interpretive tip

- Limitation in mechanical valves:
- Gross abnormalities can be detected
  - Type of valve
  - Stability of sewing ring
  - Opening and closing motion of the valve
  - Gross vegetation or thrombus
- Brisk opening velocity is generally consistent with each beat
- Bileaflet valve leaflets may be slightly out of phase normally

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Interpretive tip

- Assessing regurgitation can be limited by shadowing from the valve
- Doppler velocity index for AVR is 0.35 to 0.50.

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Opening and Closing Angles

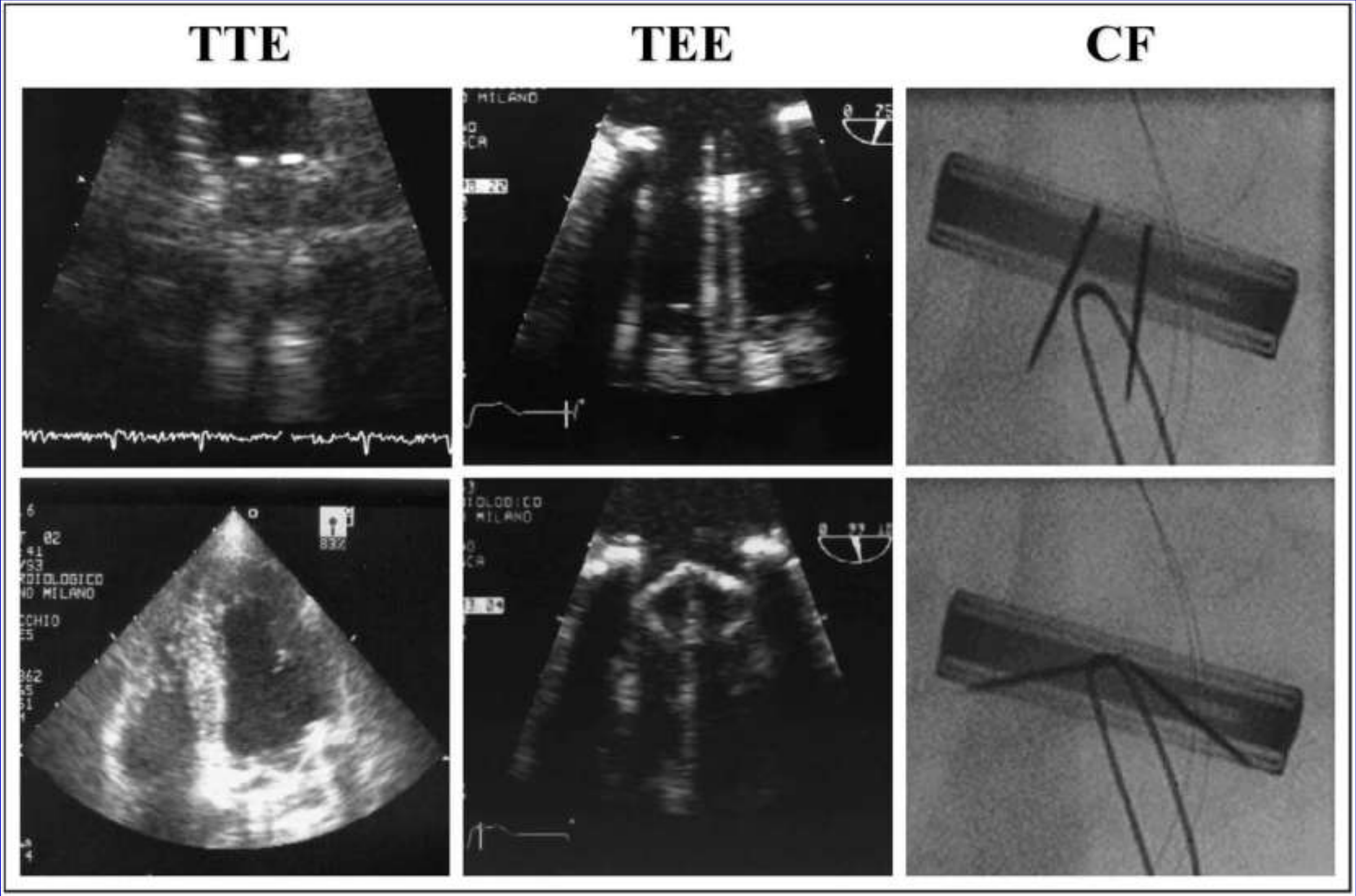

Figure 2. Normal functioning mitral bileaflet prosthesis: opening (*top panels*) and closing (*bottom panels*) angles in transthoracic apical 4-chamber view (*left*), TEE view (*middle*), and cinefluoroscopy (CF) (*right*).

Muratori M et al. Am J Cardiol. 2006;97:94-100.

Opening and Closing Angles

Table 3
Opening angle (OA) and closing angle (CA) values by cinefuoroscopy (CF), TTE, TEE and Doppler gradients

Site, Type of Prosthesis, and Leaflet Motion	Patients (n)	OA TTE (°)	OA TEE (°)	OA CF (°)	CA TTE (°)	CA TEE (°)	CA CF (°)	Mean Gradient (mm Hg)
Mitral, single-disk, normal	11	61 ± 9	61 ± 11	61 ± 10	0	0	0	4 ± 2
Mitral, single-disk, abnormal	7	37 ± 6	37 ± 4	41 ± 1	0	0	0	8 ± 1
Mitral, bileaflet, normal	27	16 ± 5	16 ± 5	19 ± 6	126 ± 14	129 ± 11	129 ± 9	6 ± 2
Mitral, bileaflet, abnormal	21	80 ± 22	83 ± 16	87 ± 14	123 ± 10	136 ± 6	133 ± 8	12 ± 5
Aortic, single-disk, normal	18	55 ± 11	56 ± 9	54 ± 8	0	0	0	24 ± 14
Aortic, single-disk, abnormal	4	43 ± 4	41 ± 1	45 ± 0	0	0	0	34 ± 6
Aortic, bileaflet, normal	15	—	13 ± 5	17 ± 5	—	—	131 ± 5	23 ± 12
Aortic, bileaflet, abnormal	8	—	20 (n = 1)	25 (n = 1)	—	—	78 (n = 1)	68 ± 12

Data are expressed as mean ± SD.

Muratori M et al. Am J Cardiol. 2006;97:94-100.

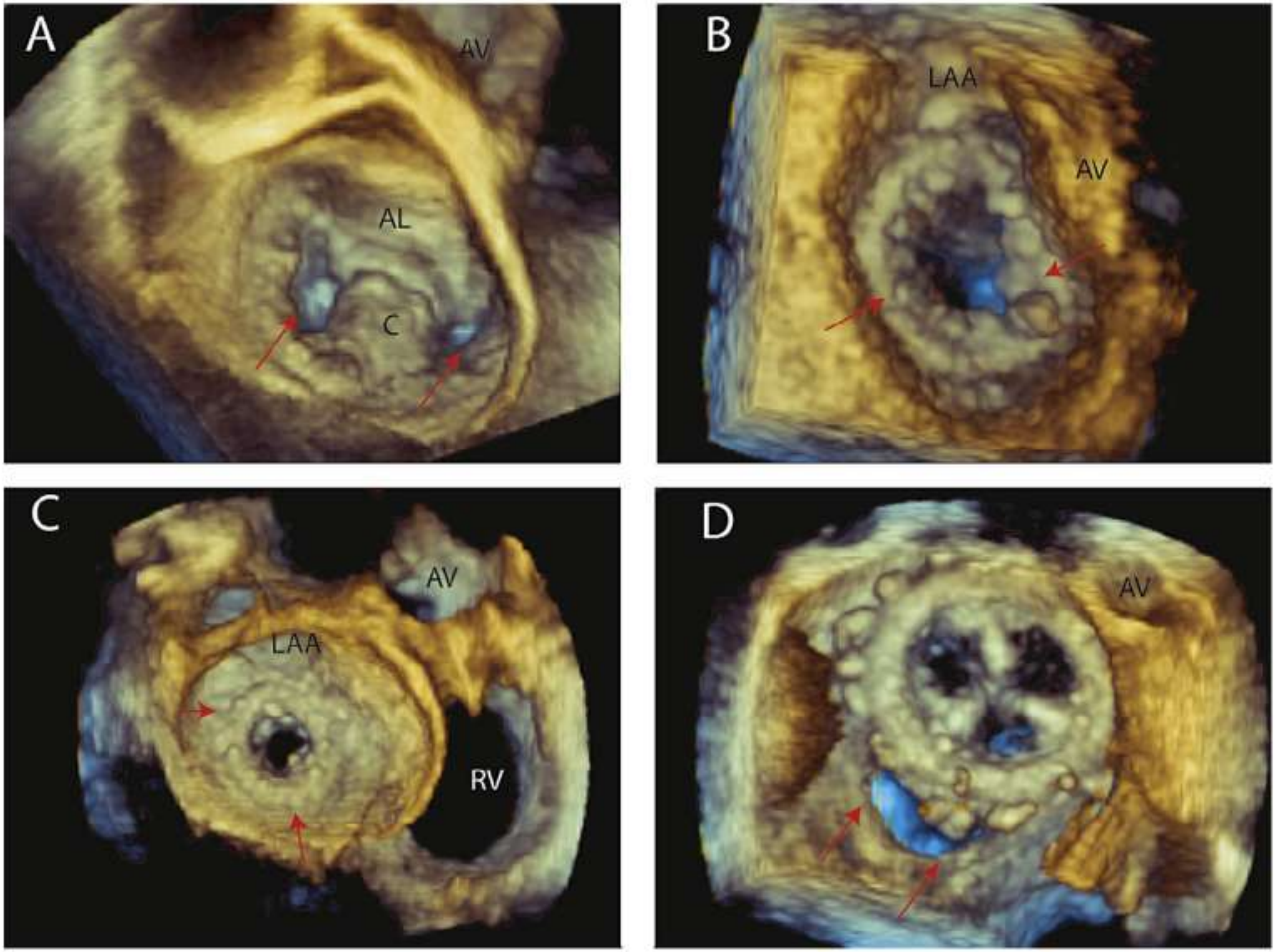

Figure 11 The unique perspective 3D TEE provides in the visualization of the mitral valve when it has been replaced or repaired surgically or percutaneously. **(A)** Image from a patient with flail mitral valve repaired with the E-valve clip. The *arrows* point to the "double orifice" mitral valve created by the clip (C). **(B)** Image from a patient with a mitral repair with an annuloplasty ring; the *arrows* point to the posterior and anterior aspects of the annuloplasty ring. **(C)** Image from a patient with a stenotic mitral bioprosthesis; the *arrows* point to the suture ring. **(D)** Image from a patient with a bioprosthetic mitral valve and a periprosthetic leak; the *arrows* point to the area of ring dehiscence. *AL*, Anterior leaflet; *AV*, aortic valve; *LAA*, left atrial appendage; *RV*, right ventricle.

Salcedo EE et al. J Am Soc Echocardiogr. 2009;22:1087-99.

Prosthetic Valvular Obstruction

- Inherent stenosis of valve
- Patient/prosthesis mismatch (may be apparent with exercise)
- Technical difficulties in implantation
- Thrombosis
- Vegetation
- Pannus ingrowth

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Prosthetic Valve Endocarditis

- Vegetation detection in TTE is challenge
- Most commonly vegetation originates at the base or sewing ring, can be confused with loose suture material
- DDX vegetation-thrombus nearly impossible
- TEE is recommended in the majority of cases, often both TTE and TEE needed
- Abscess: imaging may be difficult even with TEE, echodense or echolucent, perivalvular regurgitation is common
- Dehiscence is rocking of the valve w.r.t. the heart

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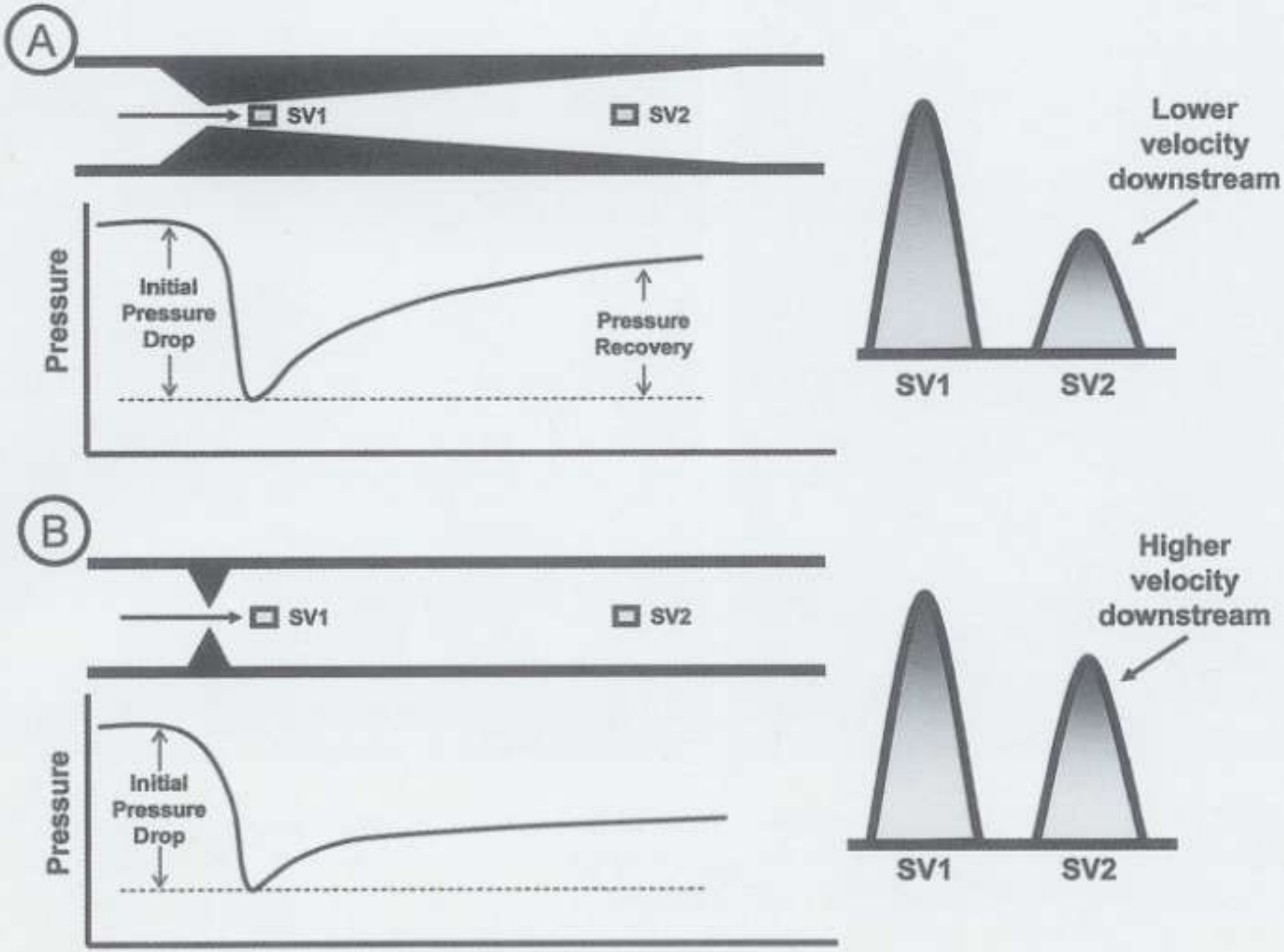

FIGURE 14.13. The concept of pressure recovery is illustrated in this schematic. In the top panel, in the absence of pressure recovery, different locations for sample volume (SV) measurement yield fairly similar velocities. In panel B, flow through a tapered stenosis results in significant pressure recovery downstream from the obstruction. In this case, sampling within the obstruction (SV1) yields a higher velocity compared to a sample site downstream (SV2) where pressure recovery has occurred. At this site, the recovery of pressure is associated with a lower velocity. See text for details.

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Physiologic Regurgitation

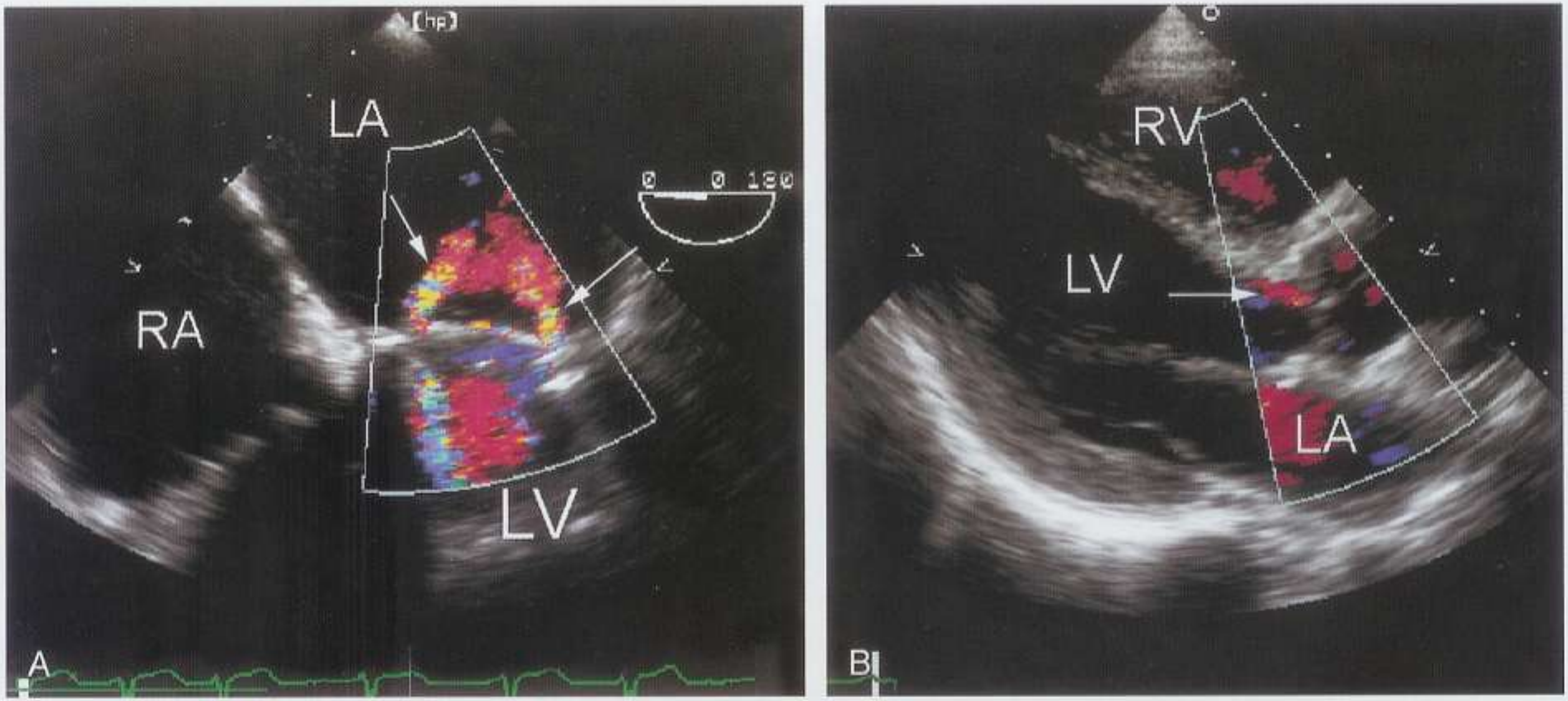

FIGURE 14.14. Physiologic regurgitation is demonstrated through a normally functioning St. Jude mitral prosthesis (*arrows*) (**A**) and a porcine aortic prosthesis (*arrow*) (**B**). LA, left atrium; RA, right atrium; RV, right ventricle; LV, left ventricle.

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Bioprosthetic fibrocalcific degeneration

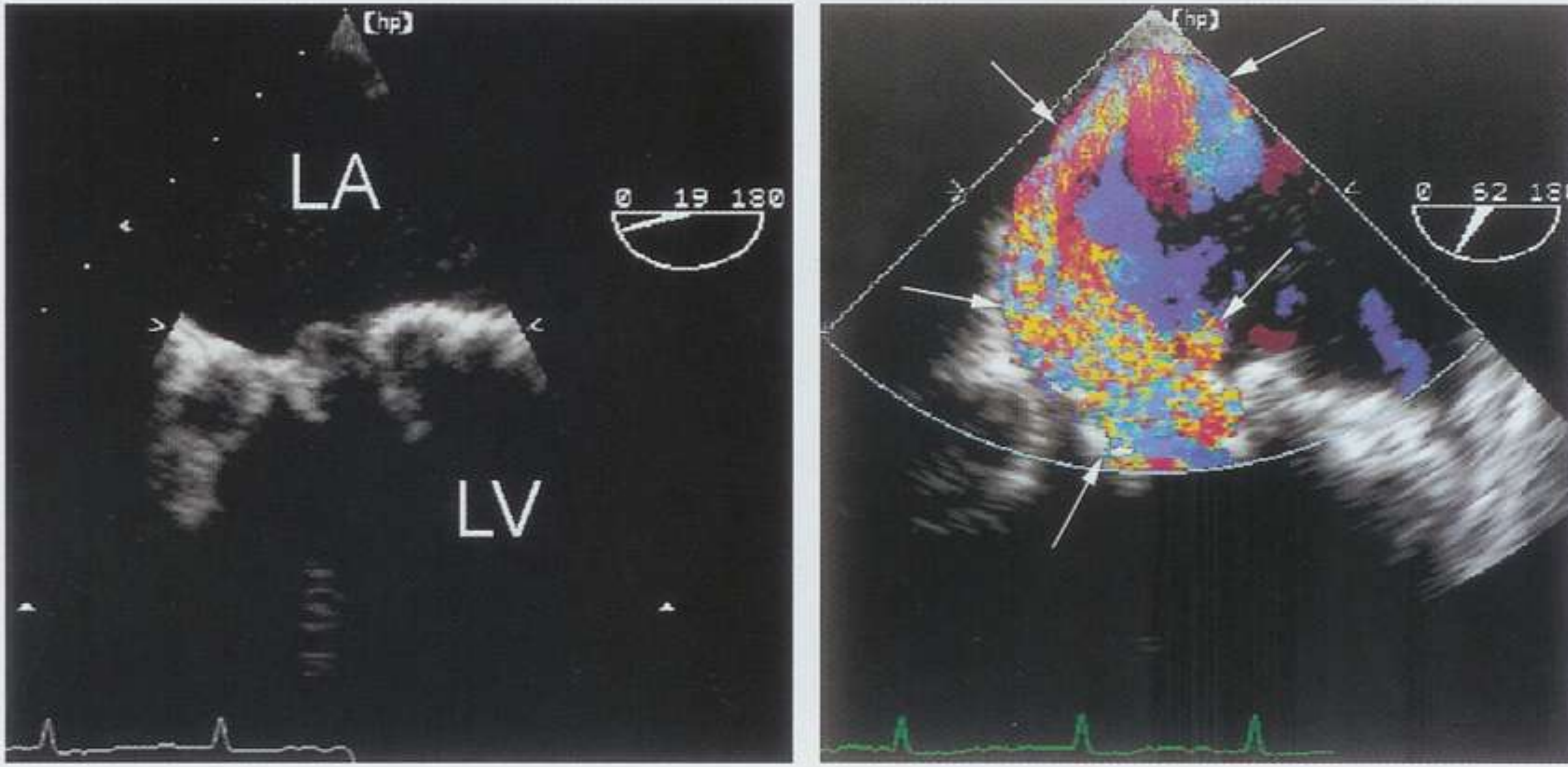

FIGURE 14.18. An example of primary tissue degeneration involving a porcine mitral valve is provided. The leaflets are thickened and fibrotic with decreased mobility **(left)**. **Right:** Color Doppler imaging demonstrates severe mitral regurgitation with an eccentric jet (*arrows*). LA, left atrium; LV, left ventricle.

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Both Echo and Doppler are Required for Proper Assessment

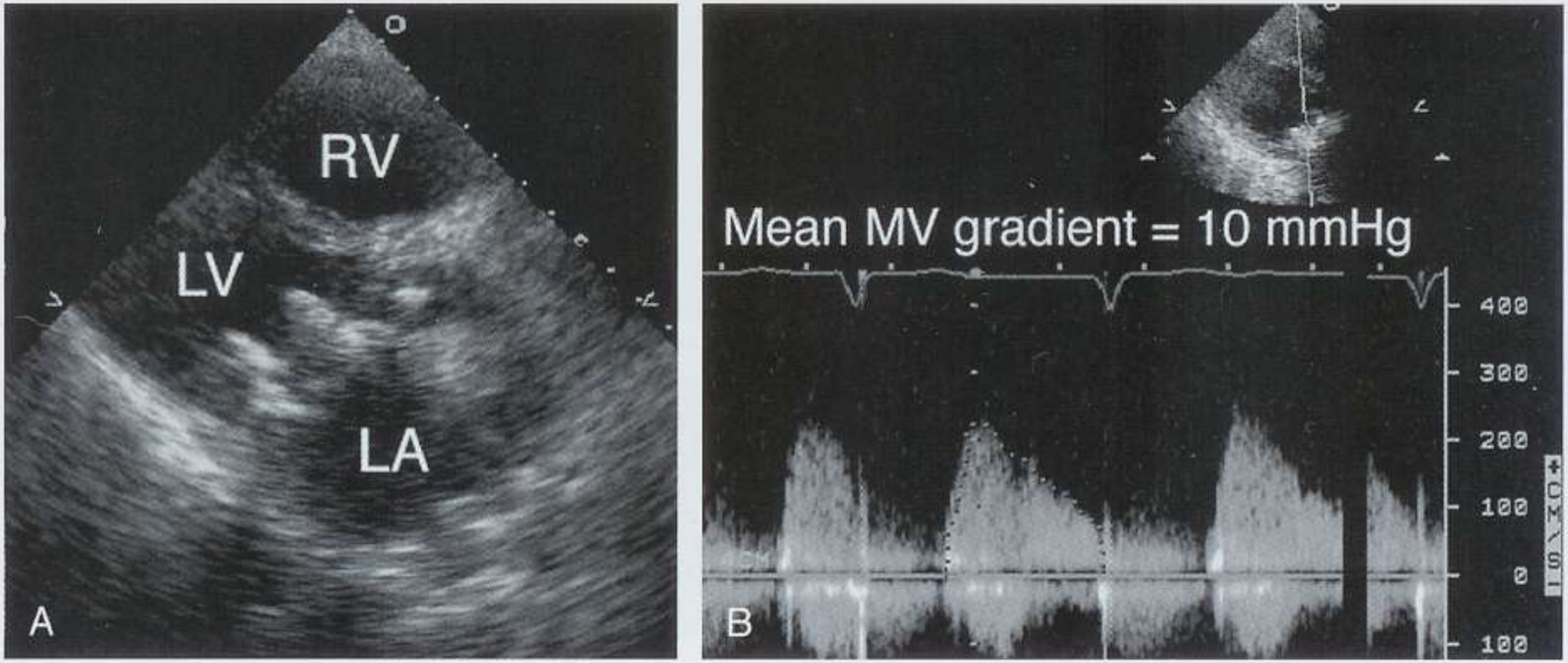

FIGURE 14.19. **A:** An example of a mildly thickened porcine mitral prosthesis is shown. The structure and motion of the leaflets are often obscured by the struts. **B:** Doppler imaging demonstrates a mean gradient of 10 mm Hg. LA, left atrium; LV, left ventricle; RV, right ventricle.

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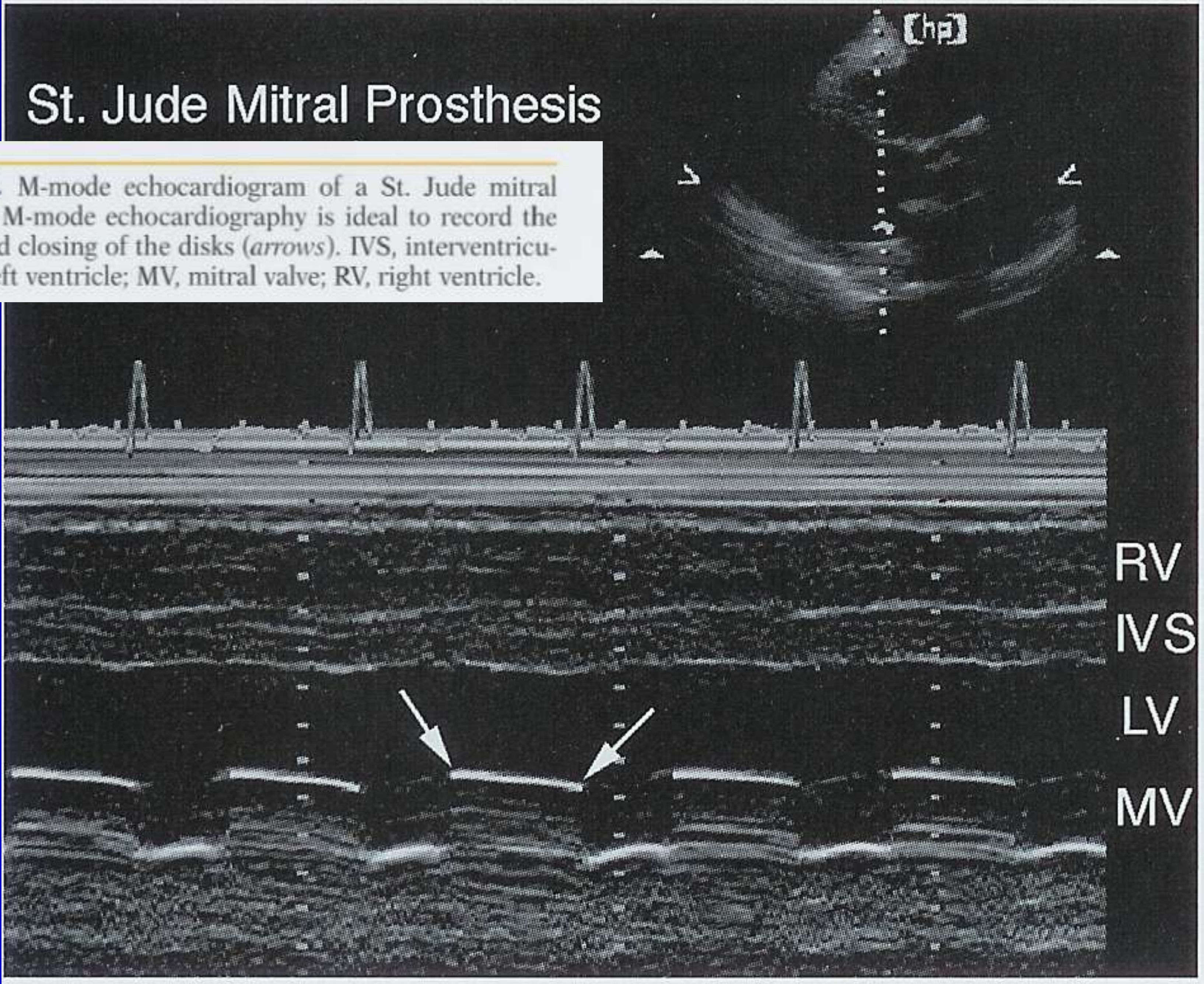

FIGURE 14.20. M-mode echocardiogram of a St. Jude mitral prosthetic valve. M-mode echocardiography is ideal to record the brisk opening and closing of the disks (*arrows*). IVS, interventricular septum; LV, left ventricle; MV, mitral valve; RV, right ventricle.

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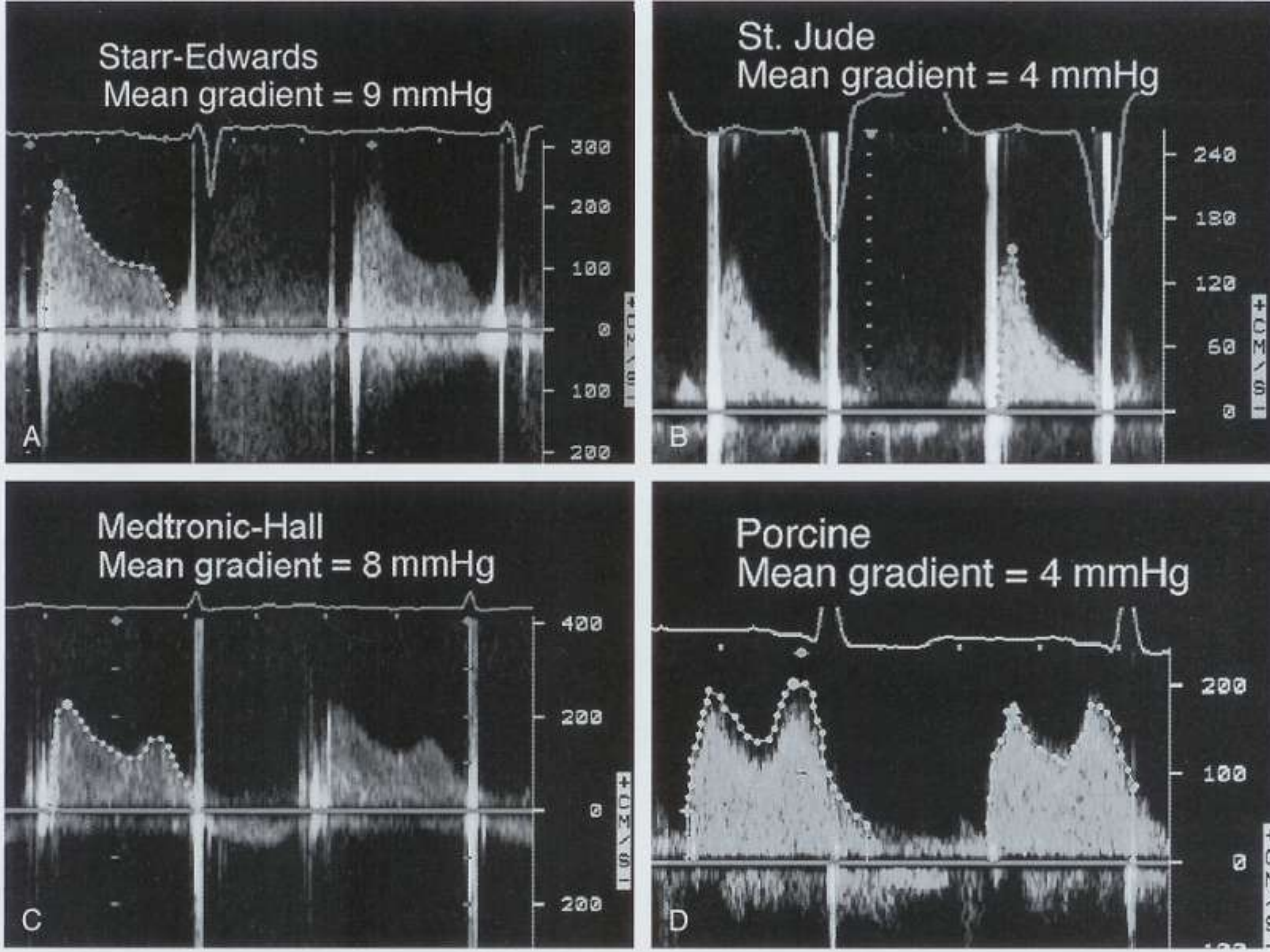

FIGURE 14.17. **A–D:** Doppler recording of flow through four different mitral prosthetic valves is demonstrated. The mean gradient across each prosthesis is indicated.

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Intraoperative TEE showing mild perivalvular leak, will likely resolve

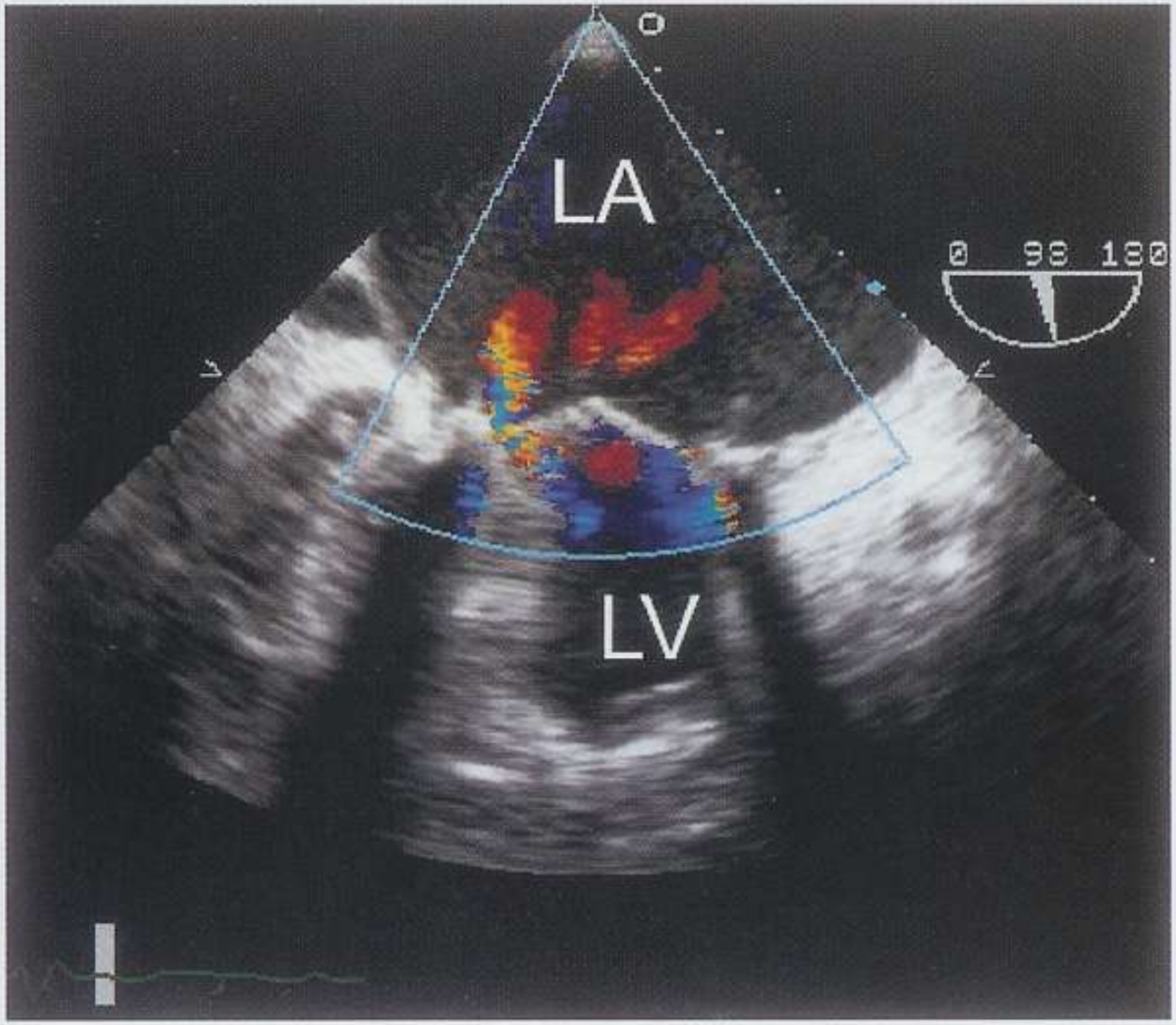

FIGURE 14.23. This St. Jude mitral prosthesis was evaluated in the operating room immediately after implantation when a mild degree of perivalvular regurgitation may be present. In most cases, this resolves over time. Color Doppler imaging indicates both central and peripheral jets, consistent with mild mitral regurgitation. LA, left atrium; LV, left ventricle.

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B: Obstruction shows poor opening click and high velocity

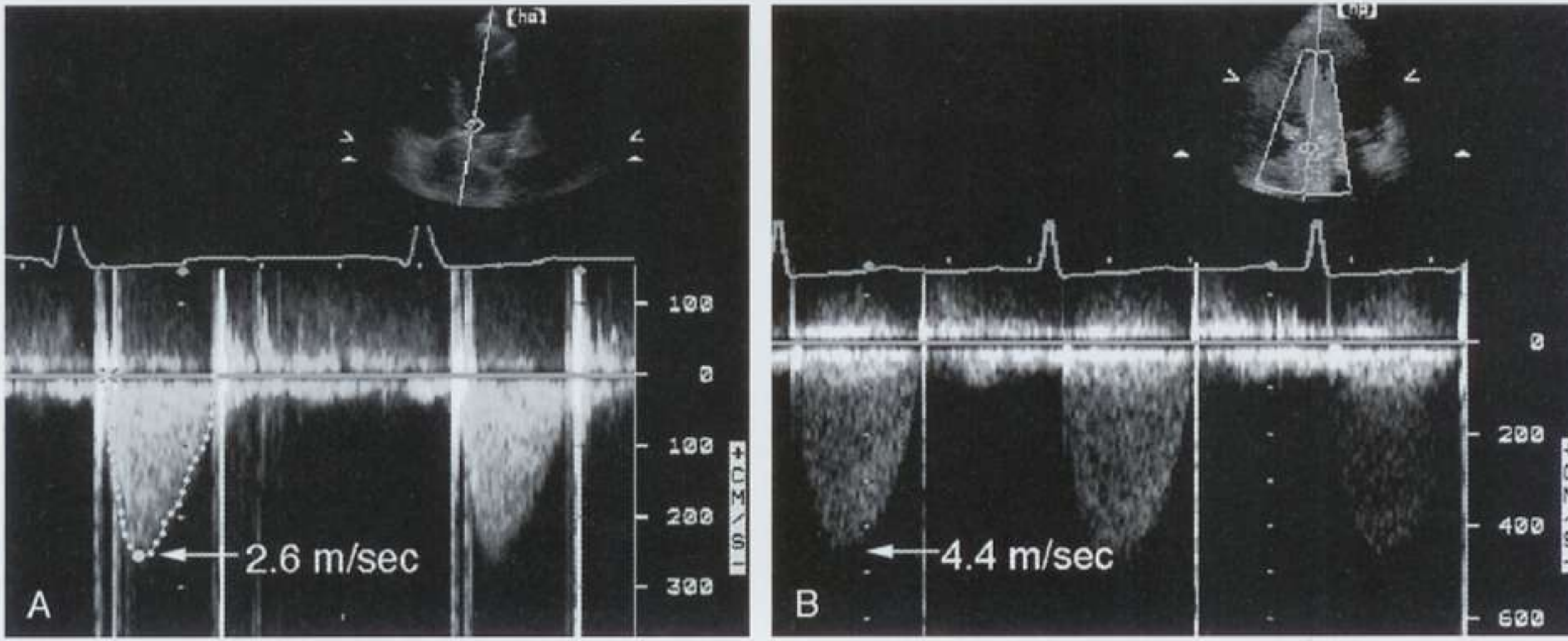

FIGURE 14.24. Examples of flow through two different St. Jude aortic prosthetic valves are provided. **A:** Flow velocity is normal and crisp valve clicks are present. **B:** Jet velocity is increased, indicating a peak pressure gradient of approximately 77 mm Hg. Valve clicks, especially at the time of valve opening, are diminished.

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TABLE 14.3 Range of Normal Values for Doppler Evaluation of Aortic Prostheses (continued)

Category	Specific Type	Size (mm)	Gradient (mm Hg) Maximum	Gradient (mm Hg) Mean	Peak Velocity (m/sec)
Bileaflet *(cont.)*					
	St. Jude Medical	19	35±11	19±6	2.9±0.5
		21	28±10	16±6	2.6±0.5
		23	25±8	14±5	2.6±0.4
		25	23±8	13±5	2.4±0.5
		27	20±8	11±5	2.2±0.4
		29	18±6	10±3	2.0±0.1
Caged ball					
	Starr-Edwards	23	33±13	22±9	3.5±0.5
		24	34±10	22±8	3.4±0.5
		26	32±9	20±6	3.2±0.4
		27	31±6	19±4	
		29	29±9	16±6	

Modified from Rosenhek R, Binder T, Maurer G, Baumgartner H. Normal values for Doppler echocardiographic assessment of heart valve prostheses. J Am Soc Echocardiogr 2003;16:1116–1127, with permission.

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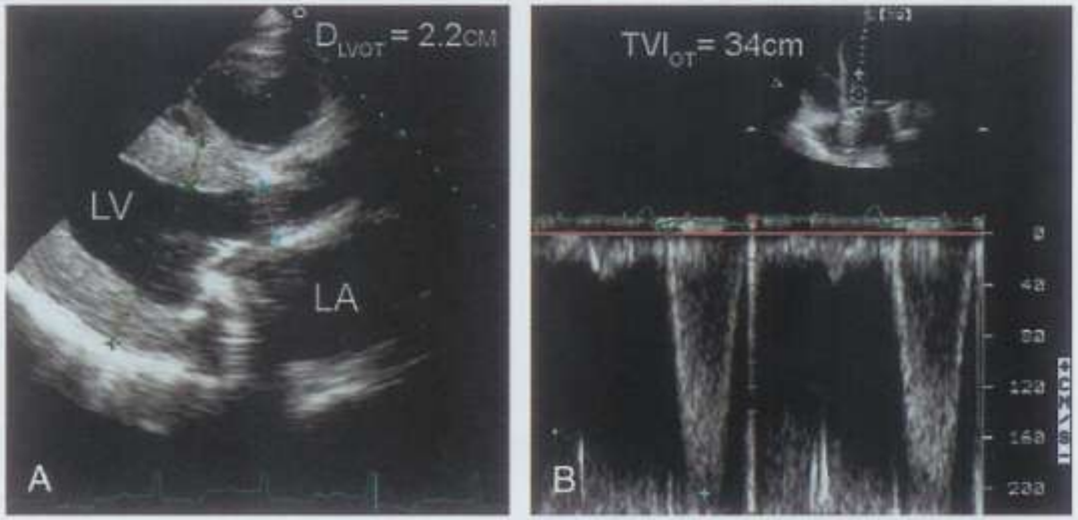
Continuity Equation in Prostheses



$$CSA_{OT} = .785 \times D^2 = 3.8cm^2$$

$$AVA = \frac{CSA_{OT} \times TVI_{OT}}{TVI_{AV}}$$

$$AVA = \frac{3.8 \times 34}{69} = 1.87\ cm^2$$

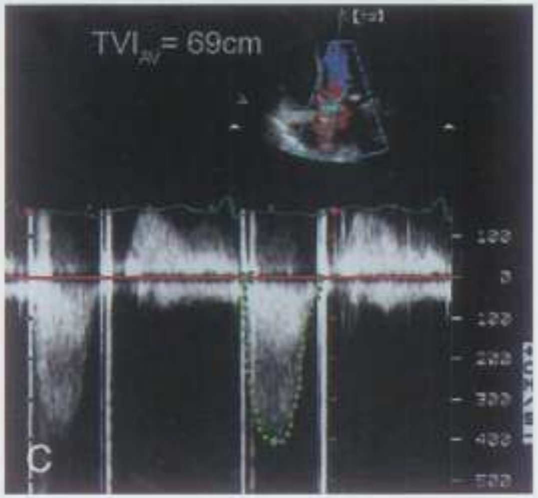


FIGURE 14.25. The continuity equation can be used to calculate the effective valve area across prostheses. **A:** The diameter of the left ventricular outflow tract is measured. **B:** Time velocity integral (TVI) of the outflow tract is calculated using planimetry. **C:** Using continuous wave Doppler imaging, flow through the prosthetic valve is recorded. Because of a hyperdynamic left ventricle (LV), the TVI_{OT} and the maximal pressure gradient are quite high. Despite the maximal gradient of 65 mm Hg, the aortic valve area is approximately 1.9 cm². The calculations used to measure valve area are provided. CSA, cross-sectional area; D_{LVOT}, outflow tract diameter; LA, left atrium.

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Peak and Mean Gradients in prostheses are of similar significance as native valves

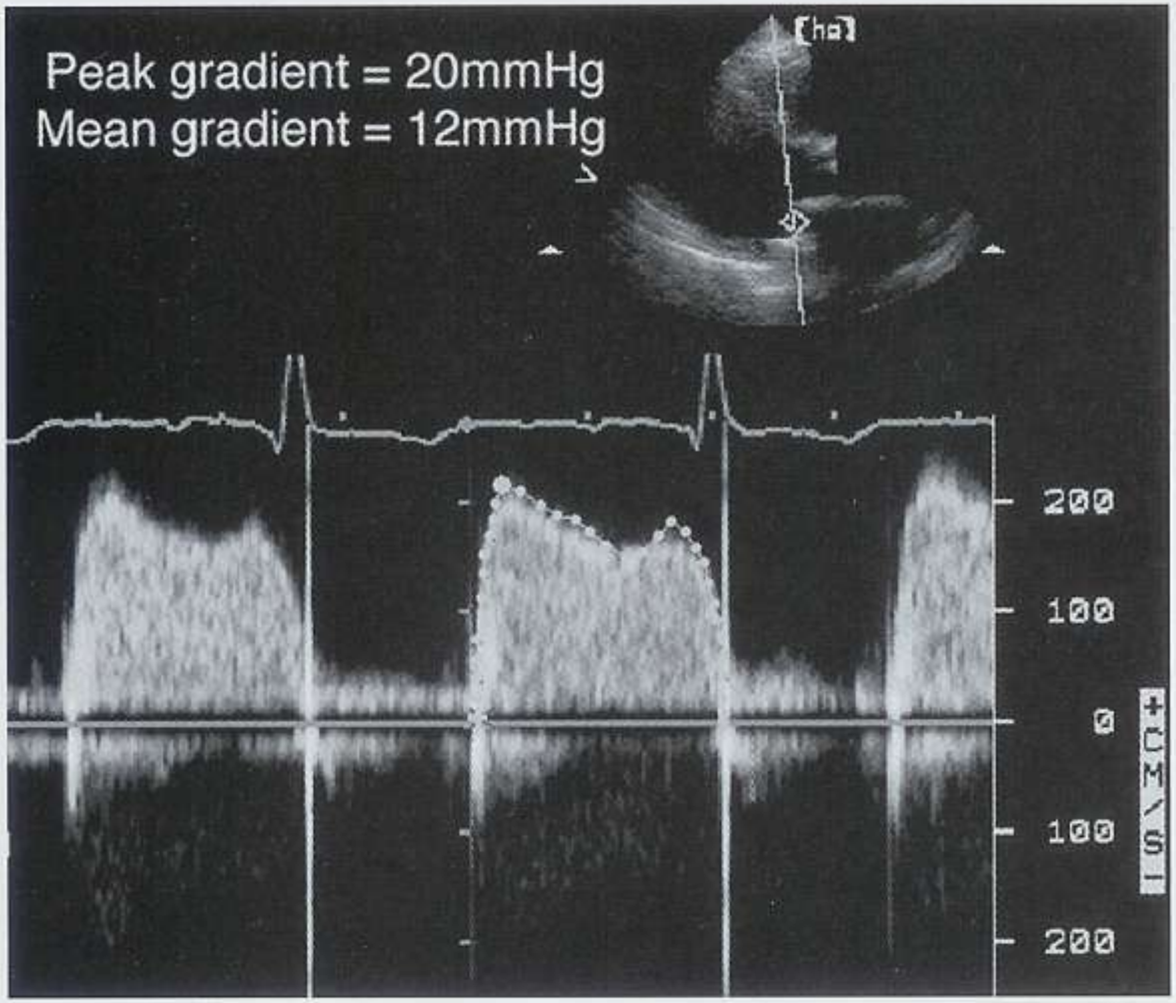

FIGURE 14.30. Doppler recording of flow through a porcine mitral valve is shown. Both the peak and mean gradient are derived by planimetry. Note that the recording was obtained from the parasternal window. In this case, this view provided optimal alignment with mitral inflow.

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Shadowing makes Doppler difficult

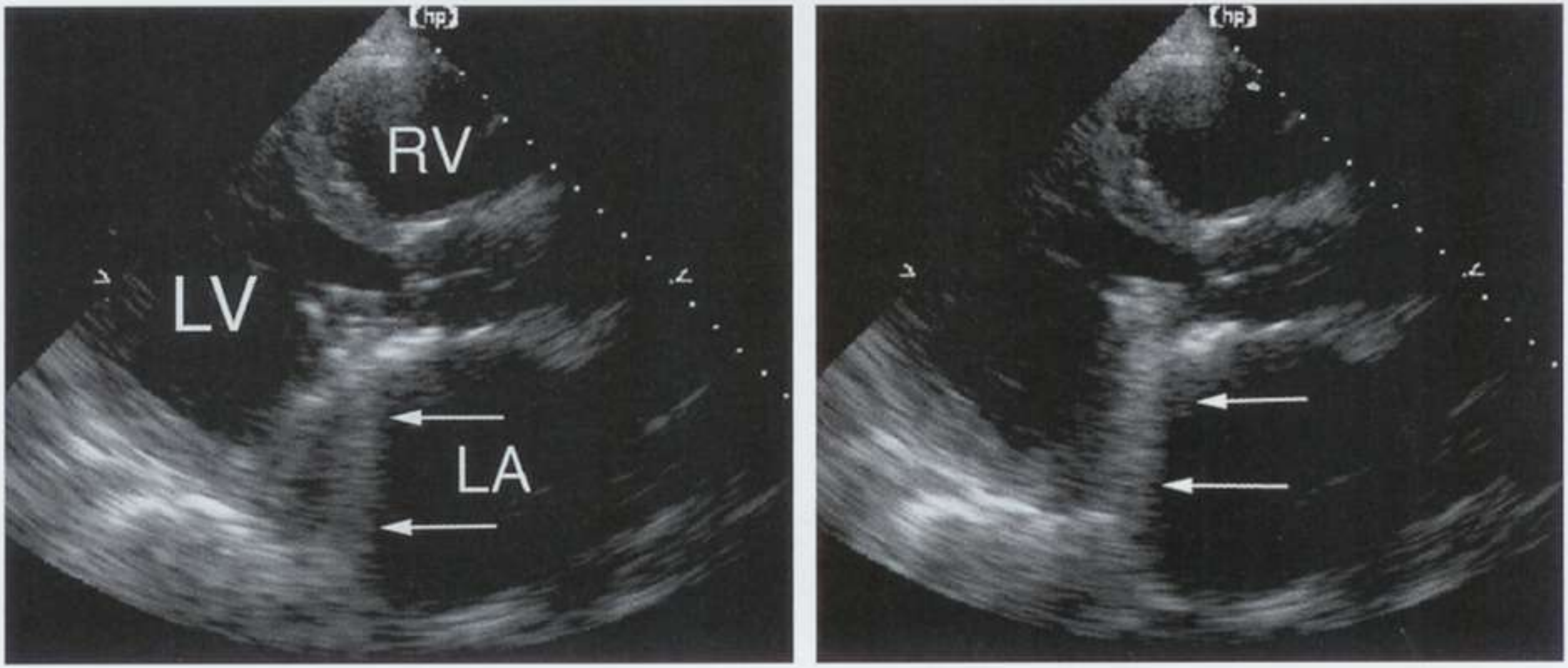

FIGURE 14.31. Detecting the presence of mitral regurgitation in patients with mechanical mitral prostheses can be difficult. In this example, a portion of the left atrium is obscured by the shadowing effect of the prosthesis, as indicated by the arrows during both systole **(left)** and diastole **(right)**. LA, left atrium; LV, left ventricle; RV, right ventricle.

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Patient-Prosthesis mismatch

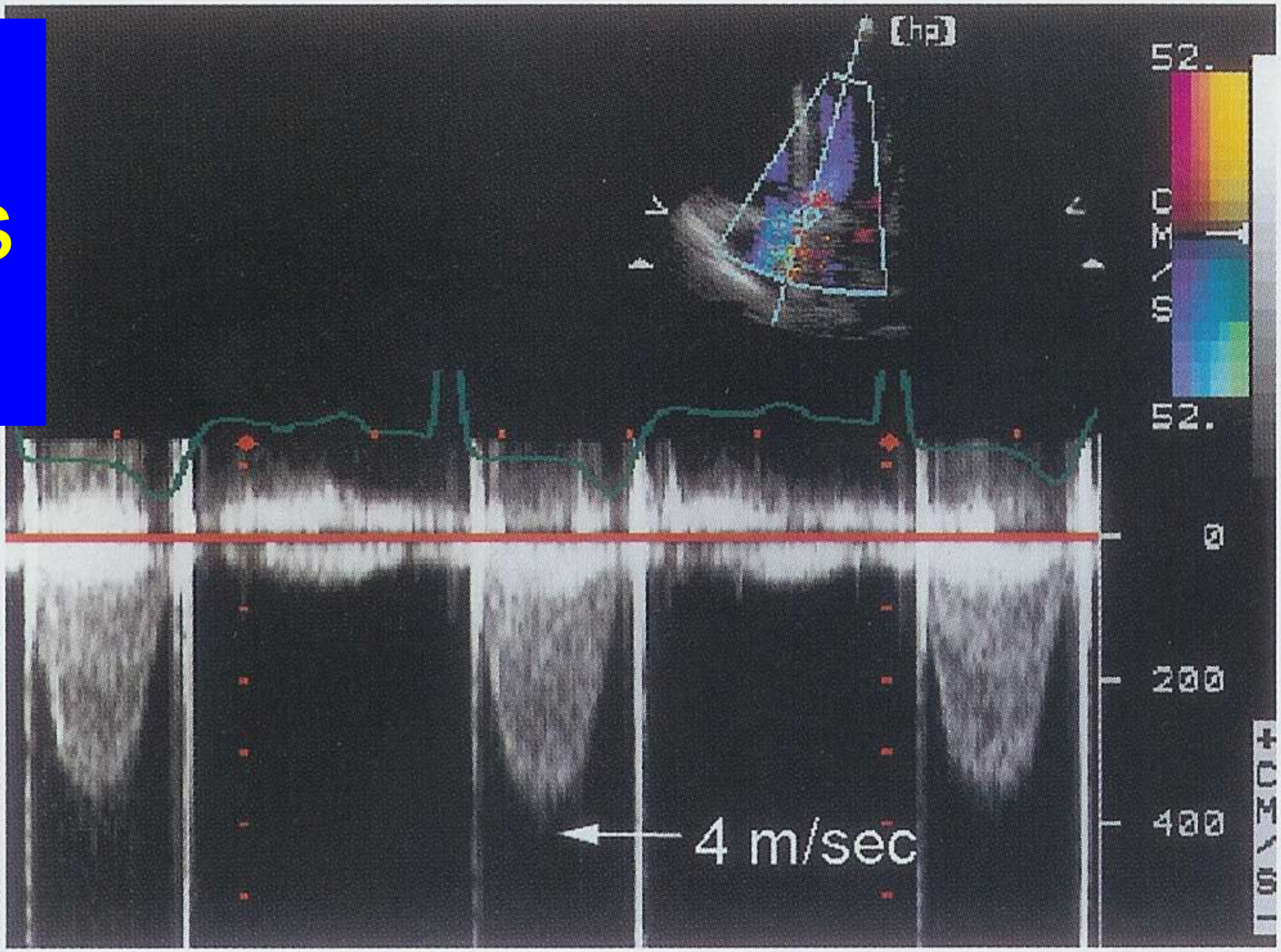

FIGURE 14.34. An example of patient-prosthesis mismatch is shown. This prosthetic valve had been implanted when the patient was young. Over time, the patient outgrew the prosthesis. The result is a 64 mm Hg peak gradient across the valve, as indicated by the Doppler recording.

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Intraoperative TEE and leaflet malfunction

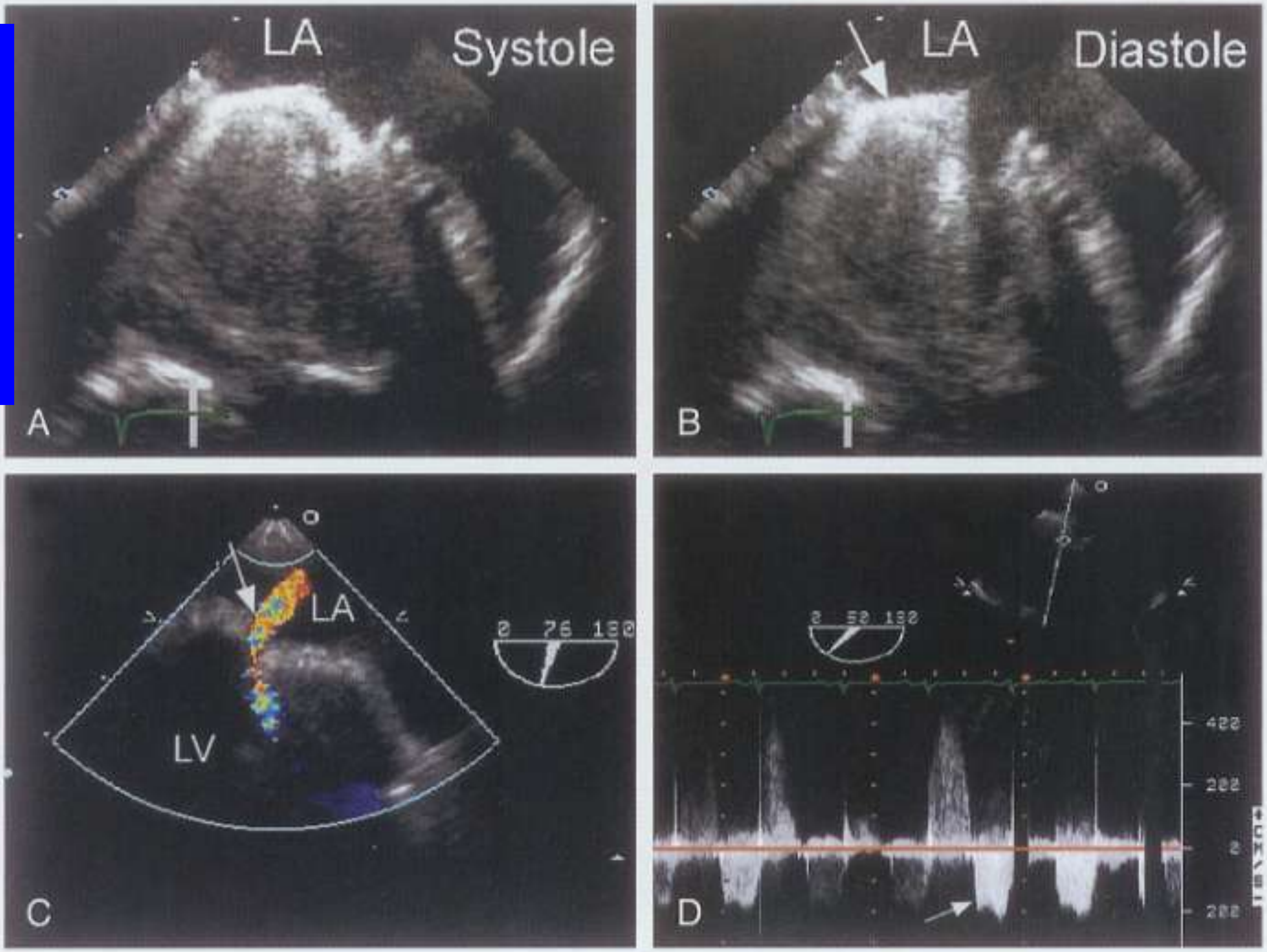

FIGURE 14.35. Intraoperative transesophageal echocardiography can be useful to identify technical problems related to prosthesis insertion. In this example, one of the hemidisks of a St. Jude mitral valve was stuck in the closed position. **A, B:** Lack of motion of the hemidisk was apparent (*arrow*). **C:** Mild mitral regurgitation was detected (*arrow*) using color Doppler imaging. **D:** Continuous wave Doppler imaging confirms both an increased gradient (*arrow*) and regurgitation through the valve. The problem was rectified before leaving the operating room. LA, left atrium; LV, left ventricle.

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Small thrombus with obstruction

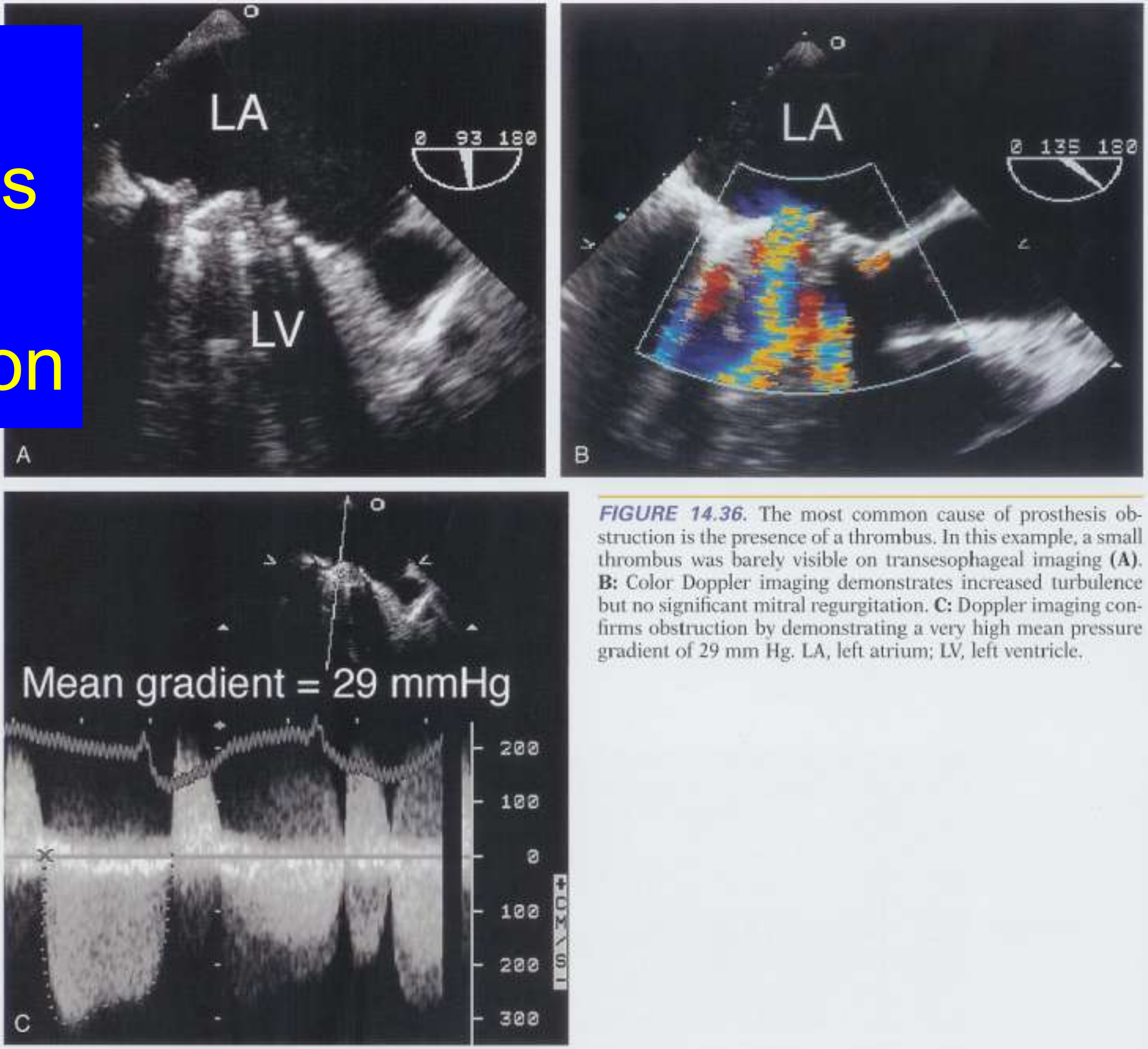

FIGURE 14.36. The most common cause of prosthesis obstruction is the presence of a thrombus. In this example, a small thrombus was barely visible on transesophageal imaging **(A)**. **B:** Color Doppler imaging demonstrates increased turbulence but no significant mitral regurgitation. **C:** Doppler imaging confirms obstruction by demonstrating a very high mean pressure gradient of 29 mm Hg. LA, left atrium; LV, left ventricle.

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Large thrombus, multiple

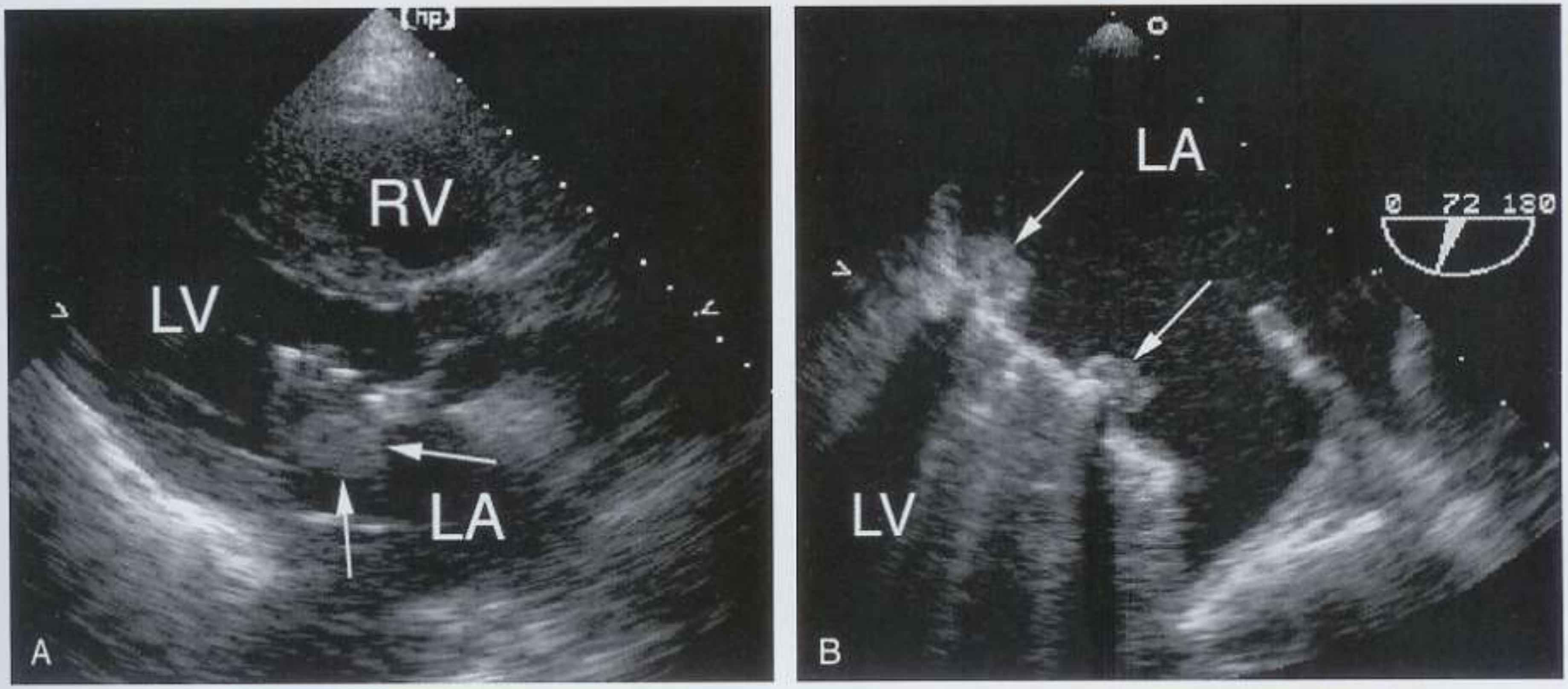

FIGURE 14.37. In this example, a large thrombus was visualized on transthoracic **(A)** and transesophageal **(B)** imaging. The thrombus can be seen on the left atrial (*LA*) aspect of the mitral prosthesis (*arrows*). **B:** Multiple thrombi were demonstrated (*arrows*) adjacent to the sewing ring. LV, left ventricle; RV, right ventricle.

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Extensive thrombus

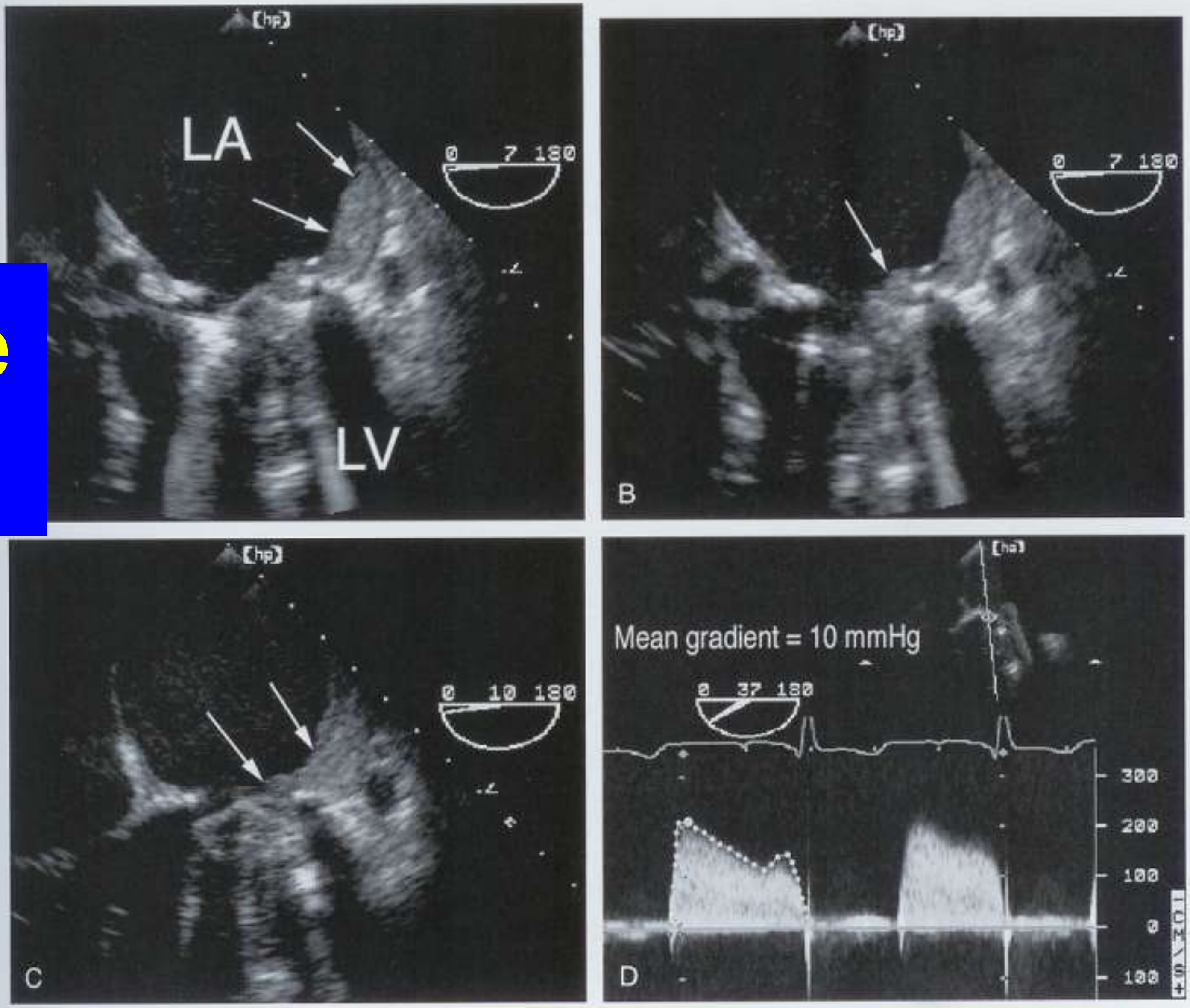

FIGURE 14.38. An extensive thrombus within the left atrium (*LA*) involving a St. Jude mitral prosthesis is demonstrated. **A–C:** The extent of the size and location of the thrombus are demonstrated (*arrows*). Reduced motion of one of the hemidisks resulted. **D:** Doppler imaging demonstrates a mean pressure gradient of 10 mm Hg. Ao, aorta; LV, left ventricle.

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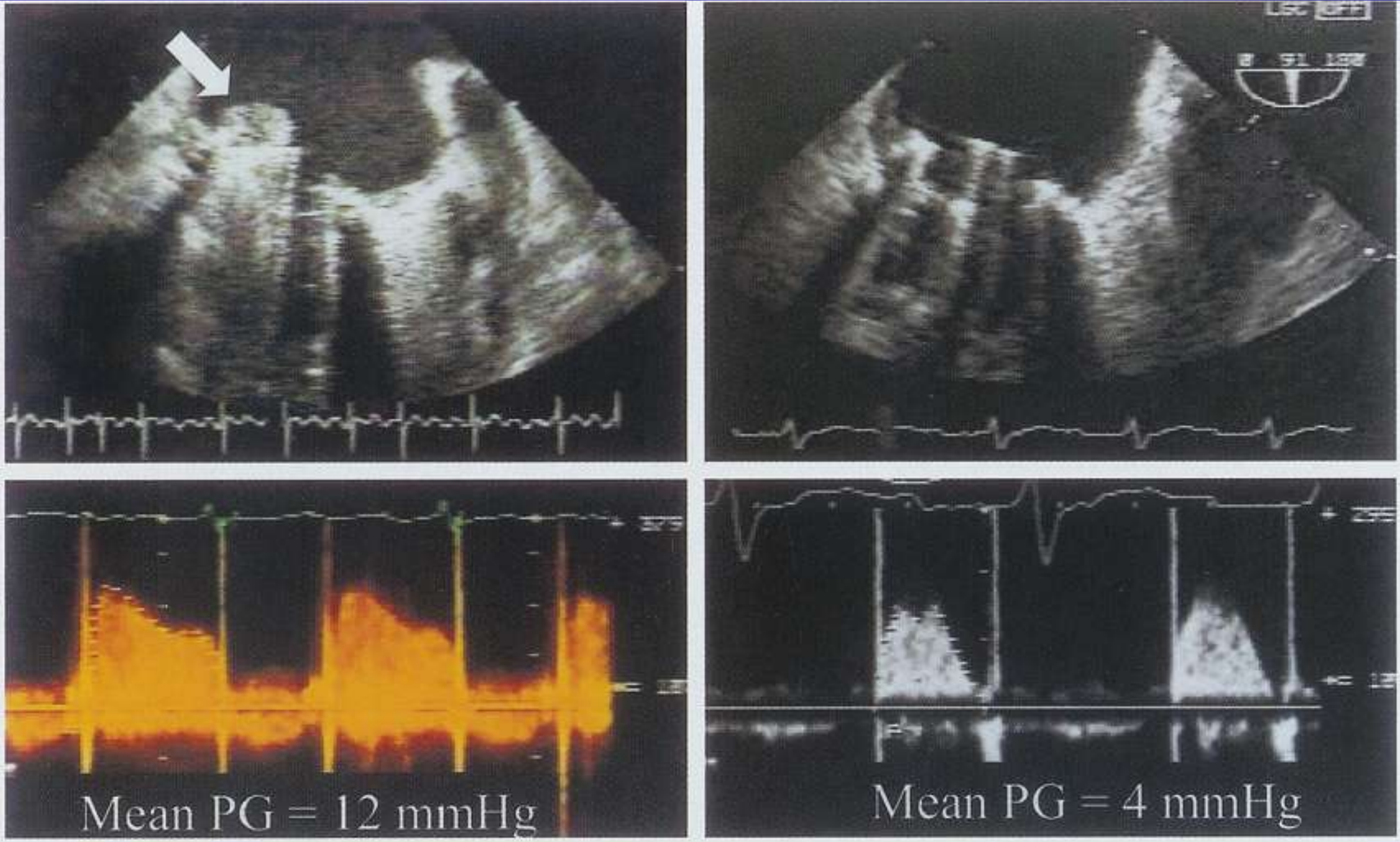

FIGURE 14.42. In the left panels, a St. Jude mitral prosthesis with thrombotic obstruction is shown. The thrombus is evident on transesophageal echocardiography (*arrow*) and Doppler demonstrates a mean gradient of 12 mm Hg. Note how the thrombus prevents opening of one hemidisc in this diastolic frame. In the right panels, following thrombolytic therapy using streptokinase, normal opening motion of both hemidiscs is restored and the mean gradient is reduced to 4 mm Hg. PG, pressure gradient. (Courtesy of W. Zoghbi, MD)

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Bioprosthetic degeneration

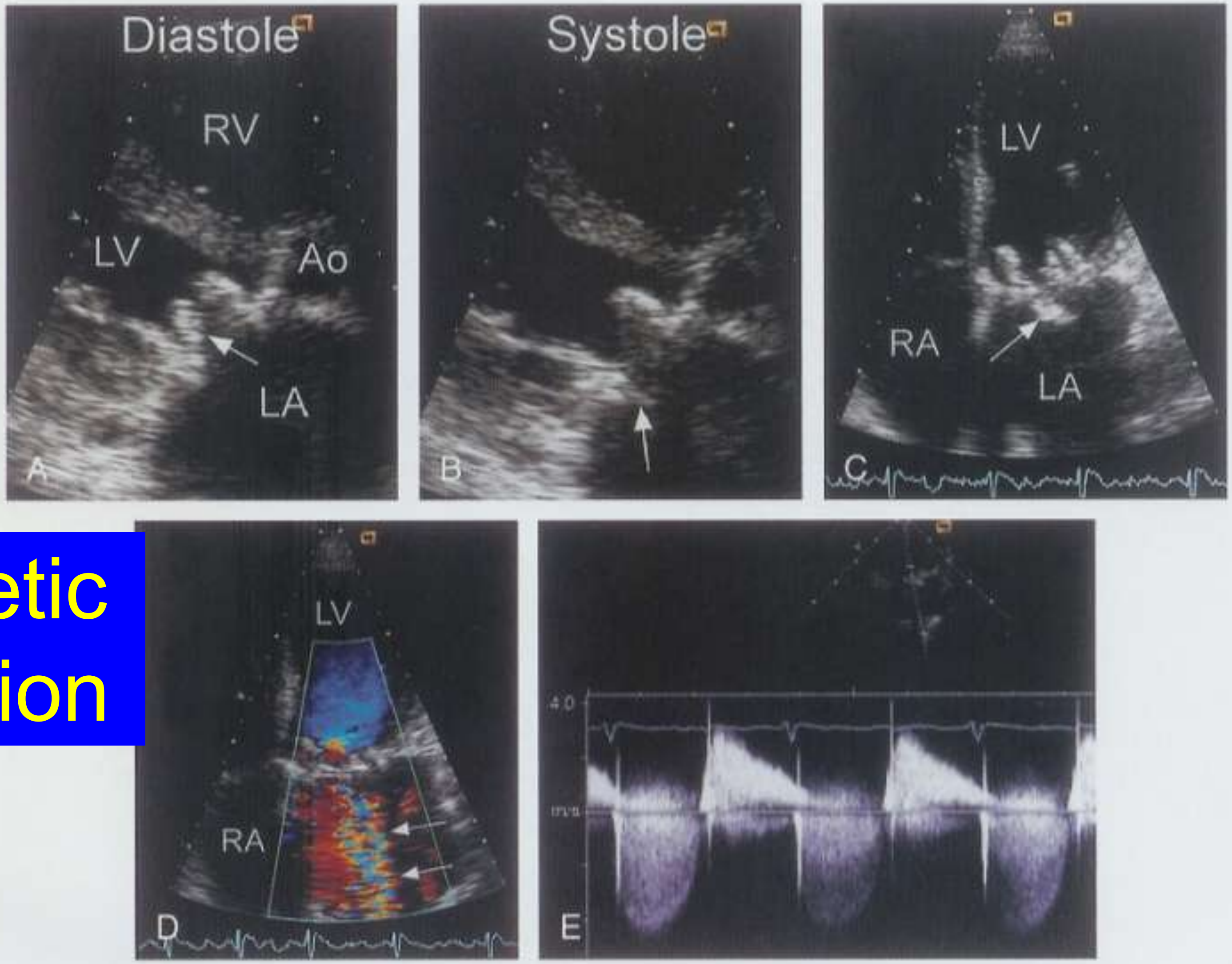

FIGURE 14.43. **A, B:** An example of primary tissue degeneration of a porcine mitral prosthesis is provided. **C:** The leaflets are markedly thickened and partially flail (*arrows*). **D:** Color Doppler imaging confirms severe mitral regurgitation (*arrows*). **E:** Continuous wave Doppler imaging demonstrates both stenosis and regurgitation. Ao, aorta; LA, left atrium; LV, left ventricle; RA, right atrium; RV, right ventricle.

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Striated Signal

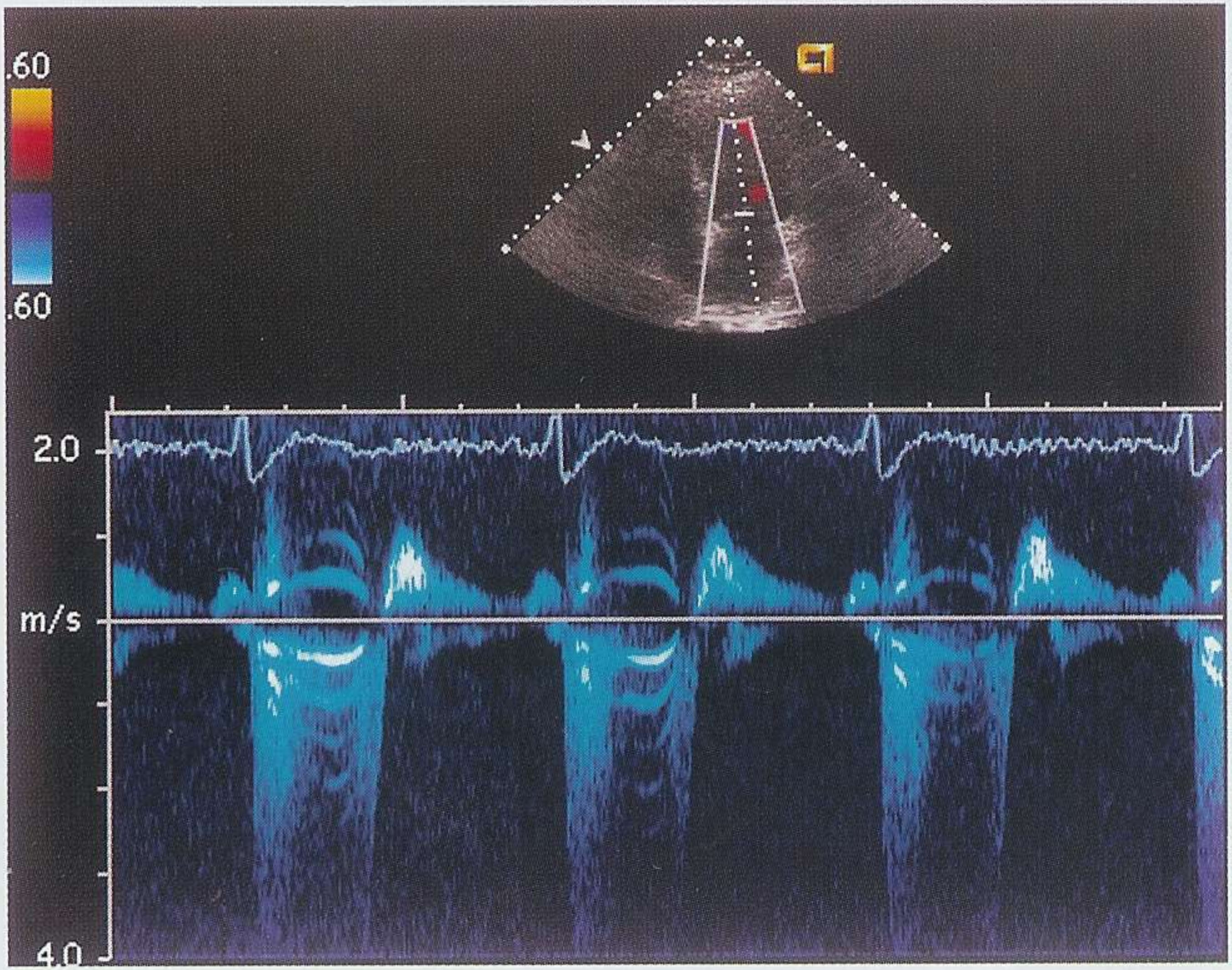

FIGURE 14.44. This particular signal may be recorded in the presence of a flail bioprosthetic valve. The unusual Doppler pattern may be the result of coarse fluttering of the flail leaflets.

Feigenbaum's Text; 6th ed, 2005, Ch. 14, Prosthetic Valves.

B: short pressure half time and high gradient indicating increased antegrade flow

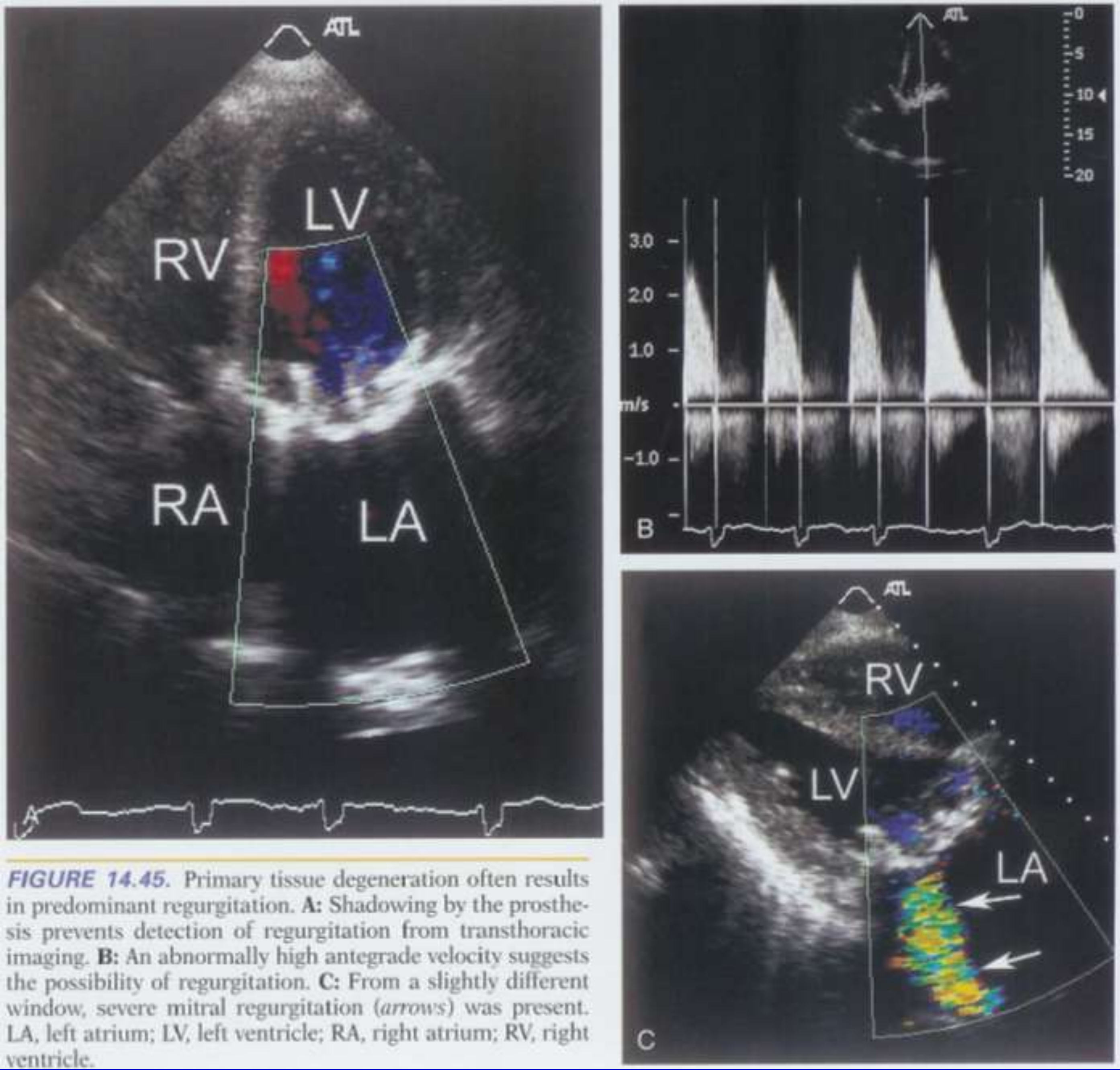

FIGURE 14.45. Primary tissue degeneration often results in predominant regurgitation. **A:** Shadowing by the prosthesis prevents detection of regurgitation from transthoracic imaging. **B:** An abnormally high antegrade velocity suggests the possibility of regurgitation. **C:** From a slightly different window, severe mitral regurgitation (*arrows*) was present. LA, left atrium; LV, left ventricle; RA, right atrium; RV, right ventricle.

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Obstruction of pulmonary homograft

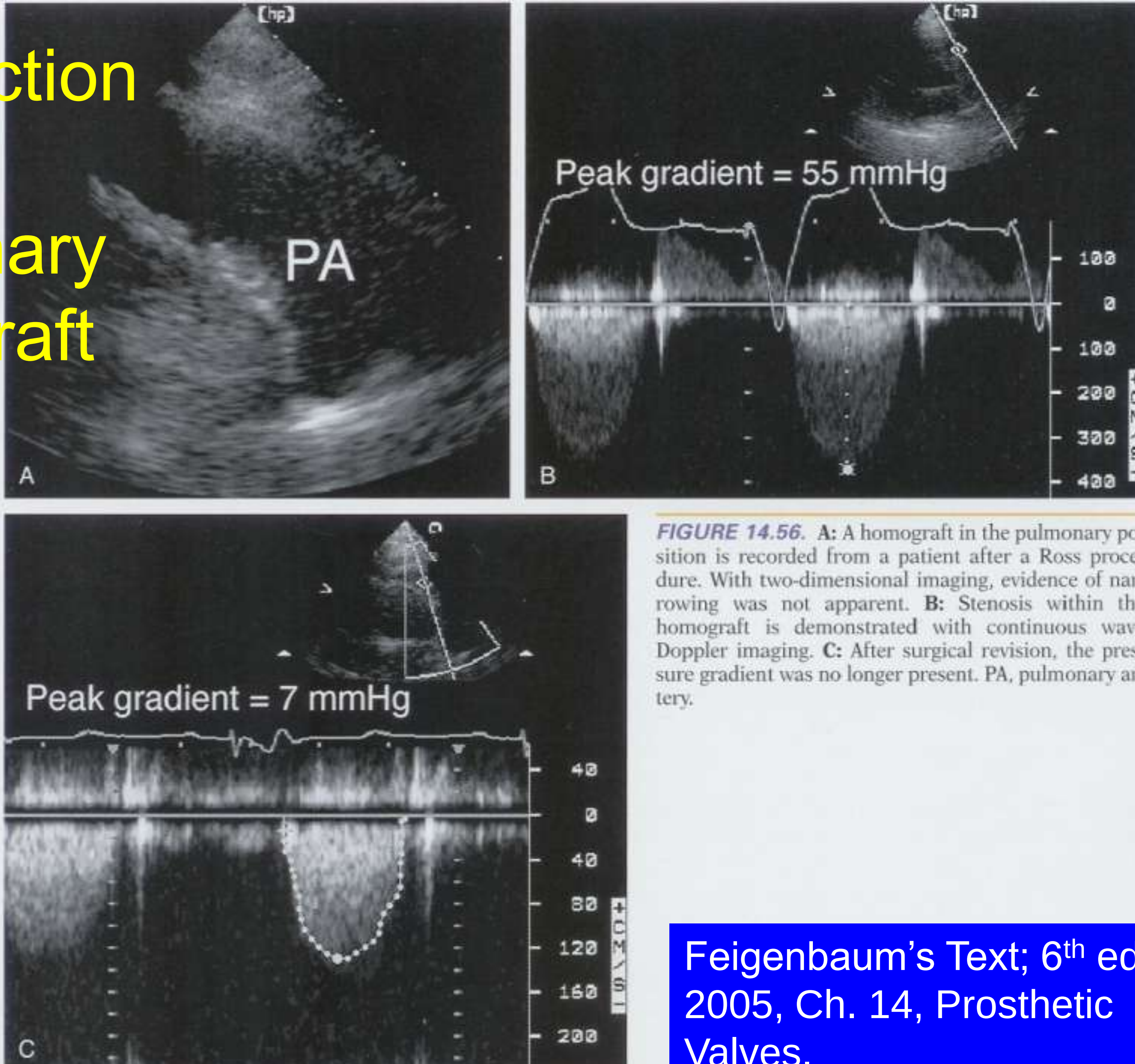

FIGURE 14.56. **A:** A homograft in the pulmonary position is recorded from a patient after a Ross procedure. With two-dimensional imaging, evidence of narrowing was not apparent. **B:** Stenosis within the homograft is demonstrated with continuous wave Doppler imaging. **C:** After surgical revision, the pressure gradient was no longer present. PA, pulmonary artery.

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Bentall repair

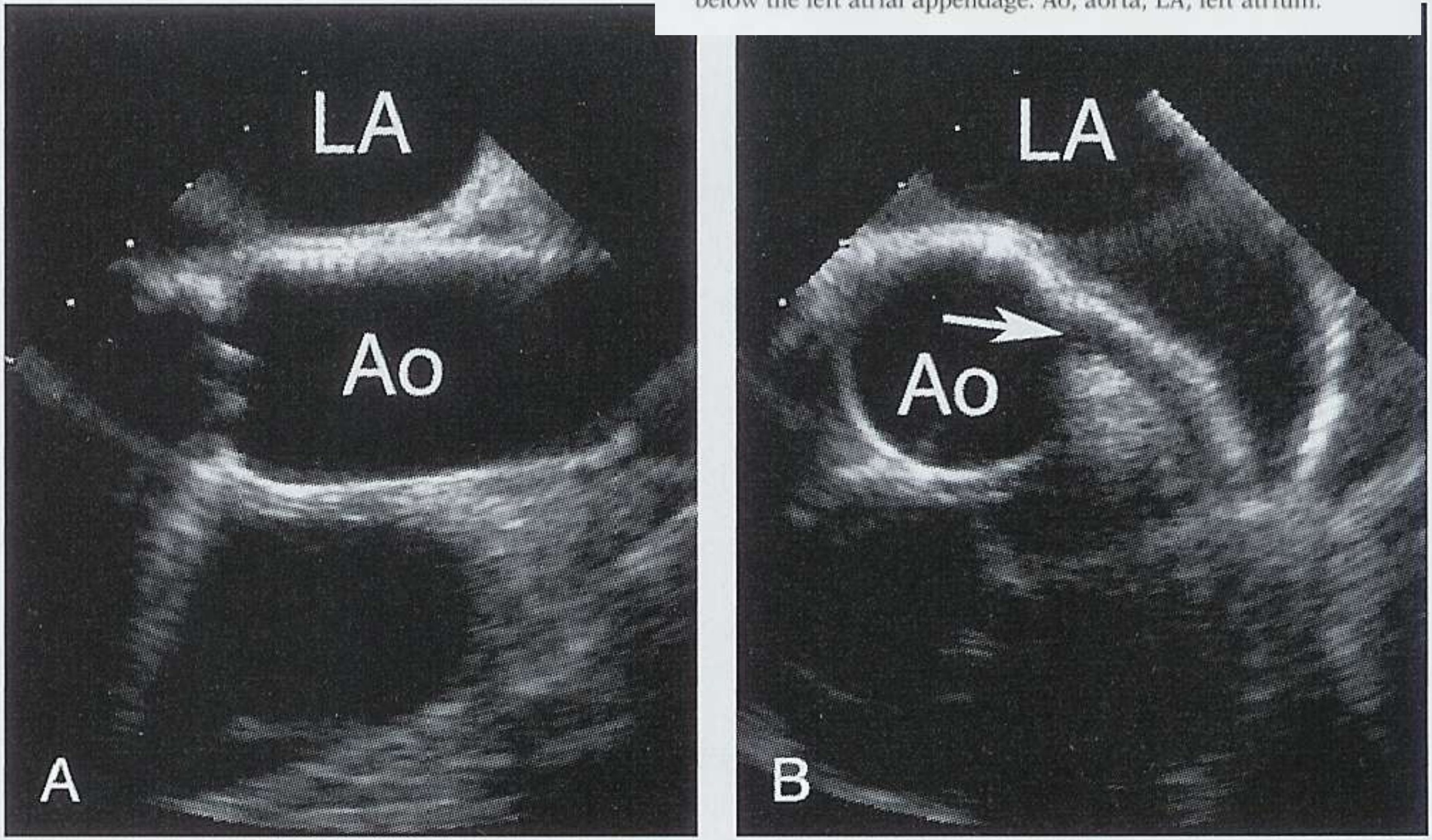

FIGURE 14.57. A Bentall repair of the aortic root is shown. **A:** The long-axis of the conduit is shown, and the highly echogenic walls of the prosthetic material are apparent. A disk-type mechanical prosthetic valve is shown. **B:** A short-axis view demonstrates the origin of the left coronary artery (*arrow*) just below the left atrial appendage. Ao, aorta; LA, left atrium.

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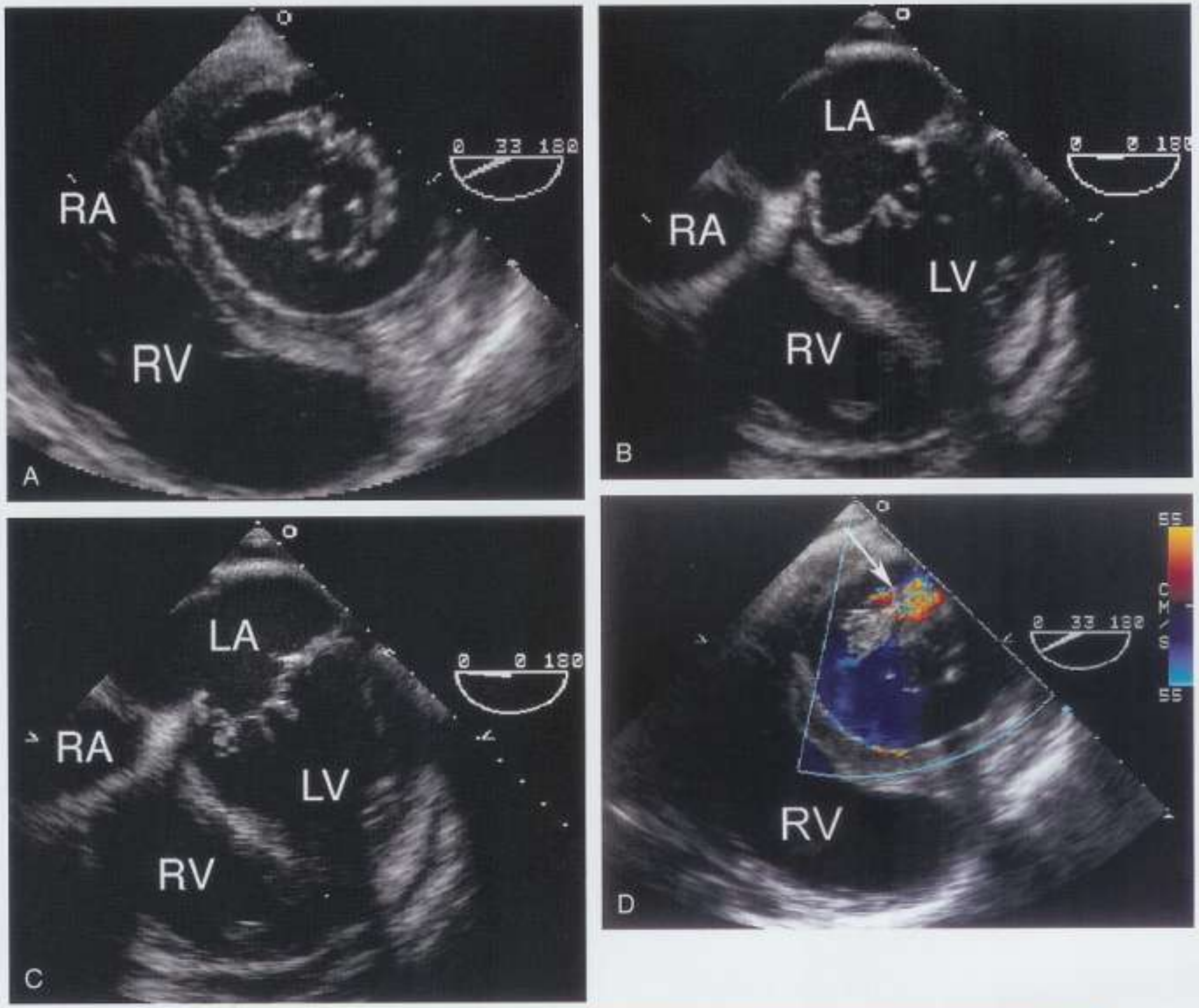

FIGURE 14.61. Mitral valve repair using the Alfieri stitch, or edge-to-edge repair, is demonstrated. In this case, a patient with mitral valve prolapse had severe mitral regurgitation. Scallops A2 and P2 were sewn together creating a double-orifice appearance to the mitral valve **(A–C)**. See text for details. In **D,** mild residual mitral regurgitation (*arrow*) is demonstrated. LA, left atrium; LV, left ventricle; RA, right atrium; RV, right ventricle.

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