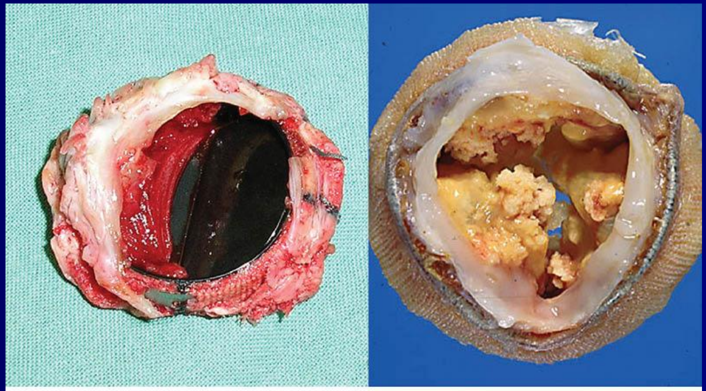
Dysfunction of the Prosthetic Valve : How to Evaluate



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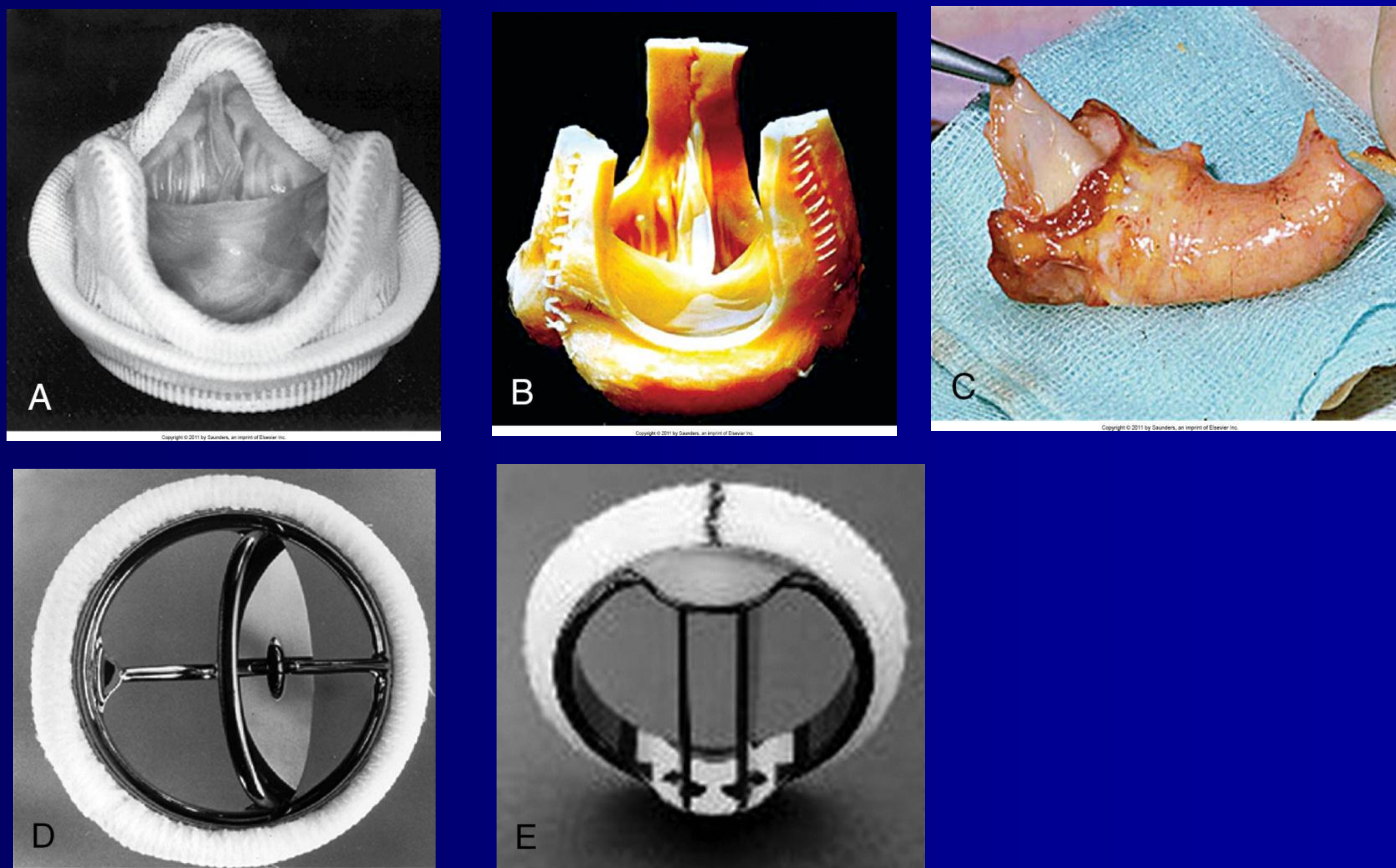
Prosthetic Valves



Prosthetic Valves

(From Kisslo J, Adams DB, Belkin RN: Doppler color flow imaging, 1988, Churchill Livingstone.)

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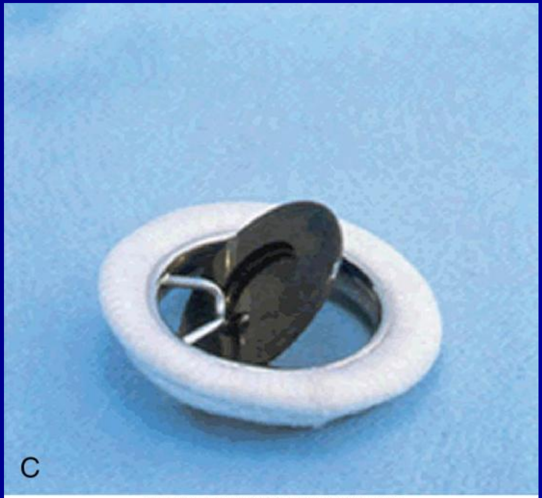

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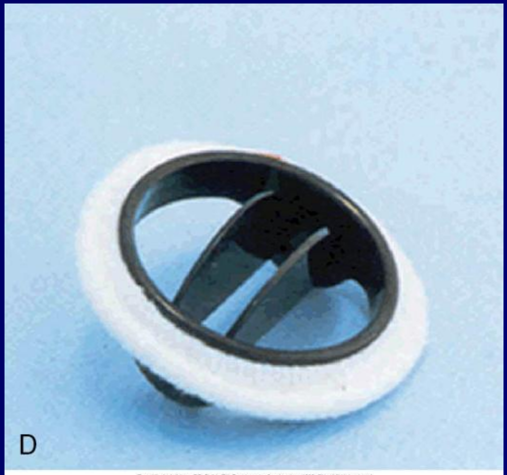

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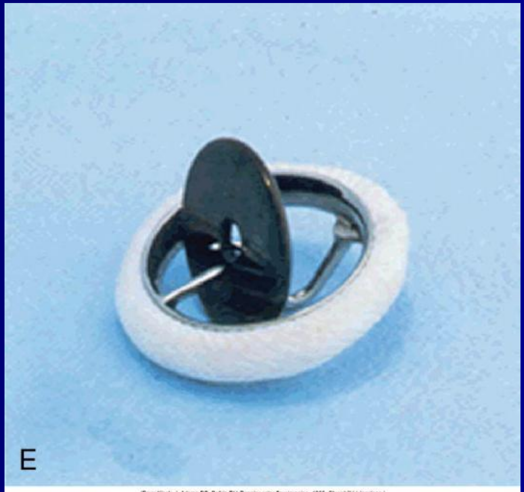

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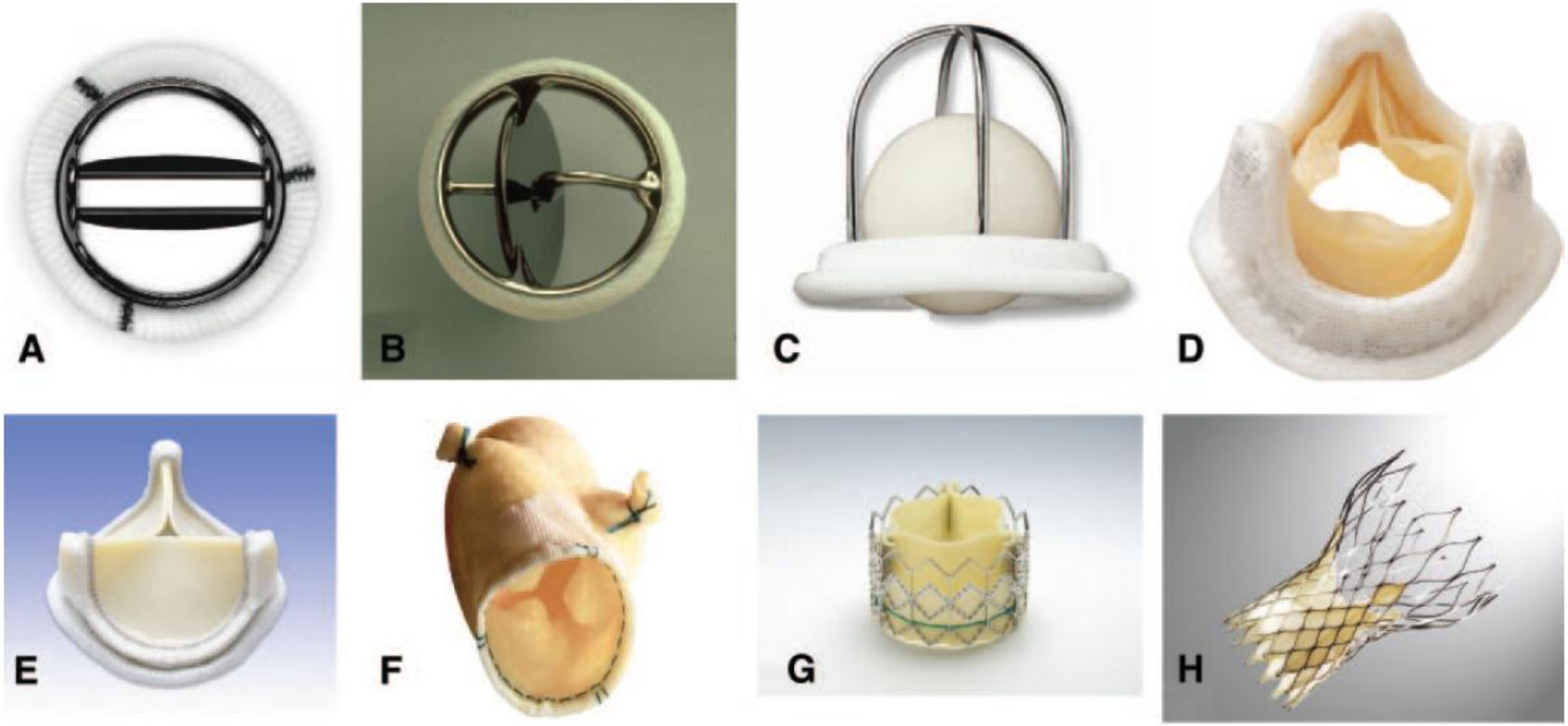


Figure 1. Different types of prosthetic valves. A, Bileaflet mechanical valve (St Jude); B, monoleaflet mechanical valve (Medtronic Hall); C, caged ball valve (Starr-Edwards); D, stented porcine bioprosthesis (Medtronic Mosaic); E, stented pericardial bioprosthesis (Carpentier-Edwards Magna); F, stentless porcine bioprosthesis (Medtronic Freestyle); G, percutaneous bioprosthesis expanded over a balloon (Edwards Sapien); H, self-expandable percutaneous bioprosthesis (CoreValve).

- **Table of Mechanical Valves**

CAGED BALL

Starr-Edwards
Smeloff-Cutter
Braunwald-Cutter
Magovern-Cromie

CAGED DISC

Beall
Cooley-Cutter
Kay-Shiley
Cross-Jones

TILTING DISC

Bjork-Shiley
Wada-Cutter
Lillehei-Kaster
Hall-Kaster
Medtronic-Hall

BILEAFLET

St. Jude
CarboMedics

Bioprosthetic Valves

HOMOGRAFTS (CADAVER VALVES)

Stented
Unstented

HETEROGRAFTS (DIFFERENT SPECIES)

Carpentier-Edwards (porcine)
Ionescu-Shiley (cow pericardium)

AUTOGRAFTS (PATIENT'S OWN TISSUE)

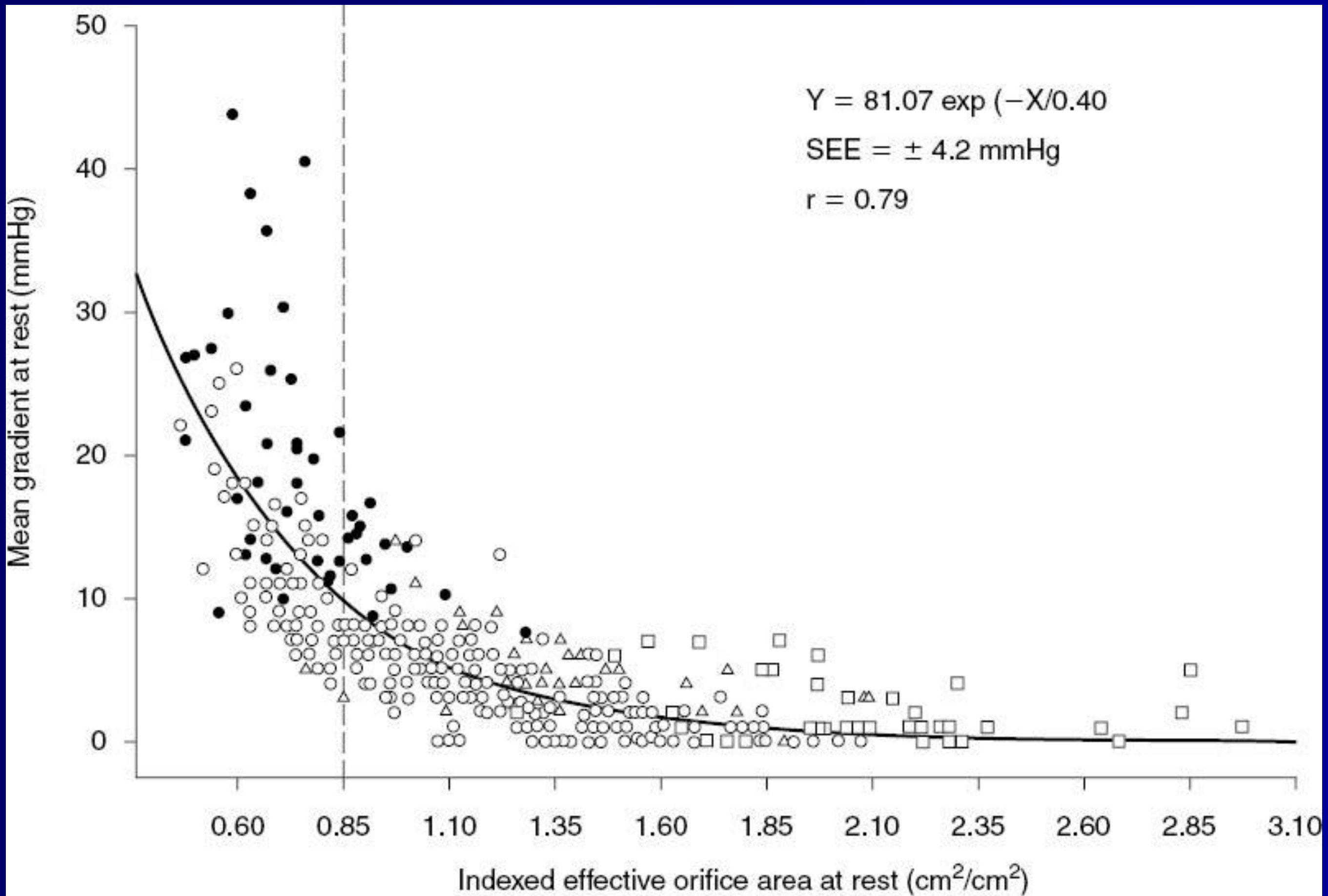
Ross procedure
Fascia lata

Valve Prosthesis-Patient Mismatch (PPM)

"Mismatch can be considered to be present when the effective prosthetic valve area, after insertion into the patient, is less than that of a normal human valve."

Rahimtoola 1978

- The EOA is a physiologic parameter derived from hydraulic principles and corresponds to the area occupied by flow as it exits the valve.
- The indexed effective orifice area (EOA) is the EOA of the prosthesis divided by the patient's body surface area (BSA).



(From Pibarot P, Dumesnil JG: Hemodynamic and clinical impact of prosthesis-patient mismatch in the aortic valve position and its prevention, J Am Coll Cardiol 2000; 36:1131-1141.)

		EOAi by Prosthesis size (mm)				
Prosthesis size (mm)	19	21	23	25	27	29
Average EOA (cm^2)	1.1	1.3	1.5	1.8	2.3	2.7
BSA (m^2)						
0.6	1.83	2.17	2.50	3.00	3.83	4.50
0.7	1.57	1.86	2.14	2.57	3.29	3.86
0.8	1.38	1.63	1.88	2.25	2.88	3.38
0.9	1.22	1.44	1.67	2.00	2.56	3.00
1	1.10	1.30	1.50	1.80	2.30	2.70
1.1	1.00	1.18	1.36	1.64	2.09	2.45
1.2	0.92	1.08	1.25	1.50	1.92	2.25
1.3	0.85	1.00	1.15	1.38	1.77	2.08
1.4	0.79	0.93	1.07	1.29	1.64	1.93
1.5	0.73	0.87	1.00	1.20	1.53	1.80
1.6	0.49	0.88	0.88	0.88	0.88	1.69
1.7	0.65	0.76	0.88	1.06	1.35	1.59
1.8	0.61	0.72	0.83	1.00	1.28	1.50
1.9	0.58	0.68	0.79	0.95	1.21	1.42
2	0.55	0.65	0.75	0.90	1.15	1.35
2.1	0.52	0.62	0.71	0.86	1.10	1.29
2.2	0.50	0.59	0.68	0.82	1.05	1.23
2.3	0.48	0.57	0.65	0.78	1.00	1.17
2.4	0.46	0.54	0.63	0.75	0.96	1.13
2.5	0.44	0.52	0.60	0.72	0.92	1.08

(From Pibarot P, Dumesnil JG: Prosthesis-patient mismatch: definition, clinical impact, and prevention, Heart 92(8):1022-1029, 2006.)

Table 1. Normal Reference Values of EOAs for the Aortic Prostheses

	Prosthetic Valve Size, mm						
	19	21	23	25	27	29	Reference
Aortic stented bioprosthesis							
Mosaic	1.1±0.2	1.2±0.3	1.4±0.3	1.7±0.4	1.8±0.4	2.0±0.4	10
Hancock II	...	1.2±0.1	1.3±0.2	1.5±0.2	1.6±0.2	1.6±0.2	10
Carpentier-Edwards Perimount	1.1±0.3	1.3±0.4	1.50±0.4	1.80±0.4	2.1±0.4	2.2±0.4	10
Carpentier-Edwards Magna*	1.3±0.3	1.7±0.3	2.1±0.4	2.3±0.5	...	...	11, 20
Biocor (Epic)*	...	1.3±0.3	1.6±0.3	1.8±0.4	...	...	12
Mitroflow*	1.1±0.1	1.3±0.1	1.5±0.2	1.8±0.2	...	...	13
Aortic stentless bioprosthesis							
Medtronic Freestyle	1.2±0.2	1.4±0.2	1.5±0.3	2.0±0.4	2.3±0.5	...	10
St Jude Medical Toronto SPV	...	1.3±0.3	1.5±0.5	1.7±0.8	2.1±0.7	2.7±1.0	10
Aortic mechanical prostheses							10
Medtronic-Hall	1.2±0.2	1.3±0.2	...	...	...	...	10
Medtronic Advantage*	...	1.7±0.2	2.2±0.3	2.8±0.6	3.3±0.7	3.9±0.7	14
St Jude Medical Standard	1.0±0.2	1.4±0.2	1.5±0.5	2.1±0.4	2.7±0.6	3.2±0.3	10
St Jude Medical Regent	1.6±0.4	2.0±0.7	2.2±0.9	2.5±0.9	3.6±1.3	4.4±0.6	27
MCRI On-X	1.5±0.2	1.7±0.4	2.0±0.6	2.4±0.8	3.2±0.6	3.2±0.6	27
Carbomedics Standard	1.0±0.4	1.5±0.3	1.7±0.3	2.0±0.4	2.5±0.4	2.6±0.4	10

EOA is expressed as mean values available in the literature.
*These results are based on a limited number of patients and thus should be interpreted with caution.

Table 2. Normal Reference Values of EOAs for the Mitral Prostheses

	Prosthetic Valve Size, mm					
	25 mm	27 mm	29 mm	31 mm	33 mm	Reference
Stented bioprosthesis						
Medtronic Mosaic	1.5±0.4	1.7±0.5	1.9±0.5	1.9±0.5	...	15, 28
Hancock II	1.5±0.4	1.8±0.5	1.9±0.5	2.6±0.5	2.6±0.7	29
Carpentier-Edwards Perimount*	1.6±0.4	1.8±0.4	2.1±0.5	...	...	28
Mechanical prostheses						
St Jude Medical Standard	1.5±0.3	1.7±0.4	1.8±0.4	2.0±0.5	2.0±0.5	28
MCRI On-X†	2.2±0.9	2.2±0.9	2.2±0.9	2.2±0.9	2.2±0.9	28

EOA is expressed as mean values available in the literature.

*These results are based on a limited number of patients and thus should be interpreted with caution.

†The strut and leaflets of the MCRI On-X valve are identical for all sizes (25 to 33 mm).

Table 3. Threshold Values of Indexed Prosthetic Valve EOA for the Identification and Quantification of PPM

	Mild or Not Clinically Significant, cm^2/m^2	Moderate, cm^2/m^2	Severe, cm^2/m^2
Aortic position	>0.85 (0.8–0.9)	≤ 0.85 (0.8–0.9)	≤ 0.65 (0.6–0.7)
Mitral position	>1.2 (1.2–1.3)	≤ 1.2 (1.2–1.3)	≤ 0.9 (0.9)

Numbers in parentheses represent the range of threshold values that have been used in the literature.

PPM: Major adverse clinical outcomes

- Less improvement in symptoms and functional class
- Higher incidence of congestive heart failure
- Higher incidence of late cardiac events
- Less regression of left ventricular hypertrophy
- Moderate impact on late (>7 years) mortality
- Major impact on early mortality, particularly in patients with poor ventricular function

- 1266 consecutive patients found a perioperative mortality rate of 67% in patients with the combined evidence of severe PPM and an ejection fraction <40% compared with only 3% in patients with no PPM and ejection fraction >40% and intermediate mortality rates in other subgroups.

- Patients with PPM who survive the operation may remain relatively asymptomatic, but their long-term event-free survival is definitely less than patients without PPM.
- More prospective series are needed to determine proper management and surveillance in asymptomatic patients with PPM.

Prevention of PPM

Step 1. Calculate the patient's BSA from the patient's height and weight.

Step 2. Multiply the BSA by 0.85 cm^2/m^2; the result provides the minimal EOA for the prosthesis to be implanted to avoid PPM.

Step 3. Choose the prosthesis in light of the result obtained in step 2 and the reference values for the different types and sizes of prosthesis

Option 1. Implant another type of prosthesis with a larger EOA, such as a stentless bioprosthesis, a mechanical prosthesis of a new generation, or an aortic homograft.

Option 2. Perform an aortic root enlargement to accommodate a larger prosthesis of the same type.

Option 3. Accept the PPM in light of other clinical conditions. The alternative options to avoid PPM (options 1 and 2) should certainly be considered in light of the patient's clinical condition and overall risk/benefit ratio.

- If the projected indexed EOA is 0.75 to 0.80 cm2/m2 in a patient who is sedentary and has good left ventricular function and it is believed that option 1 or 2 would significantly increase the operative or overall risk, it is possible that accepting this level of PPM is the best option for this particular patient.

- If, on the other hand, the clinician projects severe PPM or if the patient has poor left ventricular function, the risks associated with PPM would be much higher and would probably outweigh any additional risks associated with options 1 and 2.

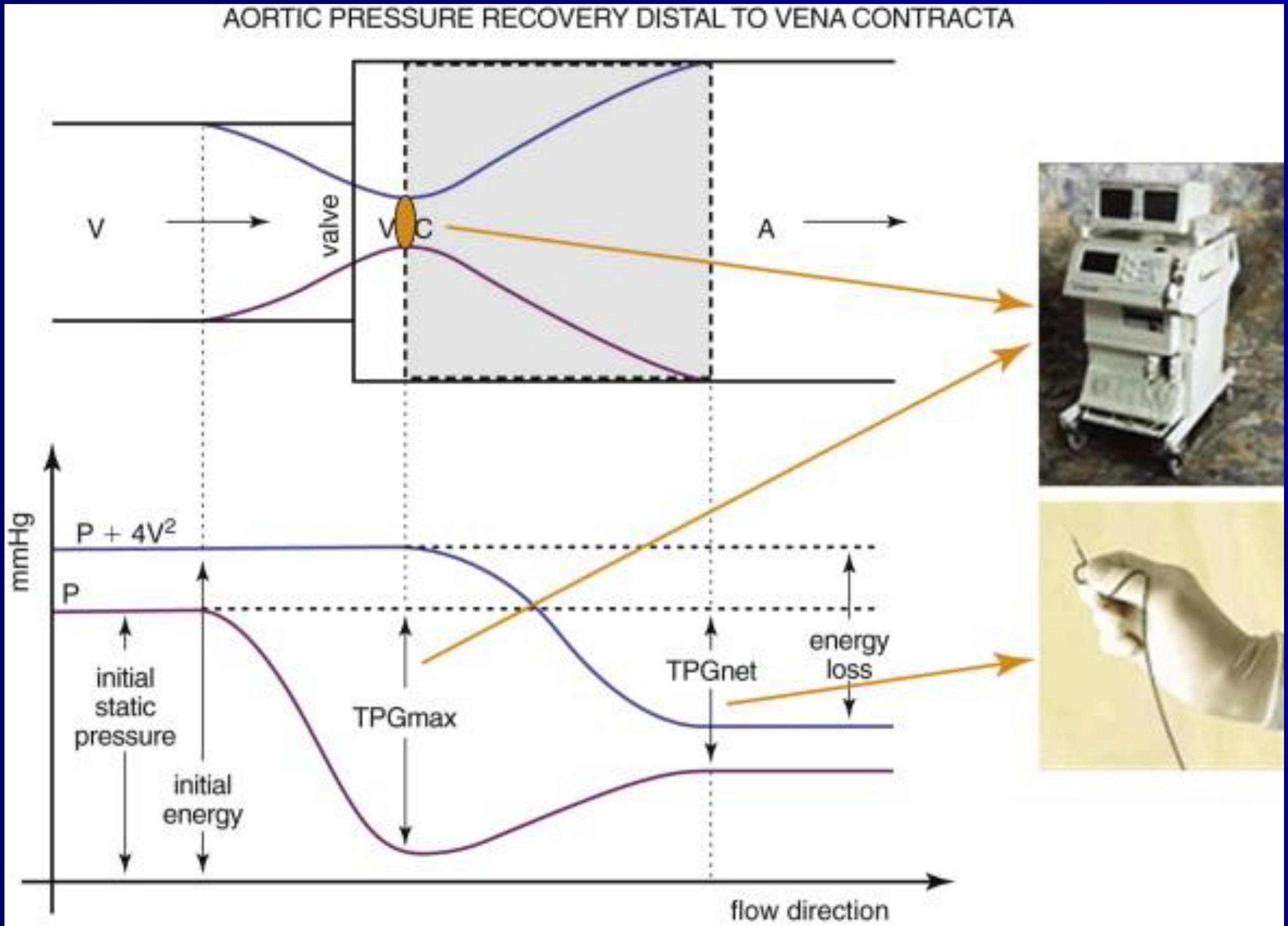
- This prospective strategy was used by Castro et al. in 657 consecutive patients in whom an aortic root enlargement (option 2) was performed whenever the indexed EOA was projected to be <0.85 cm2/m2. As a result, the overall incidence of PPM in this series was only 2.5% instead of the 17% that would have occurred had the prospective strategy not been used.

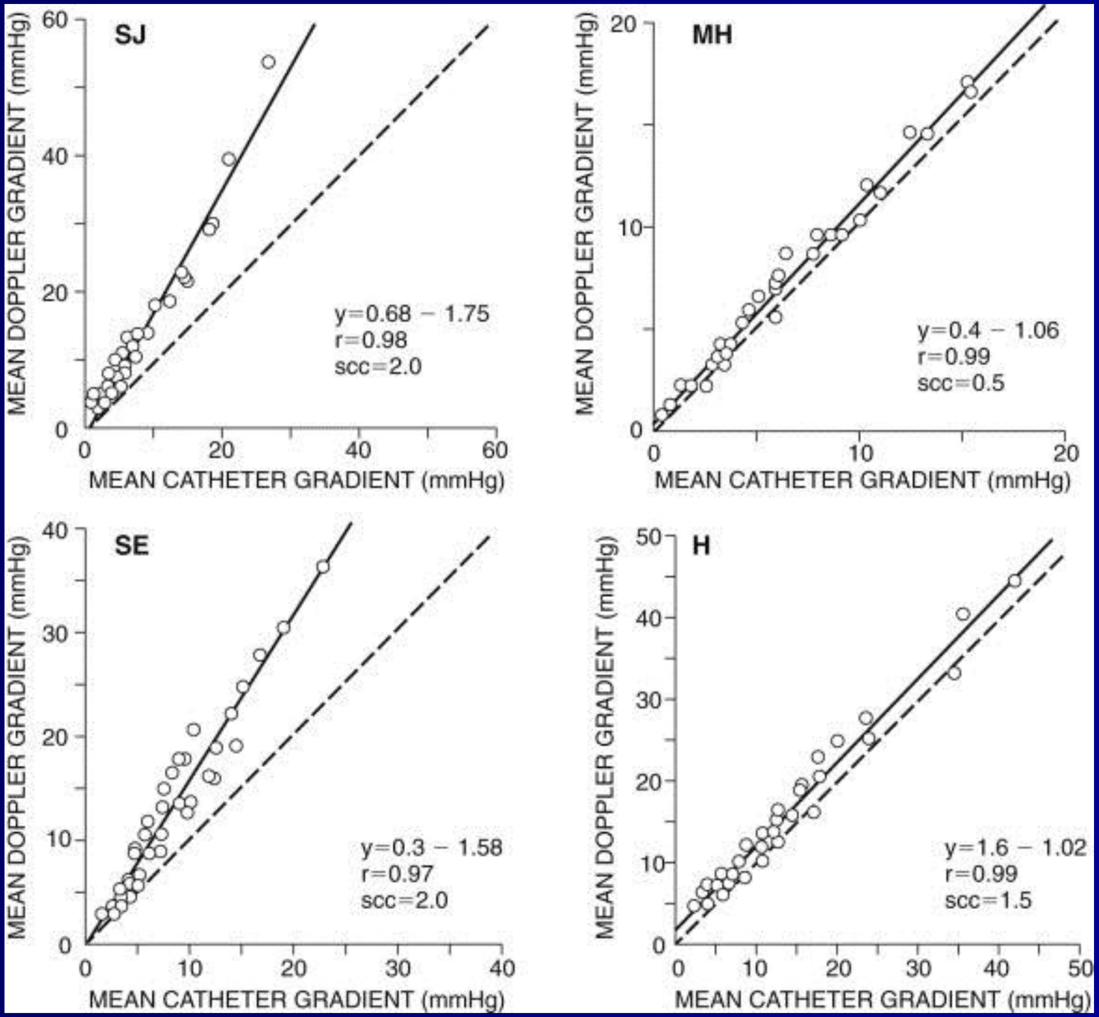
- Moreover, operative mortality rate was not increased as a result of the root enlargement that was performed using a novel technique consisting of the insertion of a patch made of Hemashield (Boston Scientific, Natick, MA).
- These results demonstrate that the prospective strategy to avoid PPM is feasible and can be applied with success.

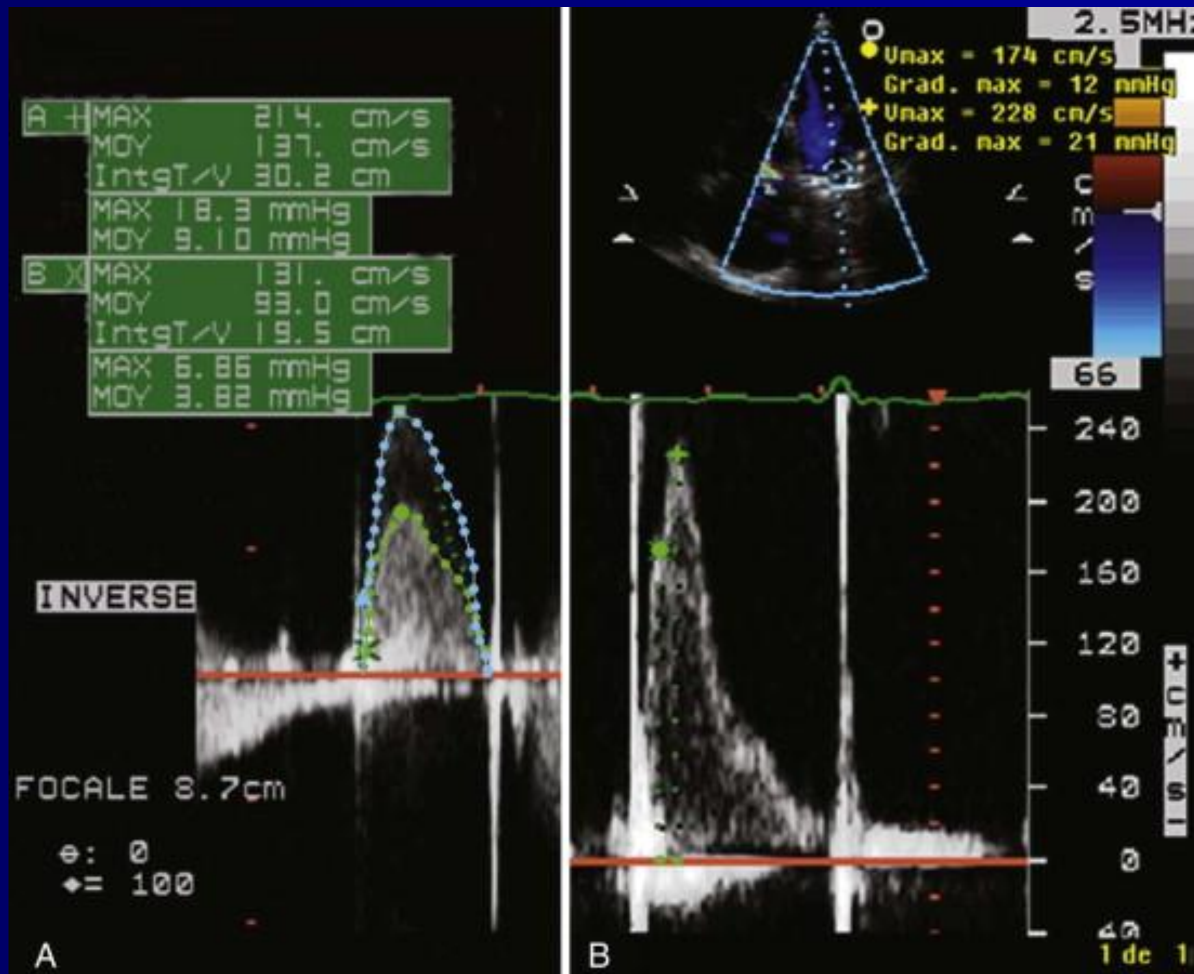
Conclusion

- PPM is a frequent and modifiable risk factor leading to worse hemodynamics, less regression of left ventricular hypertrophy, increased cardiac events, and lower survival rates. It can theoretically be avoided by the use of a prospective strategy before operation.

Pressure recovery




SJ
MEAN DOPPLER GRADIENT (mmHg)
MEAN CATHETER GRADIENT (mmHg)
y=0.68 − 1.75
r=0.98
scc=2.0
MH
MEAN DOPPLER GRADIENT (mmHg)
MEAN CATHETER GRADIENT (mmHg)
y=0.4 − 1.06
r=0.99
scc=0.5
SE
MEAN DOPPLER GRADIENT (mmHg)
MEAN CATHETER GRADIENT (mmHg)
y=0.3 − 1.58
r=0.97
scc=2.0
H
MEAN DOPPLER GRADIENT (mmHg)
MEAN CATHETER GRADIENT (mmHg)
y=1.6 − 1.02
r=0.99
scc=1.5


A
MAX 214. cm/s
MOY 137. cm/s
IntgT/V 30.2 cm
MAX 18.3 mmHg
MOY 9.10 mmHg
B
MAX 131. cm/s
MOY 93.0 cm/s
IntgT/V 19.5 cm
MAX 6.86 mmHg
MOY 3.82 mmHg
INVERSE
FOCALE 8.7cm
θ: 0
◆= 100
A
2.5MHz
Vmax = 174 cm/s
Grad. max = 12 mmHg
Vmax = 228 cm/s
Grad. max = 21 mmHg
cm/s
66
240
200
160
120
80
40
0
40
+ cm/s −
B
1 de 1

- Pressure recovery at the level of the aorta may explain small discrepancies between invasive and noninvasive measurements of gradients and EOA calculation.
- However, the clinical implications of such discrepancies are limited.

- The EOA calculated from the continuity equation is the best parameter to evaluate intrinsic prosthesis function and predict clinical outcomes.
- Bileaflet mechanical prostheses, due to their particular design, may present with artificially high gradients and small EOA by Doppler resulting from a phenomenon of pressure recovery at the valvular level.

- The latter situation is not always observed but should be suspected when the calculated EOA is significantly lower than the reference value for the same type and size of prosthesis.
- In such cases, prosthesis dysfunction can be excluded by evaluating leaflet mobility with either valve fluoroscopy or transesophageal echocardiography.

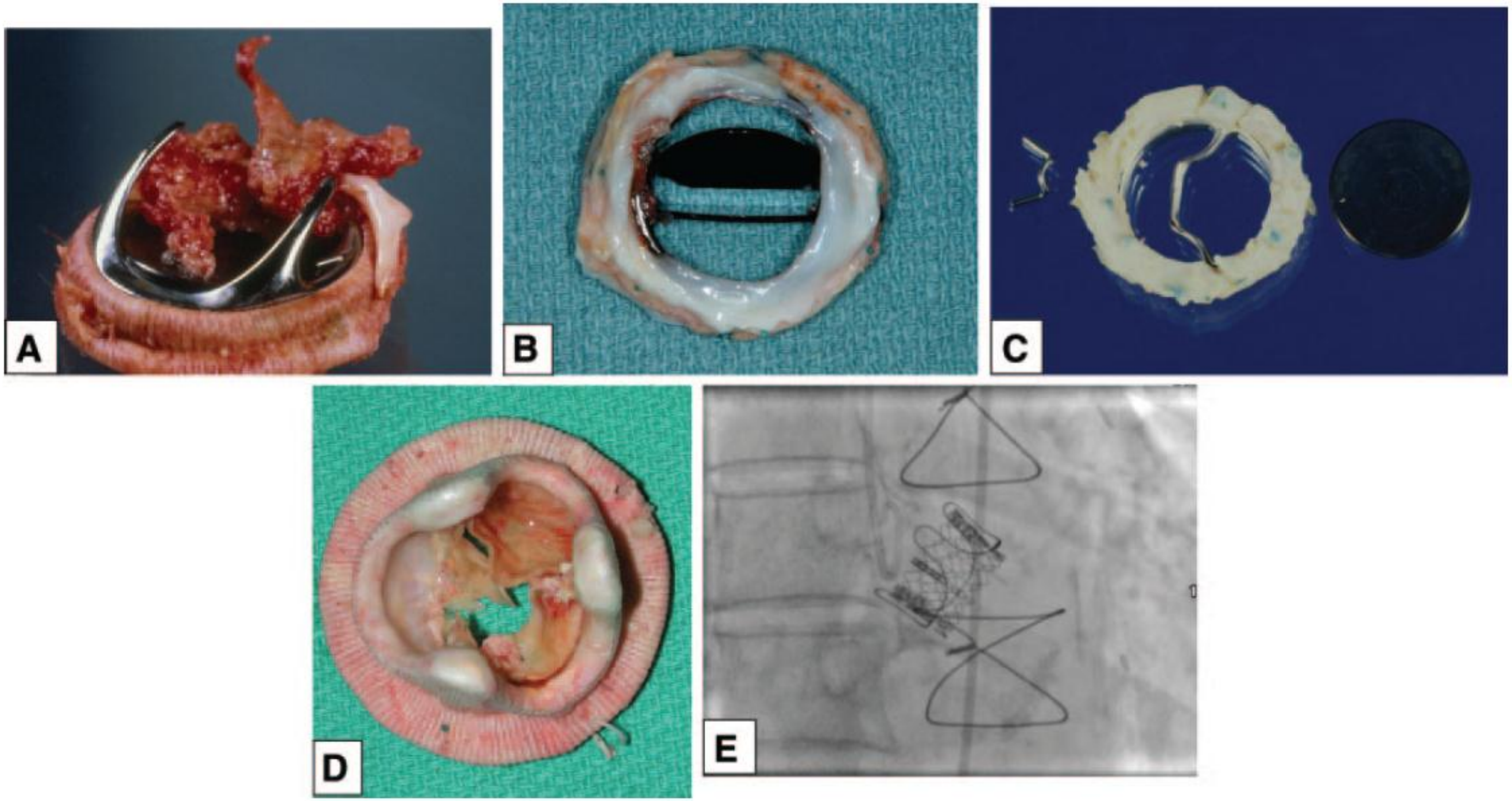


Figure 6. Prosthetic valves explanted for severe dysfunction. A, Obstructive thrombosis of a Lillehei-Kaster prosthesis. B, Pannus ingrowth interacting with leaflet opening in a St Jude Medical bileaflet valve. C, Rupture of the outlet strut and leaflet escape in a Björk-Shiley prosthesis. D, Leaflet calcific degeneration and tear in a porcine bioprosthesis. E, One of the first in-human valve-in-valve cases. A Sapien-Edwards percutaneous valve is implanted within a failed aortic Carpentier-Edwards Perimount bioprosthesis (6-month follow-up). Courtesy of Drs Jacques Métras (A, C) and Christian Couture (B), Laval Hospital, Québec, Canada; Gosta Petterson, Cleveland Clinic, Cleveland, Ohio (D); and John Webb, St Paul's Hospital, Vancouver, BC, Canada (E).

Structural Valve Degeneration (SVD)

- Progressive leaflet calcification develops in bioprosthetic valves; the incidence of significant valvular dysfunction accelerates 10 to 15 years after implantation.
- The incidence varies with the age of the patient SVD after aortic valve replacement is 60% at 10 years in patients 16 to 39 years of age compared with ≤15% at 15 years in patients ≥70 years) and is higher in mitral bioprosthetic valves.

- Allograft aortic valves inserted using the root replacement technique and stentless heterografts may have improved durability, but longer follow-up studies (>15 years) are required for confirmation. Regurgitation is the dominant form of dysfunction; stenosis is quite rare video

Valve Thrombosis

- Mechanical valves are more thrombogenic than bioprostheses, resulting in an increased risk of both thromboembolism and thrombotic valve obstruction.
- The reported incidence of prosthetic valve thrombosis varies widely from 0.1% to 0.6% per patient-year for left-sided valves.

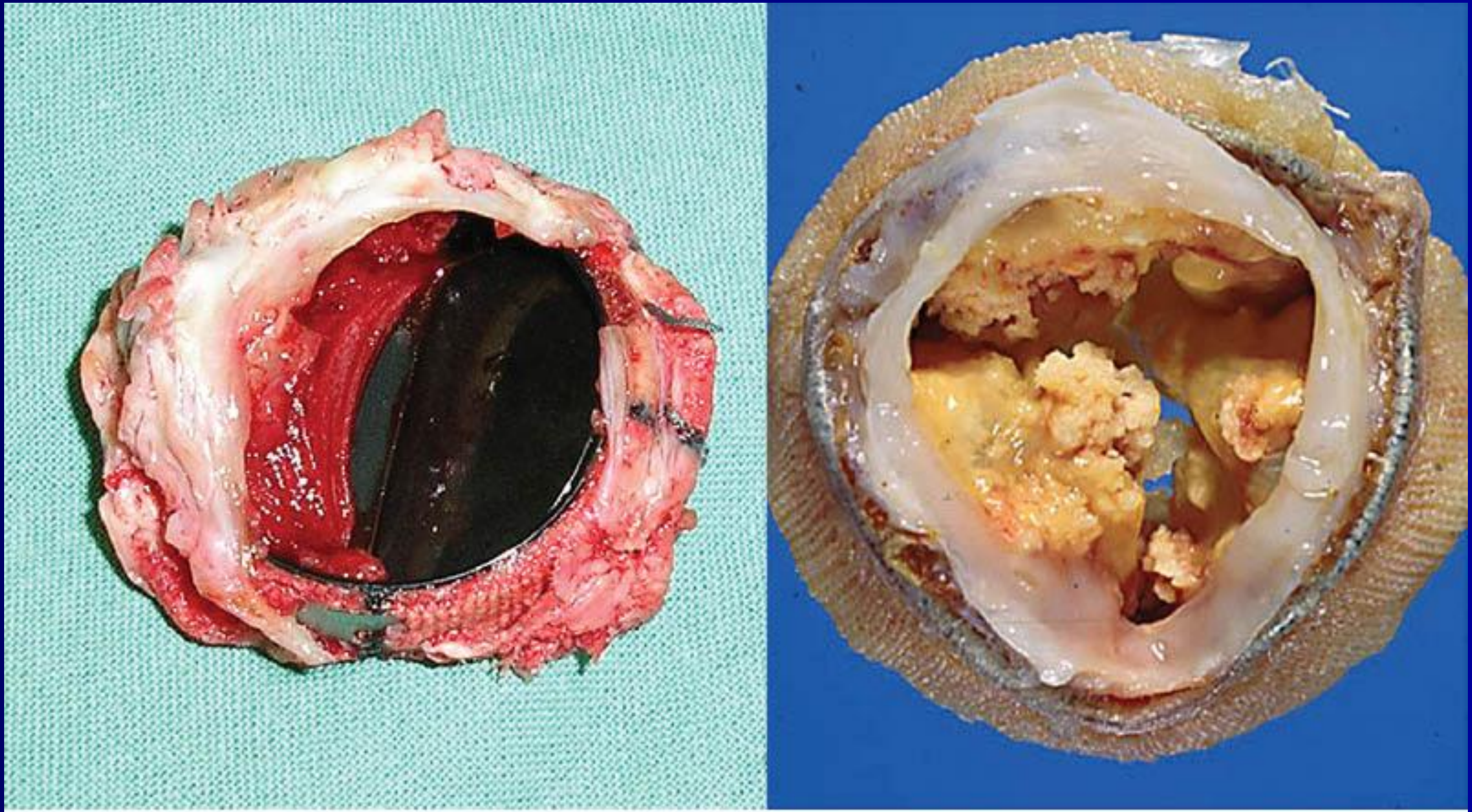
Major factors contributing to thrombosis

- inadequate anticoagulation
- a mitral location of the prosthetic valve
- and likely other patient-related factors

- The clinical presentation depends on the severity of valve obstruction and may vary from systemic embolism without hemodynamic abnormality to heart failure or even cardiogenic shock.

Pannus

- The slow ingrowth of fibrous tissue over the sewing ring in both mechanical and bioprosthetic valves.
- This abnormal overexuberant fibrous reaction usually develops over many years and may interfere with occluder/leaflet motion and narrow the inflow orifice of the prosthesis.
- Secondary thrombus formation can also occur.



Echocardiographic Assessment of Prosthetic Valve Function

Two-Dimensional Imaging

- The type and size of the valve should be established
- Assessment of chamber sizes and ventricular function
- Intermediate imaging planes are often useful to minimize shielding of the ultrasound beam by prosthesis
- Are the bioprosthetic leaflets thickened (1 to 1.2 mm)?

Two-Dimensional Imaging

- Is leaflet/occluder motion normal? (Compare with an opening angle in tilting disc and bileaflet prostheses.)
- Is there any abnormal motion of the valve bed?

Doppler Examination

- Good definition of the left ventricular outflow tract (LVOT) in the parasternal long-axis view for measurement of LVOT diameter
- PW Doppler in LVOT from the apical long-axis view for measurement of LVOT time velocity integral

Doppler Examination

- CW Doppler recording of aortic flow velocity through the prosthetic valve using multiple windows to ensure maximum velocity has been obtained
- The aortic regurgitation (AR) signal should be recorded, if present, for measurement of the AR pressure half-time

Doppler Examination

- Color flow imaging from parasternal long- and short-axis and apical windows should be performed to assess the presence, site, and severity of AR
- PW Doppler in the proximal descending thoracic aorta to detect diastolic flow reversal.

Doppler Examination

- Peak velocity (*V2*) and maximal gradient derived by the Bernoulli equation, $\Delta P = 4(V22 - V12)$, where *V2* is the peak velocity across the aortic prosthetic valve and *V1* is the peak velocity immediately proximal to the valve.
- Mean gradient

Doppler Examination

- Doppler performance index (DPI) = Peak LVOT velocity (*V1*)/Peak atrioventricular velocity (*V2*).
- Effective orifice area (EOA) (expressed in square centimeters) using the continuity equation

Doppler Examination

- Depending on the orientation of the mitral prosthesis, para-apical or parasternal views may be superior.
  - Guide CW Doppler with color flow imaging.
  - CW Doppler of the mitral regurgitation jet, if present, should look for strength of signal and signal contour.

Doppler Examination

- Color flow imaging to detect mitral regurgitation is difficult because of reverberation and acoustic shadowing.
- Both mitral inflow and “normal” regurgitation have distinctive patterns depending on valve design.

Doppler Examination

- Because of shadowing and attenuation in the left atrium associated with PMVs, a high level of suspicion is needed to assess the presence of prosthetic MR, particularly in mechanical valves. Clues to the presence of significant regurgitation are derived predominantly from the Doppler examination.

Doppler Examination

- The threshold to perform a TEE in these conditions should be low and is modulated by the clinical presentation and the presence of indirect Doppler echocardiographic signs of MR from the transthoracic examination.

The diagnosis of *aortic valve obstruction*

- Increased gradients for valve subtype and size
- Decreased EOA and DPI below the normal reference range
- Significant deviation of EOA or DPI from the baseline study

High Doppler Gradients in Small Bileaflet Prostheses

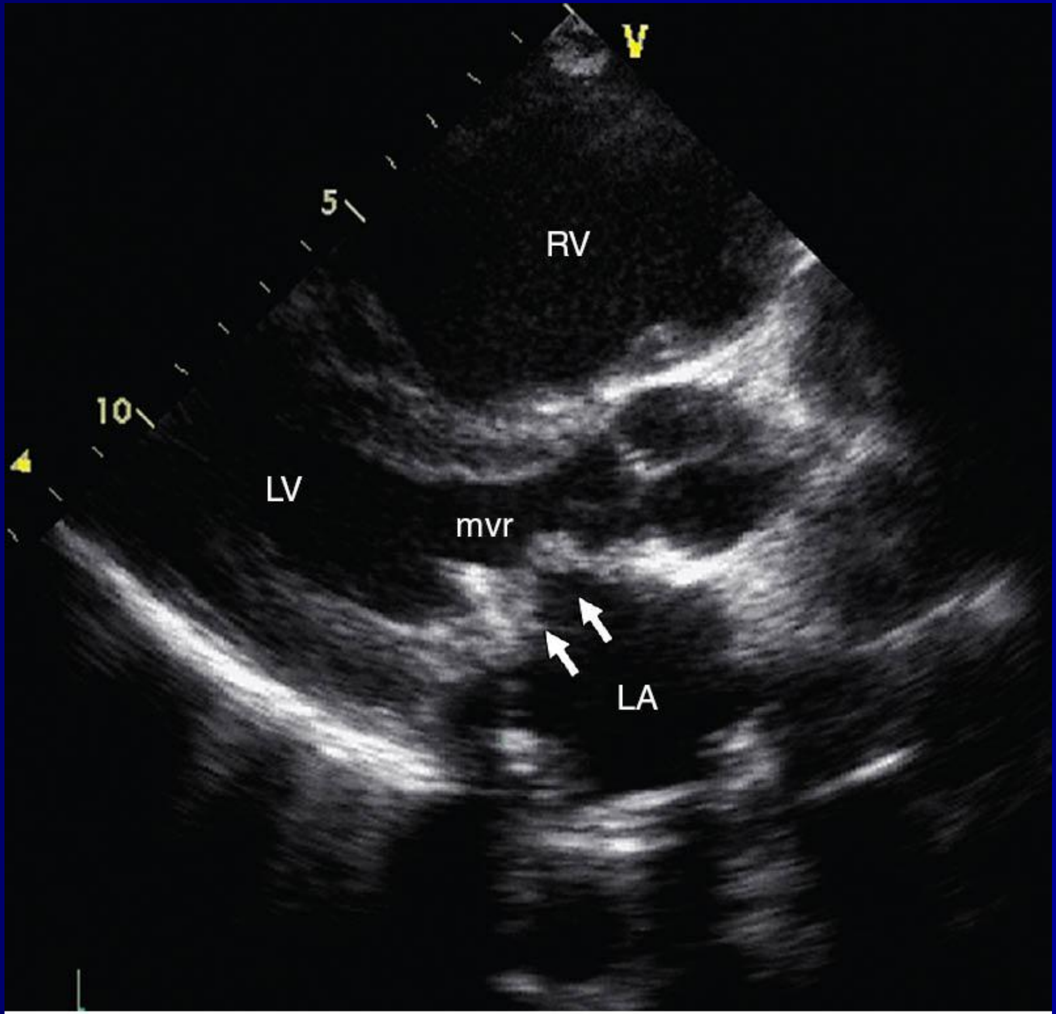
- The unique bileaflet design is characterized by localized high velocities within the divergent central orifice. In addition, there is rapid pressure recovery within the aorta immediately distal to the prosthetic valve; this phenomenon may be further exaggerated if the aorta is of small diameter.

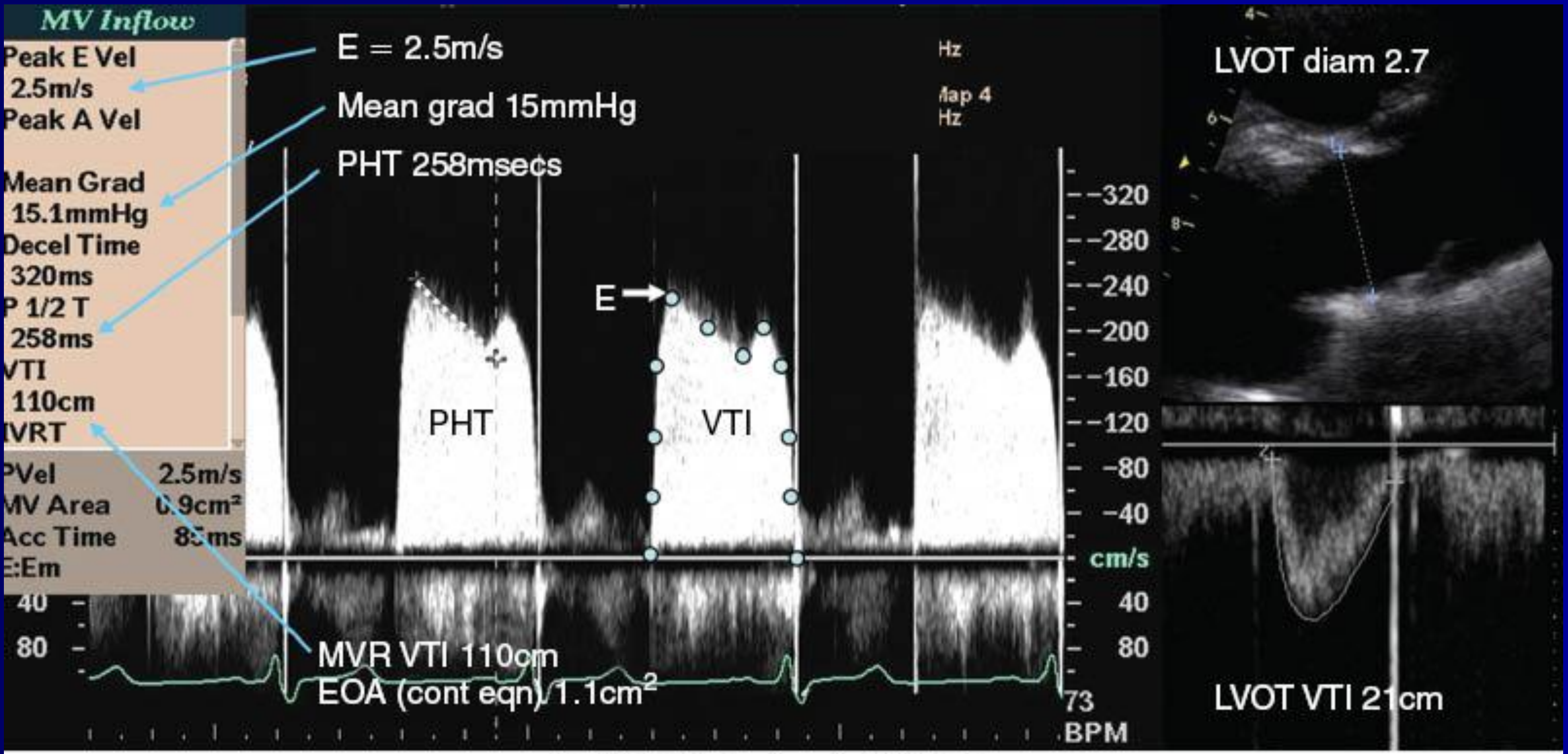
- This can result in high recorded Doppler gradients (typically with the small 19- and 21-mm valve sizes), which are significantly higher than those recorded by conventional cardiac catheterization techniques. If a small aortic root is present, equations have been developed to correct for pressure recovery.

Doppler Parameters Used to Assess Mitral Prosthetic Valve Function

- Peak early mitral inflow velocity (*E)*
- Mean gradient
- Pressure half-time
- The mitral valve effective orifice area (EOA) is determined by the continuity equation (no aortic or mitral regurgitation). EOA (cm2) = [CSA*LVOT* × VTI*LVOT*]/VTI*PMV*, where *CSA* is the cross-sectional area, *LVOT* is the left ventricular outflow tract, *VTI* is the velocity-time integral, and *PMV* is the prosthetic mitral valve.

- The mitral valve EOA, when derived using the PHT method as for native mitral valve stenosis, has never been validated for mitral prostheses and does not correlate closely with other measures of EOA.


V
5
10
RV
LV
mvr
LA


MV Inflow
Peak E Vel
2.5m/s
Peak A Vel
Mean Grad
15.1mmHg
Decel Time
320ms
P 1/2 T
258ms
VTI
110cm
IVRT
PVel 2.5m/s
MV Area 0.9cm²
Acc Time 85ms
E:Em
E = 2.5m/s
Mean grad 15mmHg
PHT 258msecs
E
PHT
VTI
MVR VTI 110cm
EOA (cont eqn) 1.1cm²
cm/s
BPM
LVOT diam 2.7
LVOT VTI 21cm

Variables indicating severe aortic prosthetic regurgitation

- PHT of regurgitant jet ≥250 ms
- Restrictive mitral inflow pattern (in acute AR)
- Holodiastolic reversals in the descending thoracic aorta
- Regurgitant fraction ≥55%

Variables indicating severe mitral prosthetic regurgitation

- Increased mitral inflow peak velocity (≥2.5 m/s) and normal mitral inflow PHT (≤150 ms)
- Dense mitral regurgitaion CW signals
- Regurgitation fraction ≥55%
- Effective regurgitation orifice ≥0.35 cm^2
- Systolic flow reversals in the pulmonary vein

- Great deal of acoustic masking posterior to the valve in standard echocardiographic views
- Bioprosthetic valves have much fewer reverberations and artifacts compared with mechanical valves.

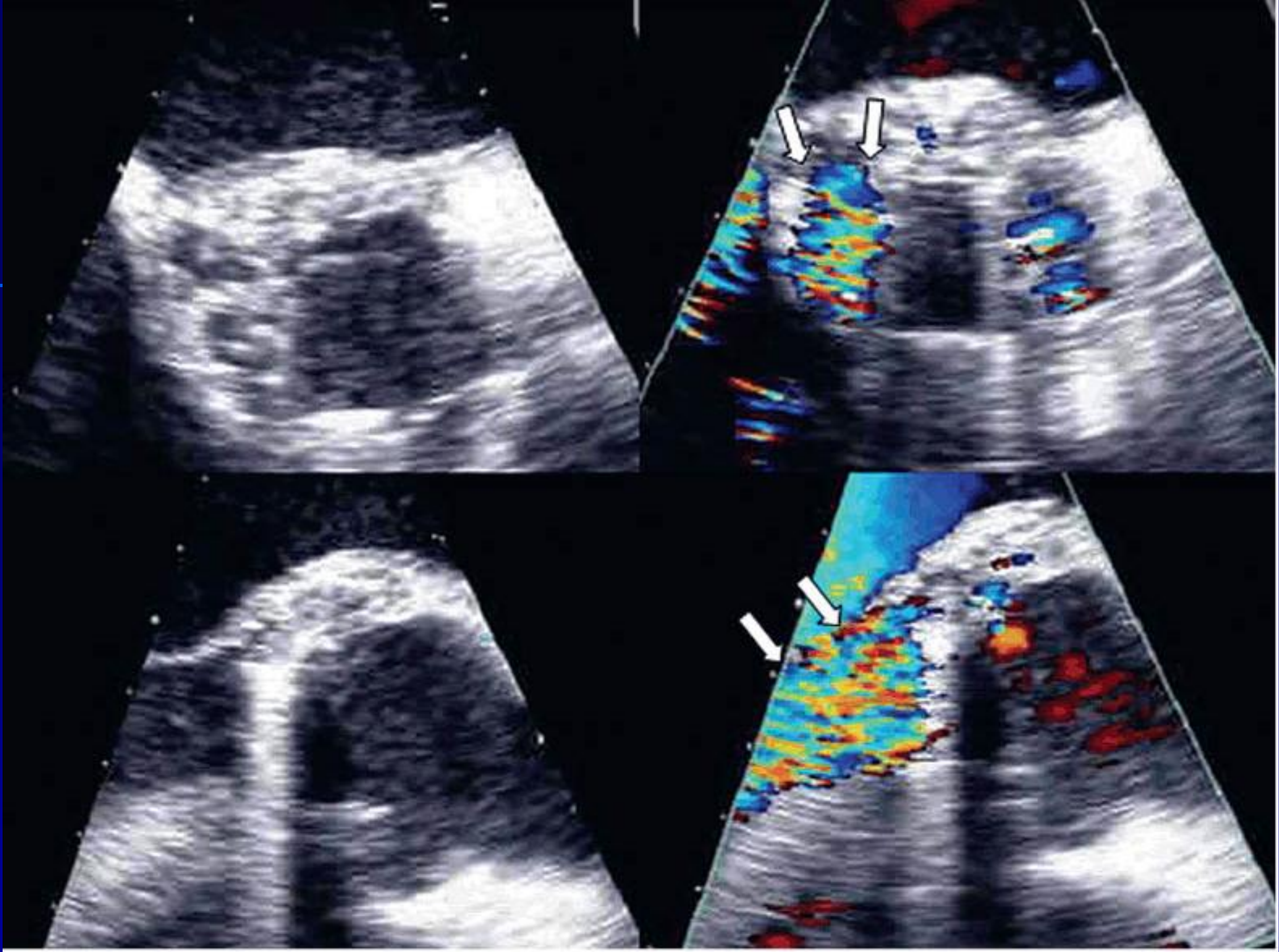


Fig. 26.1 TEE of a patient demonstrating significant prosthetic paravalvular regurgitation as a result of paraprosthetic abscess formation with valvular dehiscence *(arrows)*.

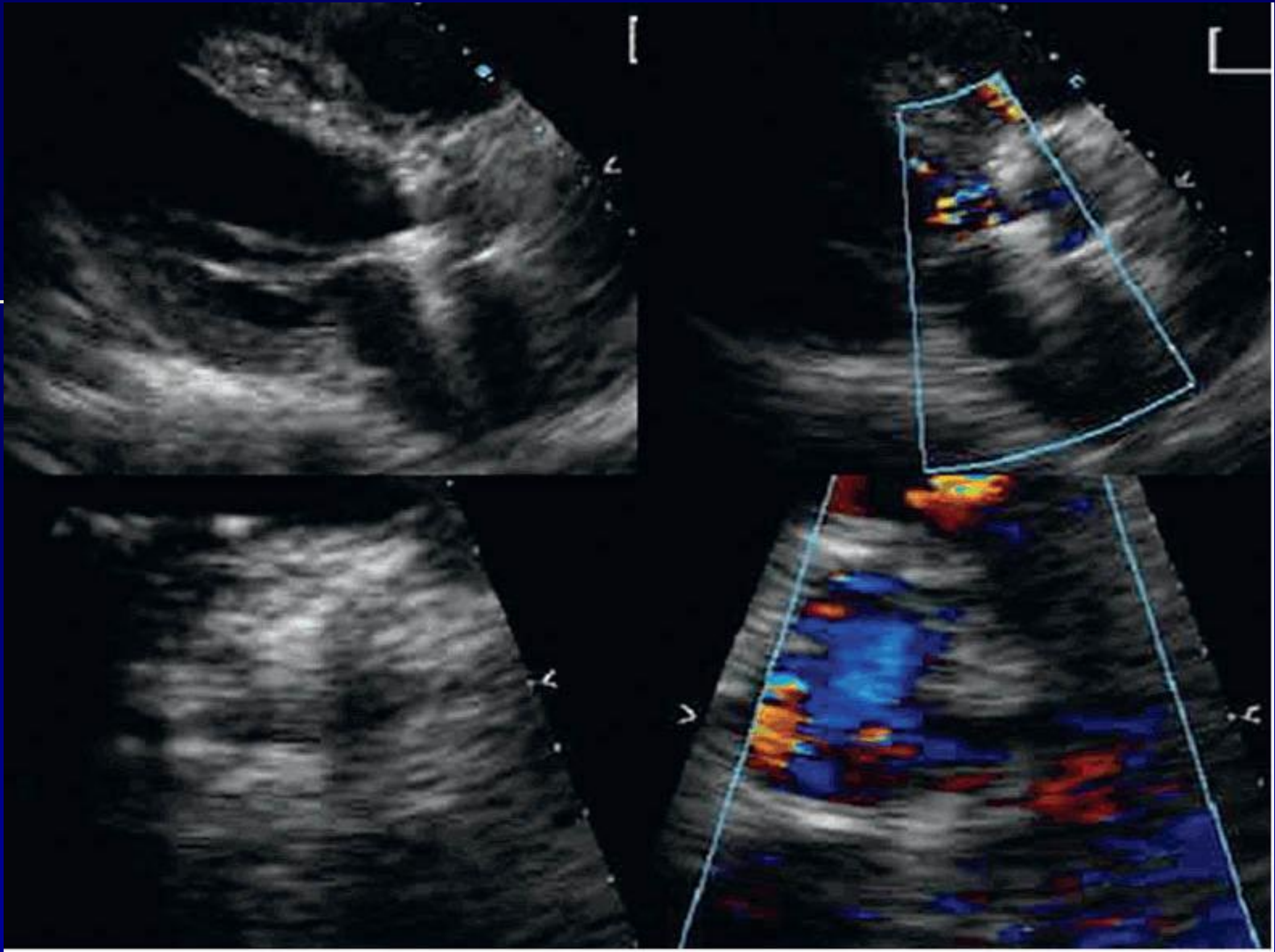


Fig. 26.2 Transthoracic echocardiography images from the same patient in Figure 26.1 did not demonstrate a paraprosthetic abscess or paravalvular regurgitation. Both were hidden by shadowing from the prosthesis. Indirect clues for a significant leak included increased LV end-diastolic diameter (5.9 cm) and holodiastolic reversal in the descending thoracic aorta.

- A recent study peak E velocity ≥1.9 m/s, a TVIPMV/TVILVOT ratio ≥2.2, and a normal PHT were associated with a high likelihood of significant prosthetic MR.
- Peak E velocity <1.9 m/s, a TVI ratio <2.2, and PHT <130 ms are collectively indicative of a high likelihood (98%) of a normal prosthetic valve function.

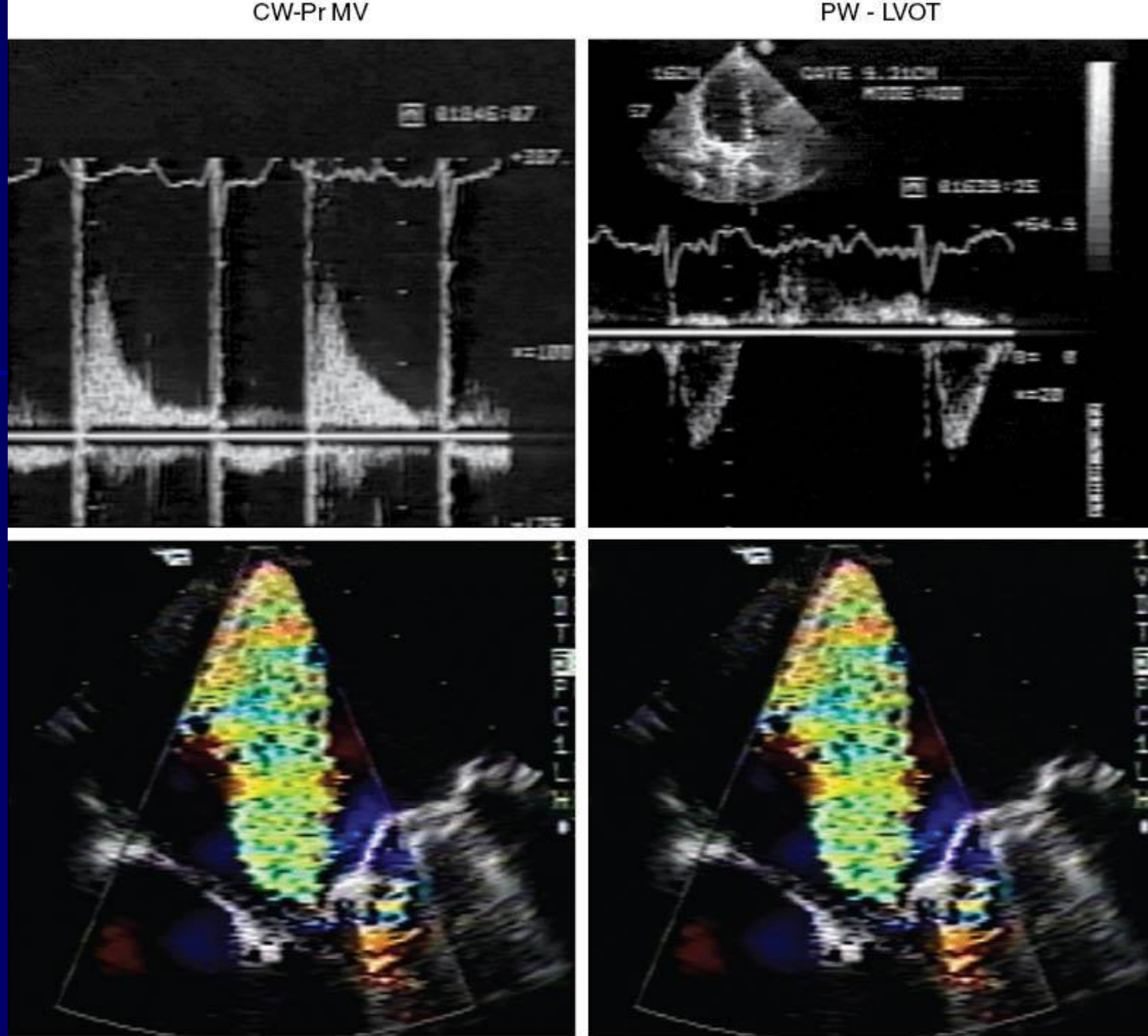
PROSTHETIC MECHANICAL MITRAL VALVE
BEST CLUES FOR DYSFUNCTION

- Peak E velocity $\geq$ 1.9 m/s
- $TVI_{MV}/TVI_{LVO} \geq 2.2$

PHT < 130 ms — Regurgitation

PHT $\geq$ 130 ms — Stenosis

(Modified from Fernandes V, Olmos L, Nagueh SF, et al: Peak early diastolic velocity rather than pressure half-time is the best index of mechanical prosthetic mitral valve function, Am J Cardiol 89:704-710, 2002.)



$TVI_{MV}/TVI_{LVOT} = 3.7$

Fig. 25.2 An example of the application of Doppler data from TTE examination to assess for the severity of prosthetic MR. By CW Doppler, peak E velocity is increased at 2.2 m/s *(upper left)*. Diastolic TVI across PMV by CW = 37 cm. In comparison, systolic TVI by PW Doppler across LVOT = 10 cm *(upper right)*. Therefore the ratio of TVI_{PMV}/TVI_{LVOT} is highly increased at 3.7. On TEE, a large regurgitant jet is seen in the transverse (T) plane *(lower left)* and longitudinal (L) planes *(lower right)*. *Pr,* Prosthetic.

(From Olmos L, Salazar G, Barbetseas J, et al: Usefulness of transthoracic echocardiography in detecting significant prosthetic mitral valve regurgitation, Am J Cardiol *83:199-205, 1999.)*

- In addition it is possible to quantify the regurgitant volume and regurgitant fraction of prosthetic MR.
- TOE allows the direct visualization of the MR jet and the determination of the underlying location and etiology, because it provides a clear view of the prosthetic mitral valve.

- It is possible to measure the proximal jet diameter and maximum regurgitant jet area in multiple planes as well as maximal regurgitant flow rate (Q max) and regurgitant orifice area using the proximal flow convergence zone.

Table 26.1 -- Grading the Severity of Aortic Regurgitation Using Doppler Techniques Combined With Echocardiography

Severity of AR	Color Flow Doppler JH/LVOH (%)	Vena Contracta Width (cm)	Pressure Half-Time (ms)	Regurgitant Volume (mL per beat)	Regurgitant Fraction (%)	Regurgitant Orifice Area (cm^2)	Supportive Signs
Mild	<25	<0.3	>500	<30	<30	<0.10	No or brief early diastolic flow reversal in descending aorta
Moderate	25-64	0.3-0.6	500-349	30-59	30-49	0.10-0.29	Early diastolic flow reversal in descending aorta
Severe	>65	>0.6	<200	≥60	≥50	≥0.30	Holodiastolic flow reversal in descending aorta; LV enlargement

Table 26.3 -- Angiographic Grading of the Severity of Aortic Regurgitation

Grade	Degree of LV Opacification	Intensity of Dye	Clearance of Dye From LV
I (mild)	Incomplete	Aorta > LV	Completely cleared on each beat
II (moderate)	Complete but faint	Aorta > LV	Incomplete clearance
III-IV (severe)	Complete opacification	Aorta ≤ LV	Slow

Adapted from references 11 and 12.

Thank you!

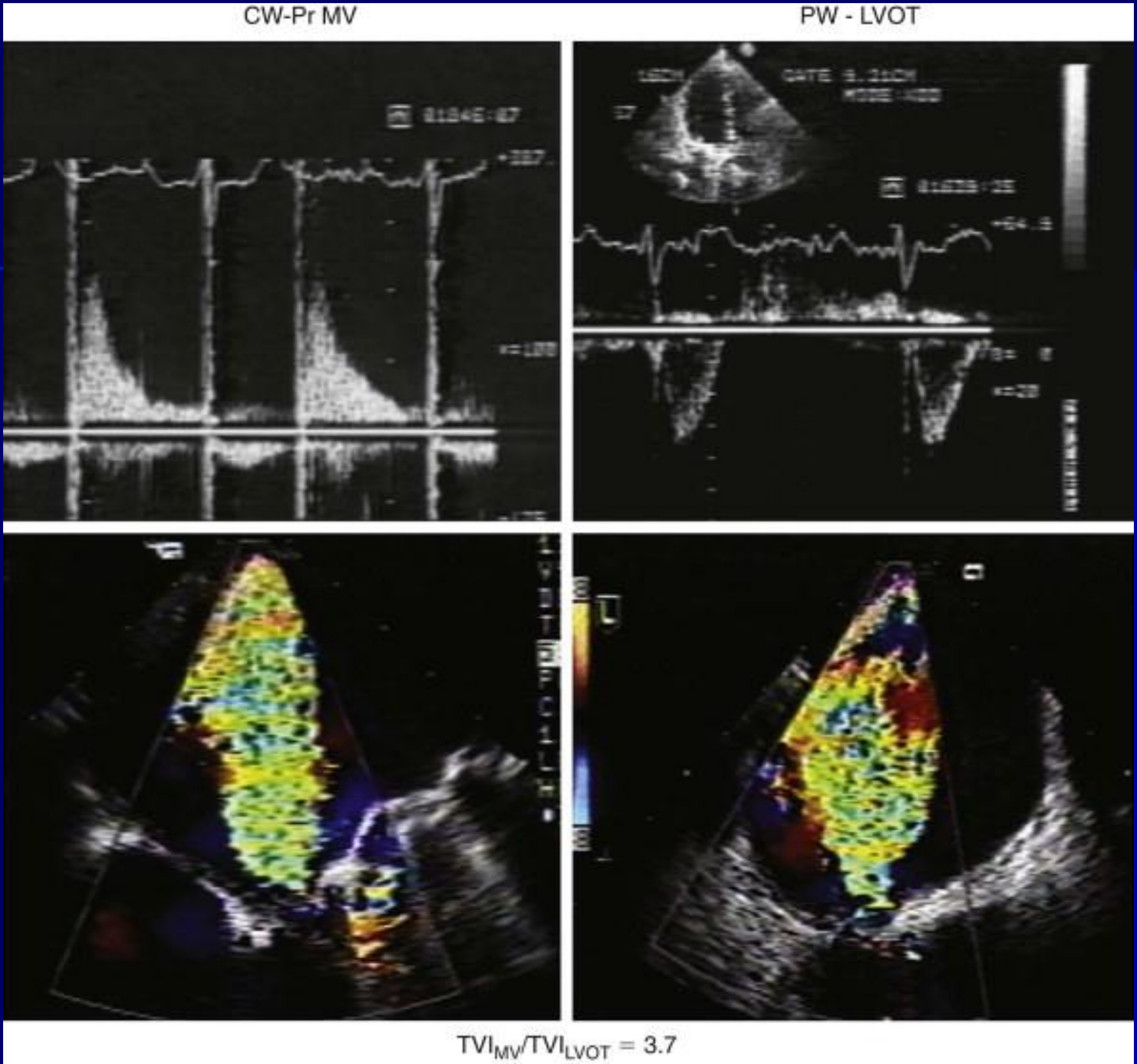
Structural Valve Degeneration

- Structural valve degeneration (SVD) is the usual cause of obstruction in bioprosthetic valves. Development of progressive leaflet degeneration is inevitable; the incidence of significant valvular dysfunction accelerates 10 to 15 years after implantation. The incidence varies with the age of the patient (SVD after aortic valve replacement [AVR] is 60% at 10 years in patients aged 16 to 39 years compared with ≤15% at 15 years in patients ≥70 years) and is higher in mitral bioprosthetic valves.

Valve Thrombosis

- Mechanical valves are more thrombogenic than bioprostheses, resulting in an increased risk of both thromboembolism and thrombotic valve obstruction. The reported incidence of prosthetic valve thrombosis varies widely from 0.1% to 0.6% per patient-year for left-sided valves.

- Major factors contributing to thrombosis include inadequate anticoagulation, a mitral location of the prosthetic valve, and likely other patient-related factors.[2] The clinical presentation depends on the severity of valve obstruction and may vary from systemic embolism without hemodynamic abnormality to heart failure or even cardiogenic shock.


CW-Pr MV
PW - LVOT
TVI$_{MV}$/TVI$_{LVOT}$ = 3.7

- *Patient-valve mismatch* should be suspected if abnormally elevated Doppler gradients are obtained despite (1) no obvious structural abnormality of the prosthesis, (2) normal values for EOA and DPI for valve subtype and size, and (3) indexed EOA ≤0.85 cm2/m2. Typically, the prosthesis size is small and patients are older with larger body surface area.