Echocardiographic Evaluation of Mitral Valve Prostheses

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Which of the following statements regarding the obstructed/thrombosed prosthetic mitral valve is correct?

- 1. A pressure half-time >130 msec is the single best indicator of prosthetic obstruction.
- 2. Taking into account heart rate is not necessary when assessing trans-mitral gradients.
- 3. Pannus in-growth is more common in the mitral position than with aortic PHVs.
- 4. A peak velocity ≥2.5 m/sec suggests significant stenosis.
- 5. Randomized, controlled trials have demonstrated that bolus infusion of rt-PA is the fibrinolytic regimen of choice.

Which of the following statements concerning prosthetic mitral regurgitation is correct?

- 1. Pseudo-regurgitation is an issue most often encountered during performance of TEE.
- 2. Any degree of regurgitation indicates dysfunction of a mechanical valve.
- 3. Structural valve deterioration is an uncommon cause of pathological regurgitation.
- 4. Mitral bioprostheses are less prone to suffer structural valve deterioration than are aortic bioprostheses.
- 5. Annular dehiscence most often is a consequence of infective endocarditis.

As recommended by the 2014 AHA/ACC Valvular Heart Disease Guideline, which of the following statements regarding follow-up of prosthetic heart valves by echocardiography is true?

- 1. Annual TTE is reasonable staring at 5 years following mechanical valve replacement.
- 2. An initial TEE should be performed routinely to assess valve hemodynamics within 2 months of implantation.
- 3. Change in clinical status should prompt early echocardiography.
- 4. Annual TTE is reasonable staring at 5 years following bioprosthetic valve replacement.

GUIDELINES AND STANDARDS

Recommendations for Evaluation of Prosthetic Valves With Echocardiography and Doppler Ultrasound

A Report From the American Society of Echocardiography's Guidelines and Standards Committee and the Task Force on Prosthetic Valves, Developed in Conjunction With the American College of Cardiology Cardiovascular Imaging Committee, Cardiac Imaging Committee of the American Heart Association, the European Association of Echocardiography, a registered branch of the European Society of Cardiology, the Japanese Society of Echocardiography and the Canadian Society of Echocardiography, Endorsed by the American College of Cardiology Foundation, American Heart Association, European Association of Echocardiography, a registered branch of the European Society of Cardiology, the Japanese Society of Echocardiography, and Canadian Society of Echocardiography

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2014 AHA/ACC Guideline 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

Developed in Collaboration With the American Association for Thoracic Surgery, American Society of Echocardiography, Society for Cardiovascular Angiography and Interventions, Society of Cardiovascular Anesthesiologists, and Society of Thoracic Surgeons

Nishimura RA et al. Circulation 2014;129:e521-e643.

Overview

- Description of the various types of prosthetic heart valves
- Echocardiographic evaluation of normally-functioning prosthetic heart valves
- Evaluation of prosthetic heart valve dysfunction

Prosthetic Heart Valves

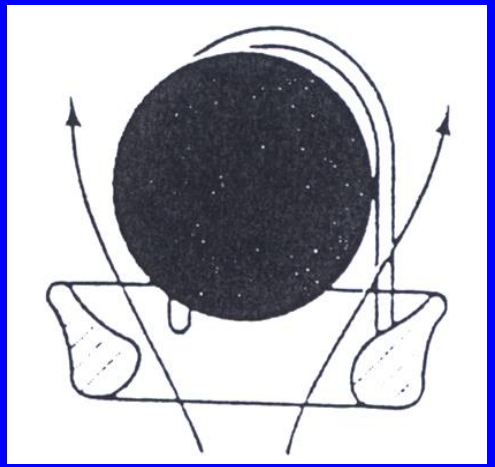
- Mechanical valves
- Tissue (biological) valves
  - Human
    - Allografts
    - Autografts
  - Animal (xenografts)
    - Porcine aortic valves
    - Bovine pericardial tissue
    - Stented or stentless
- Annular rings
- Percutaneous valves/clips

Mechanical Heart Valves

- Ball-in-cage
  - Starr Edwards valve
- Single tilting disc
  - Medtronic Hall valve
  - OmniScience valve
  - Bjork-Shiley valve
- Bileaflet tilting disc
  - St. Jude Medical valve
  - Carbomedics valve/Sorin
  - On-X
  - ATS

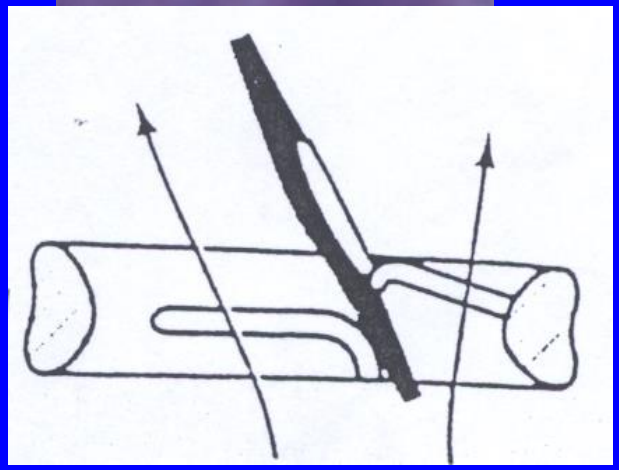
Ball-in Cage
Starr Edwards Valve

- Durable
- Circular sewing ring
- Silastic ball
- Cage with arches
- High profile
- Flow occurs around the ball
- Regurgitant volume of 2-5 mL



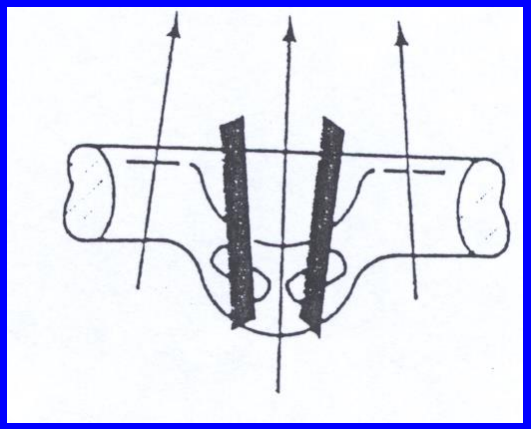
Single Tilting Disc Valves

- Circular sewing ring
- Circular disc eccentrically attached by metal struts
- Opening angle 60^{o} to 80^{o}
- Flow occurs through major and minor orifices
- Regurgitant volume of 5-9 mL



Bileaflet Tilting Disc Valves

- 2 semicircular discs attached to rigid valve ring by small hinges
- Opening angle 75^{o} to 90^{o}
- 3 orifices
  - Central and 2 lateral orifices
- Regurgitant volume of 5-10 mL



Stented Heterograft Valves

- Sewing ring with 3 semirigid stents or struts and fabric sewing cuff
  - Porcine aortic tissue
  - Bovine pericardium
- Trileaflet
  - Opens to a circular orifice
- Regurgitant volume of about 1 mL
  - 10% exhibit a small degree of regurgitation on color flow imaging

Percutaneous Clip

- Mitra-Clip®
- Perctaneous edge-to-edge technique to reduce MR
- FDA-approved for degenerative MR

Echocardiographic Approach to Assessment of Prosthetic Heart Valves

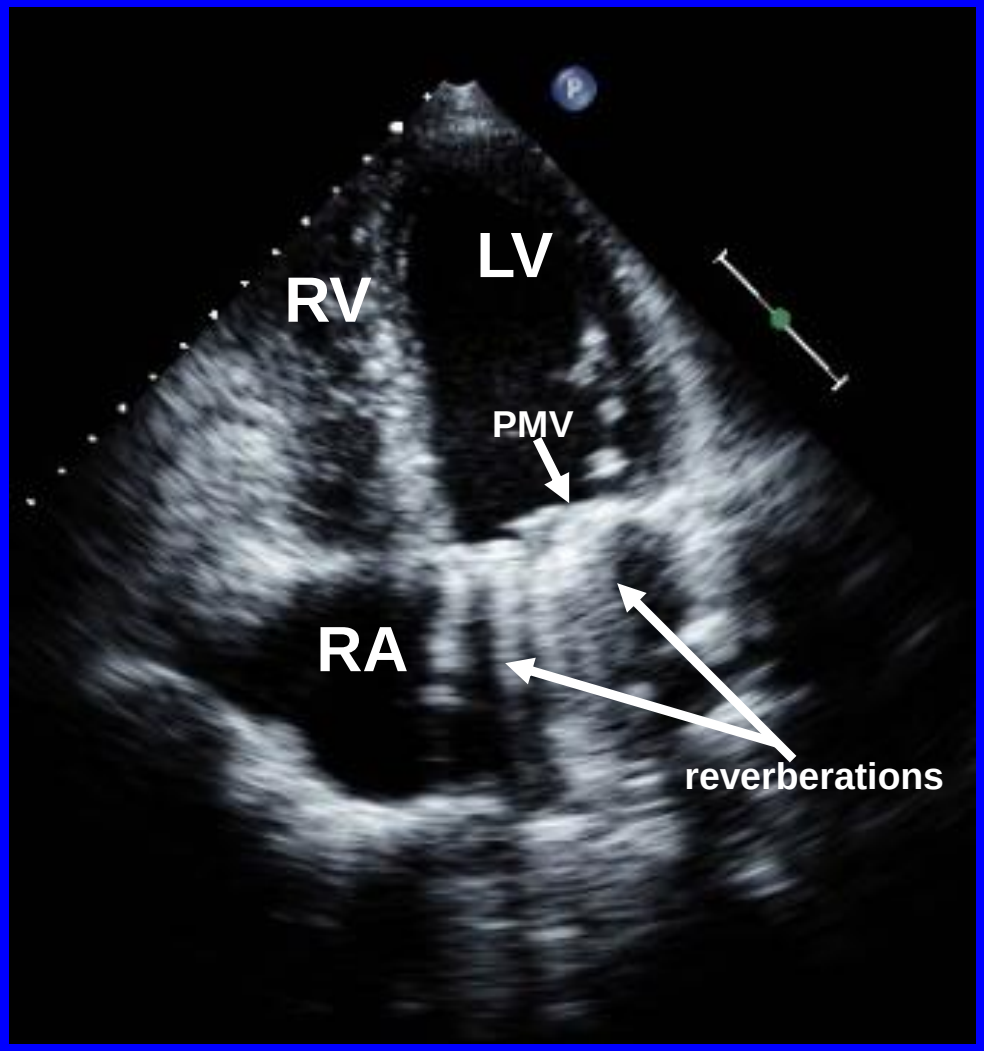
- Evaluation similar to that of native valves
- Reverberations and shadowing play a significant role
- Fluid dynamics of each specific valve prosthesis influences the Doppler findings

Echocardiographic Approach to Prosthetic Heart Valves—All Valve Types

- Complete 2D/3D imaging
- Determine transvalvular pressure gradients
- Estimate valve orifice area
- Evaluate severity and location of regurgitation
- Estimate pulmonary artery systolic pressure
- Assess chamber sizes and function
- Evaluate other valves
- Clinical data
  - Size and type of prosthesis
  - HR, BP, BSA
- ***ALWAYS COMPARE TO BASELINE STUDY!***

Echocardiographic Approach to Prosthetic Heart Valves—Caveats

- "Normal" Doppler values based on:
  - Prosthesis size
  - Prosthesis type
  - Position
- Higher gradients compared to native valves
- Reverberation artifacts/shadowing
- Differential diagnosis of high valve gradients:
  - True stenosis
  - High cardiac output states
  - Significant regurgitation
  - Patient-prosthesis mismatch
  - Pressure recovery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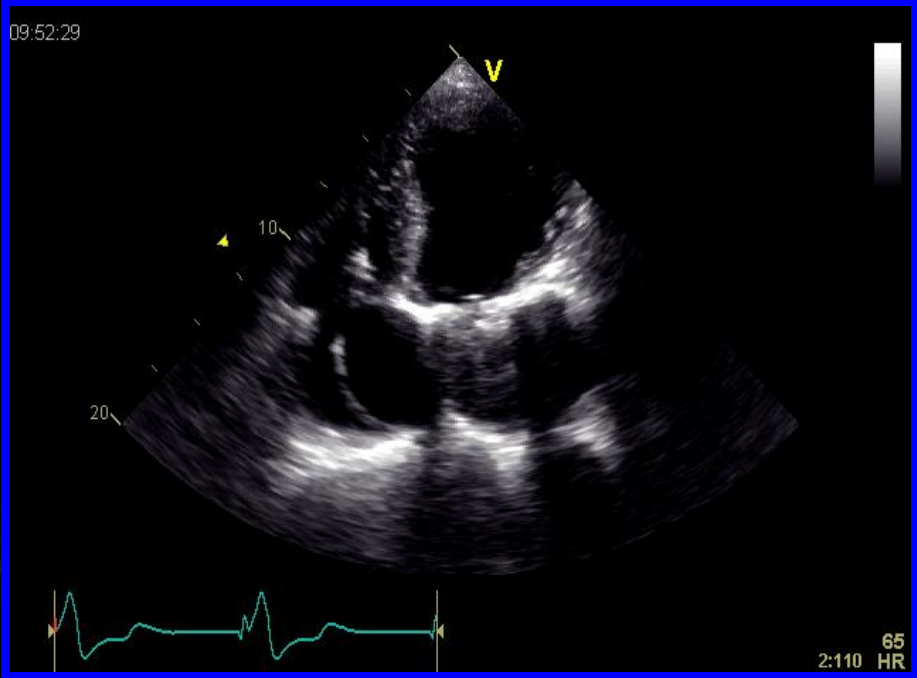
PMV
RA
reverberations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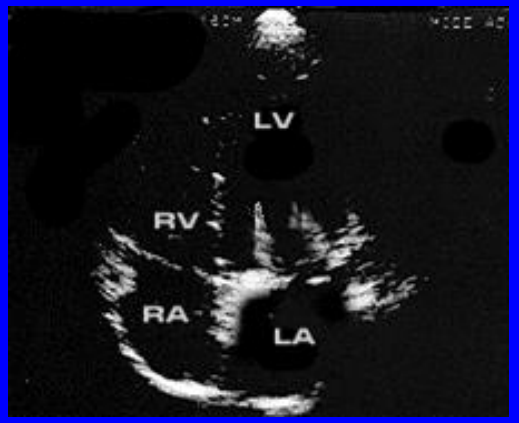
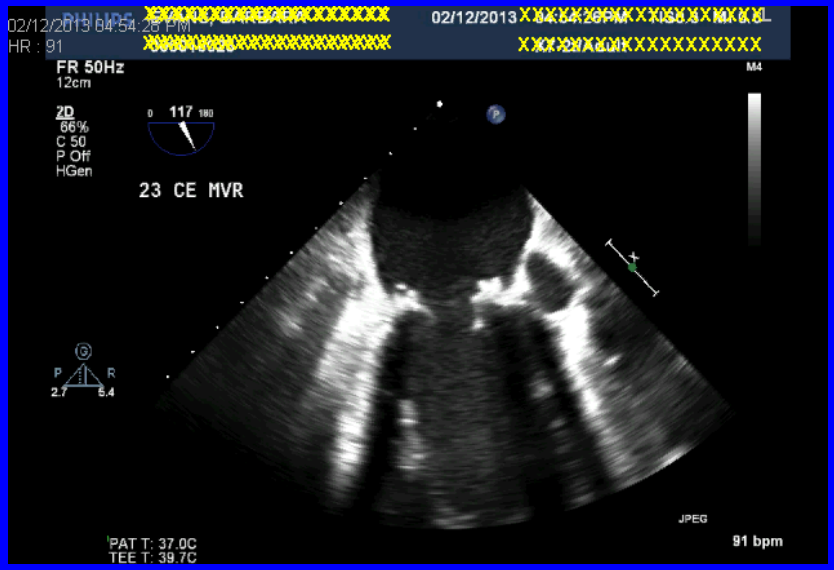
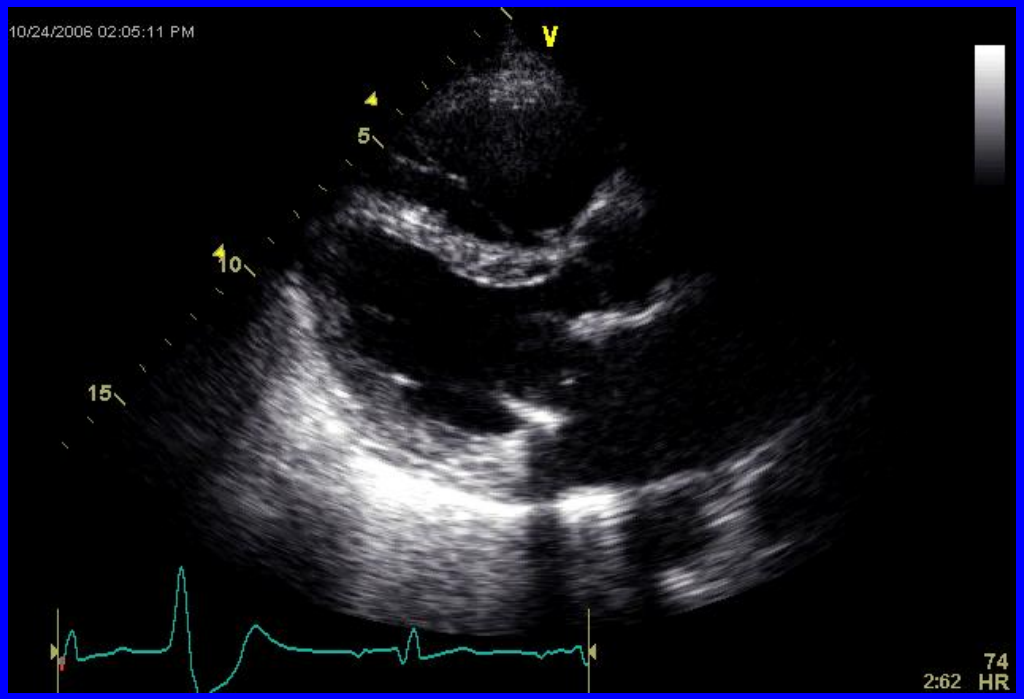
Normal Appearance—Tissue Valves

- Stented valves
  - 3 cusps and struts with echogenic sewing ring



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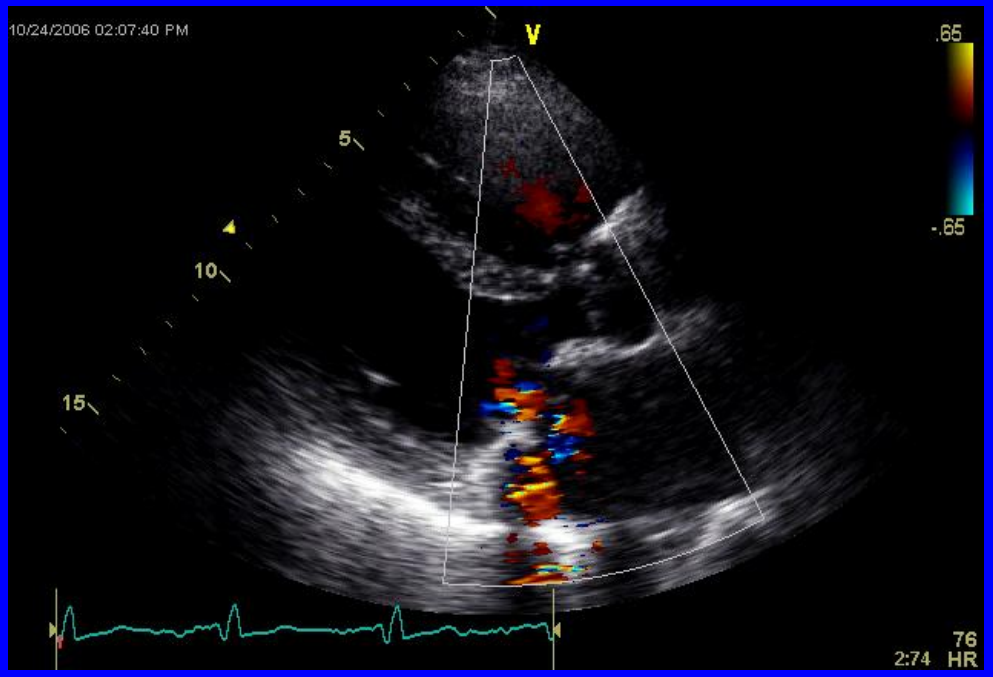
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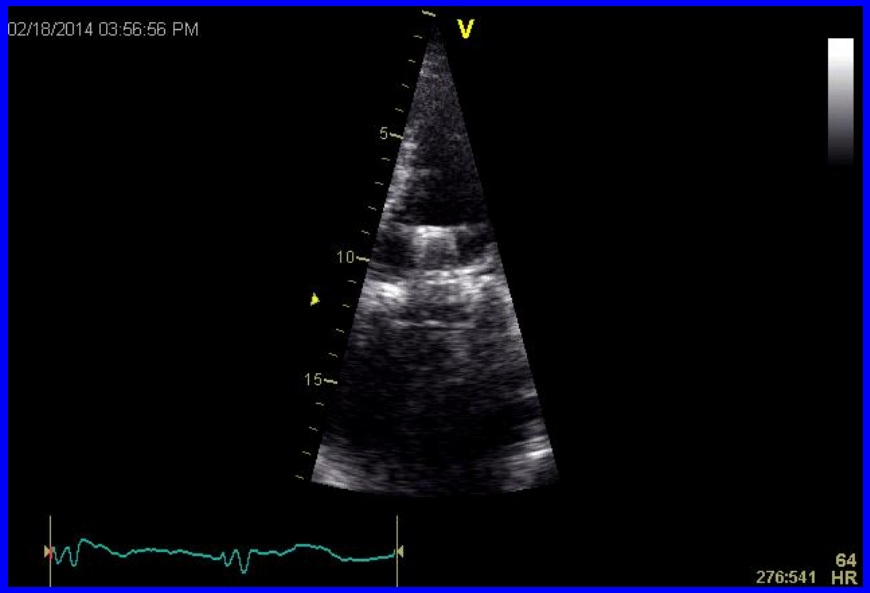
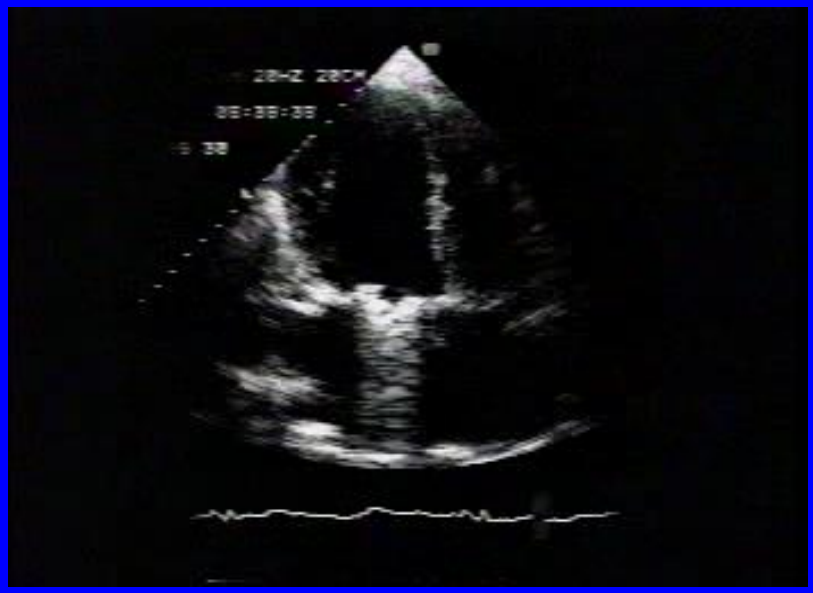
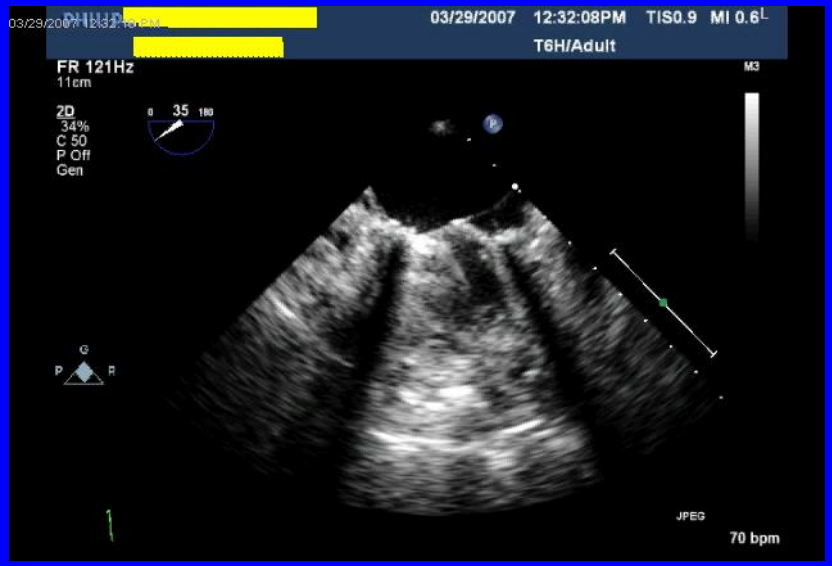
Normal Appearance—Mechanical Valves



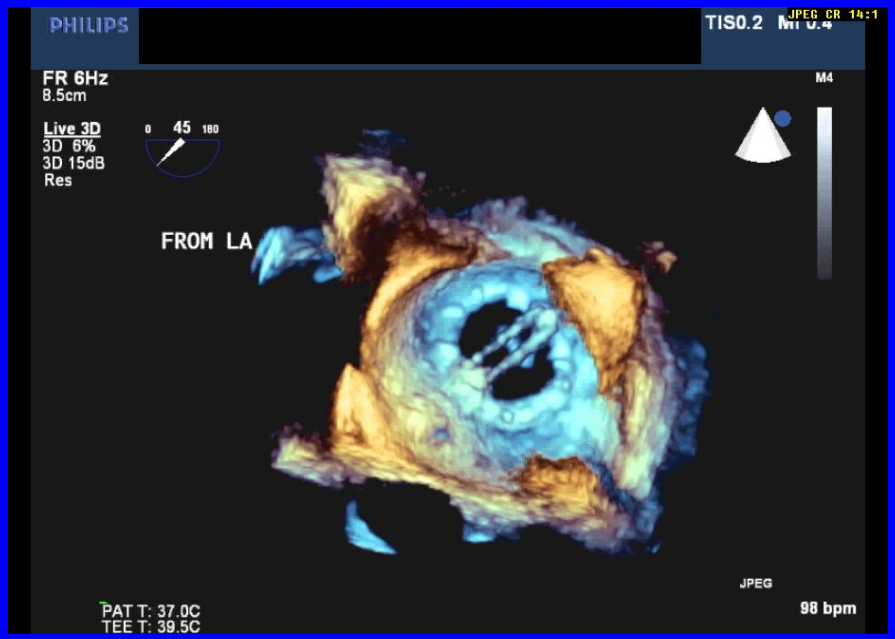
Ball in cage



Single disk



Bileaflet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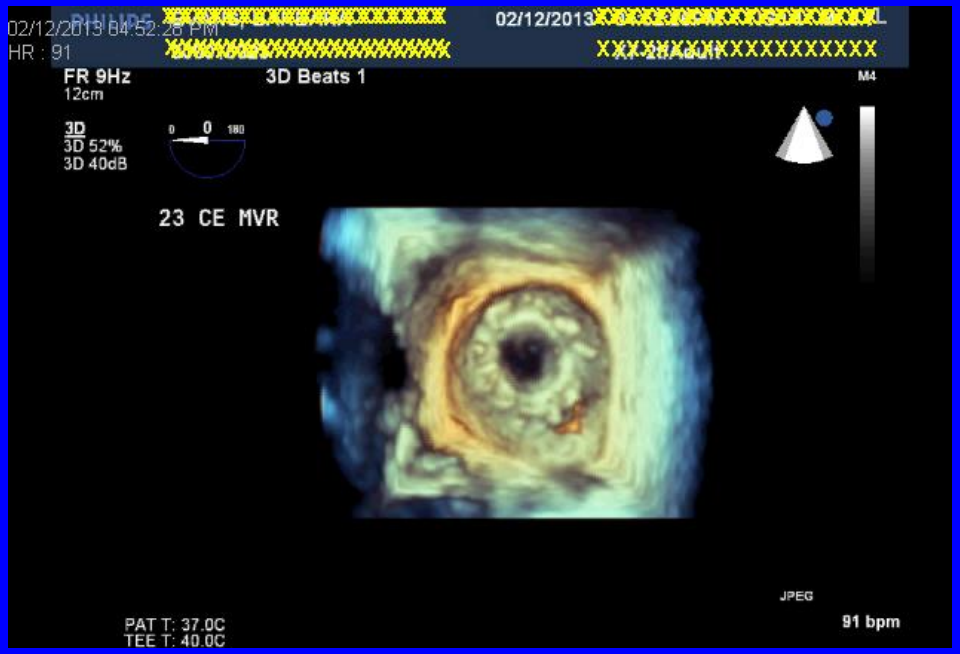
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Complications of Prosthetic Valves

- Early
  - Paravalvular leaks
  - Thrombosis/stuck occluders
  - Low output state
  - LVOT obstruction
  - Infective endocarditis
  - Patient prosthesis mismatch (PPM)
- Late
  - Structural valve deterioration
  - Thrombosis/thromboembolism
  - Bleeding
  - Pannus ingrowth
  - Regurgitation
  - Infective endocarditis
  - Patient prosthesis mismatch (PPM)
  - Hemolysis
  - Pseudoaneurysm formation

Probability of an Event at 15-years

	Mitral Valve Replacement		
	Mechanical	Bioprosthesis	p Value
	n = 88	n = 93	
Death from any cause	81 ± 4%	79 ± 4%	0.30
Any valve-related complication	73 ± 6%	81 ± 5%	0.56
Systemic embolism	18 ± 5%	22 ± 5%	0.96
Bleeding	53 ± 7%	31 ± 6%	0.01
Endocarditis	11 ± 4%	17 ± 5%	0.37
Valve thrombosis	1 ± 1%	1 ± 1%	0.95
Perivalvular regurgitation	17 ± 5%	7 ± 4%	0.05
Reoperation	25 ± 6%	50 ± 8%	0.15
Primary valve failure **(SVD)**	5 ± 4%	44 ± 8%	0.0002

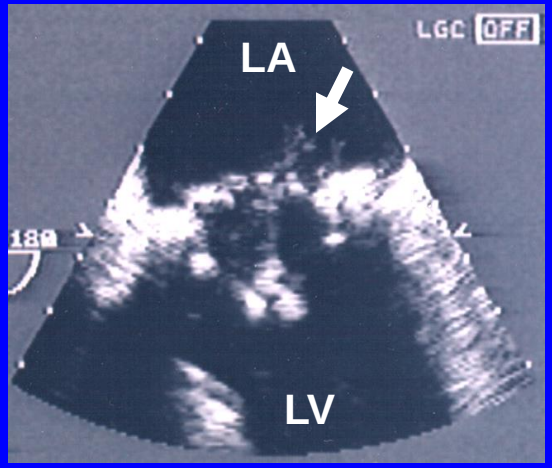
Hammermeister K et al. J Am Coll Cardiol 2000;36:1152.

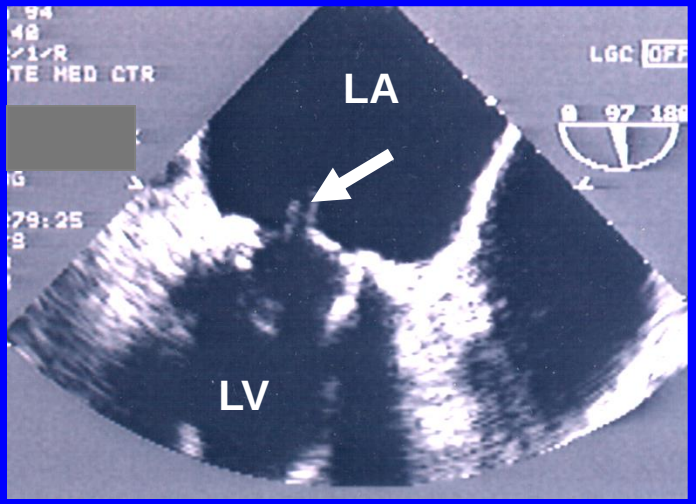
Prosthetic Valve Dysfunction

- Approach to suspected dysfunction
  - TTE/Doppler
  - TEE
    - Atrial side of mitral prosthesis
  - Cine fluoroscopy
    - May provide superior assessment of mechanical valve opening and closing motion
    - No assessment of pressure gradients
  - Cardiac CT
  - Cardiac catheterization
  - Stress echocardiography

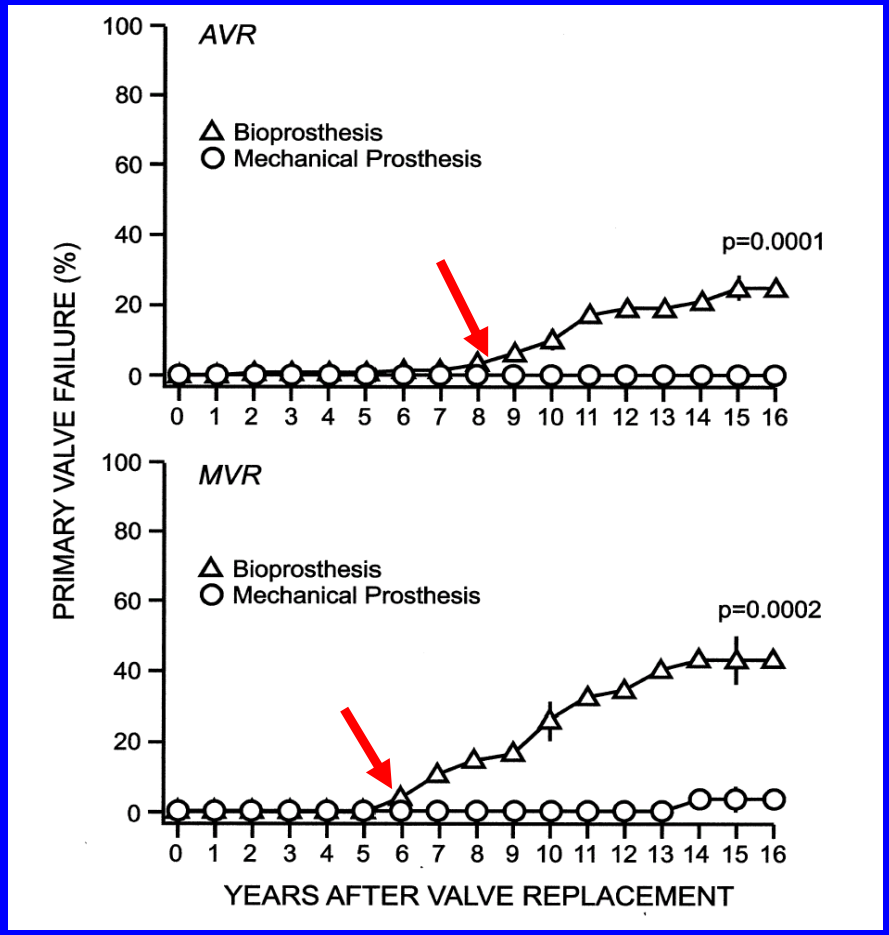
Structural Valve Deterioration

- Tissue Valves
  - More common
    - Younger patients
    - Altered Ca^{++} metabolism
    - Valve type
  - Thickening, calcification, perforation, or spontaneous tissue degeneration of leaflets
  - Regurgitation
    - Usually gradual
    - Can be acute and massive
  - Stenosis
  - Combination

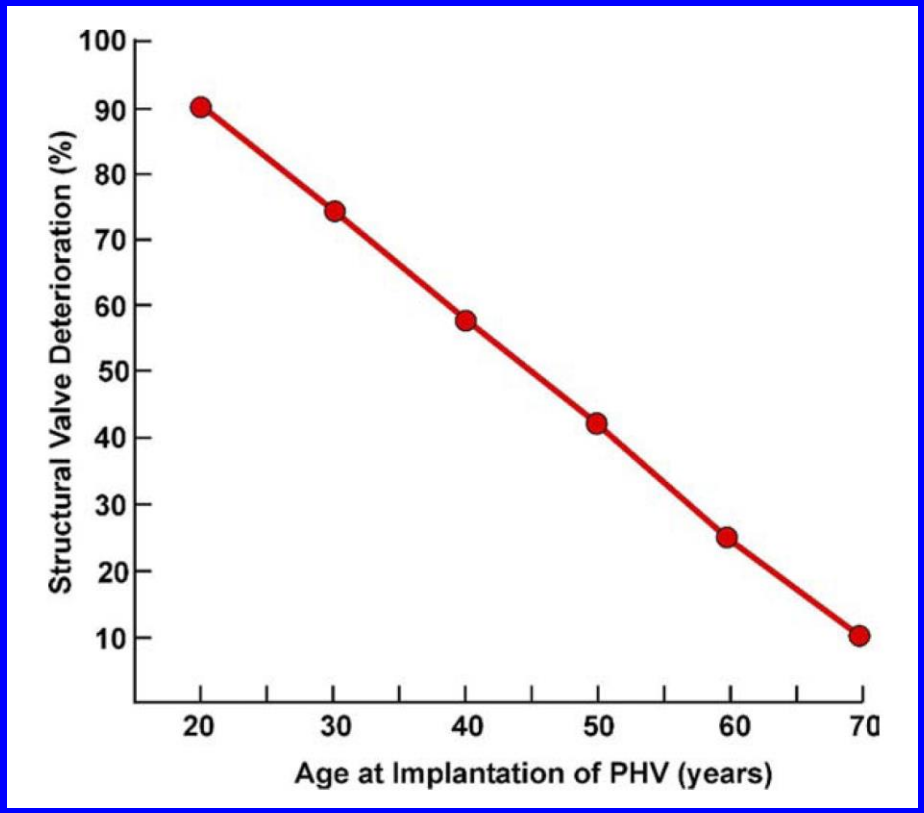




Structural Valve Deterioration



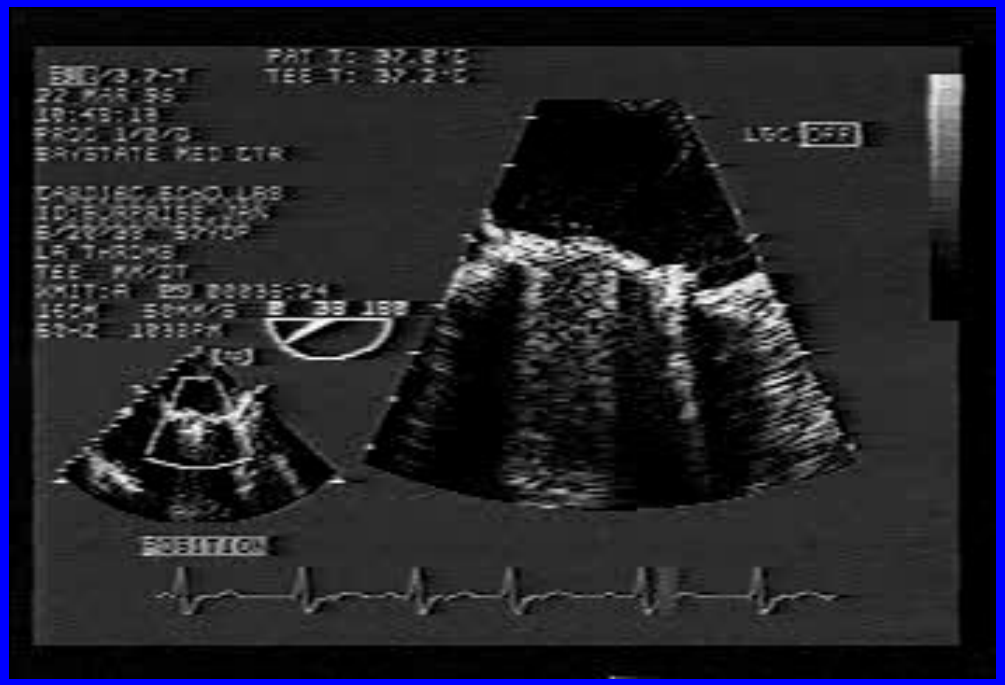
Hammermeister K et al. J Am Coll Cardiol 2000;36:1152.



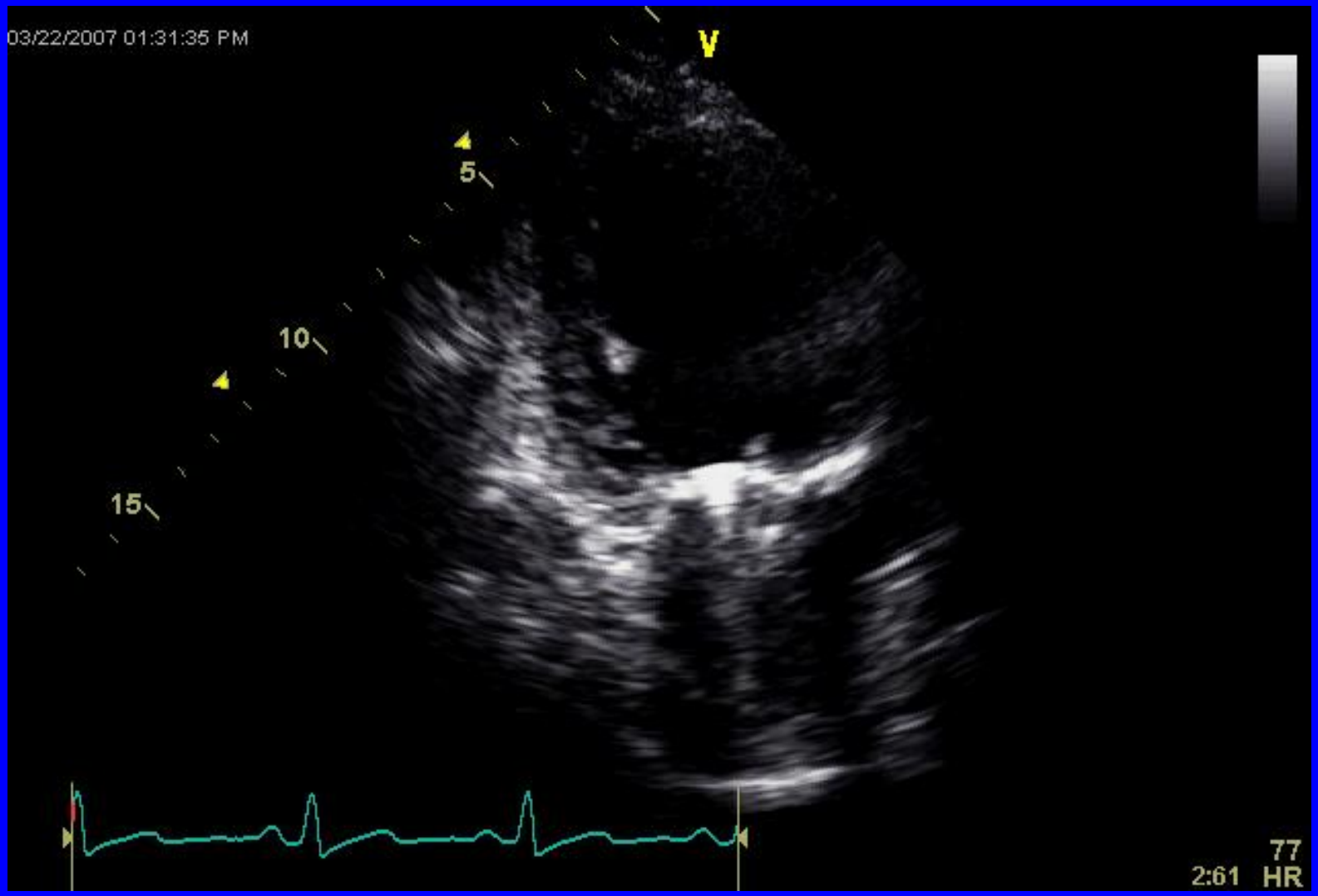
Rahimtoola SH. J Am Coll Cardiol 2010;55:2413.

Valve Thrombosis

- Incidence
  - 0.3% to 1.3%/yr
- Highest risk
  - Mitral and tricuspid positions
- Inadequate anticoagulation
  - Mechanical valves
- Clinical manifestations
  - Incidental finding
  - Peripheral embolization
  - Stenosis
  - Regurgitation
  - Heart failure
- Gradual or acute symptom onset
- Treatments
  - Anticoagulants
  - Thrombolysis
  - Surgery



Bileaflet MVR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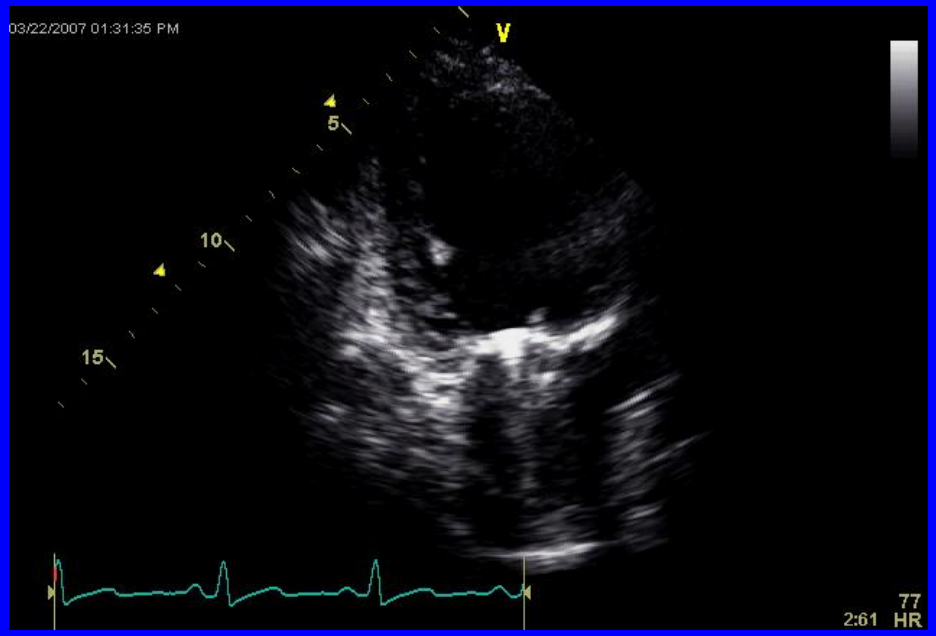
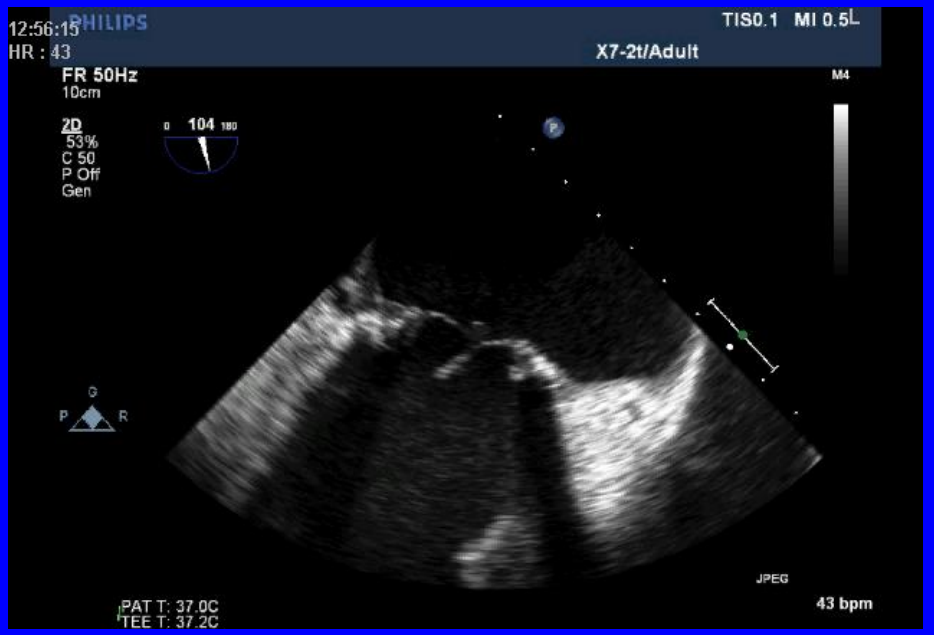
Non-obstructive Thrombosis



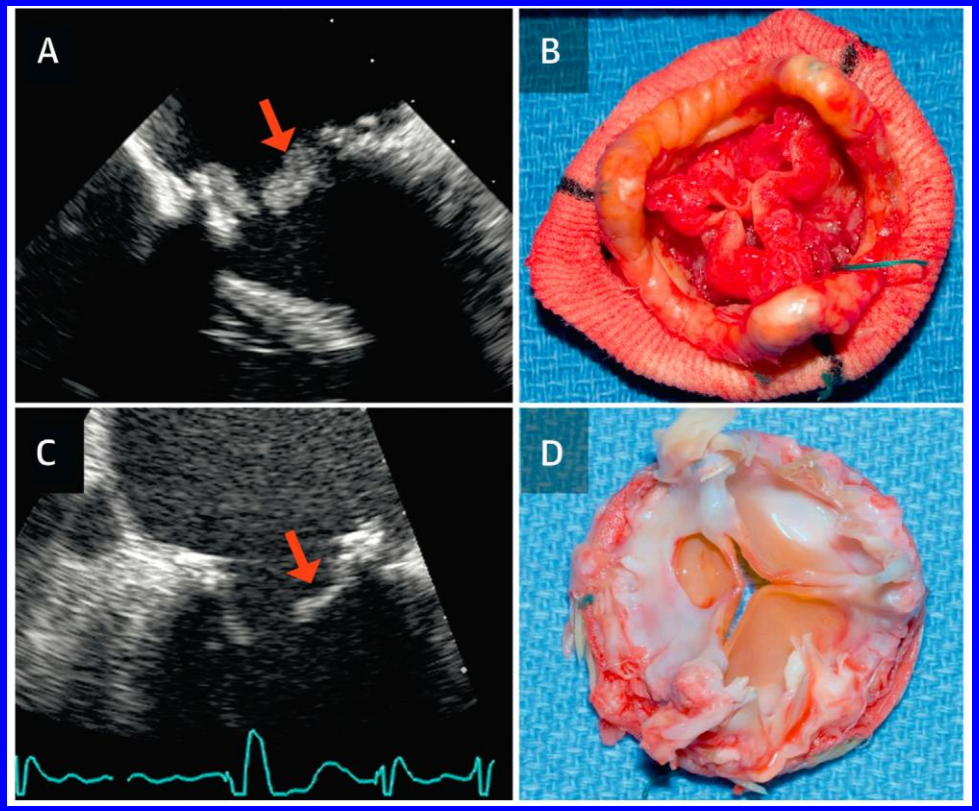
Mechanical Prosthesis



Bioprosthesis

BPVT vs. Structural Valve Deterioration

BP valve thrombosis



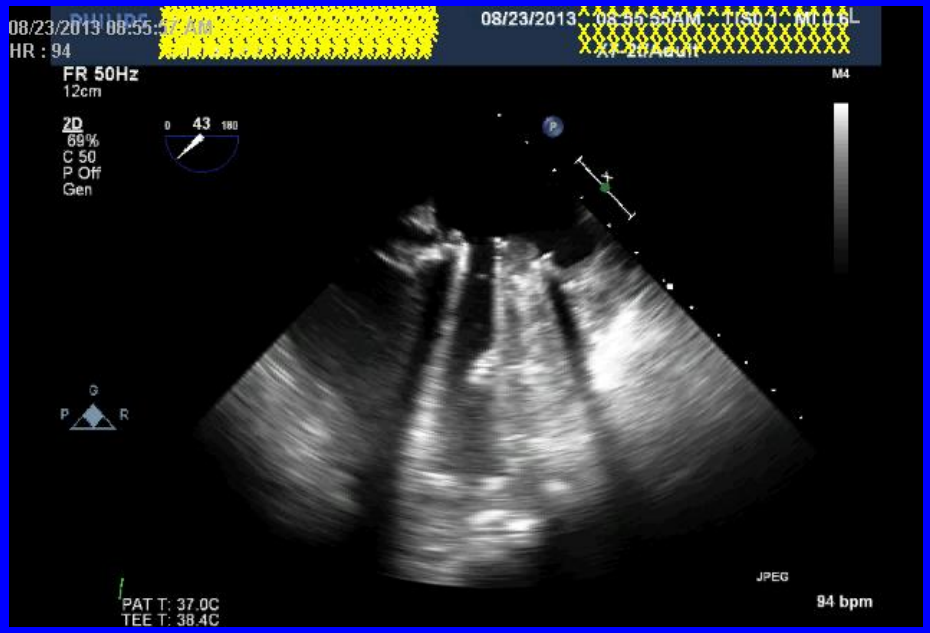
Structural valve deterioration

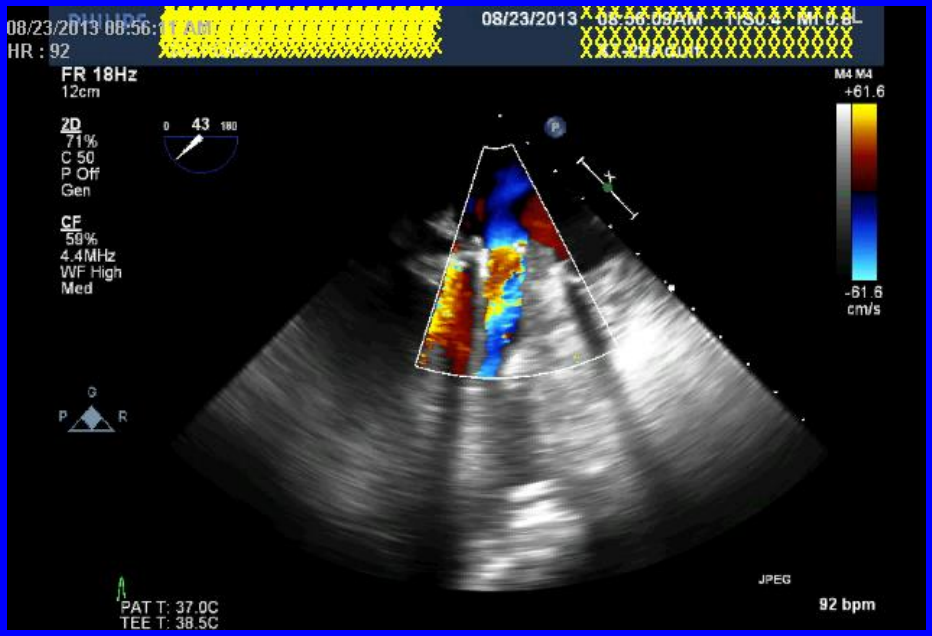
TABLE 5 Test Performance Characteristics for the Diagnosis of BPVT

	Total Score	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Variables					
A. 50% mean gradient increase	1	45	89	68	77
B. Increase cusp thickness	1	74	69	55	84
C. Abnormal cusp mobility	1	63	70	51	81
D. Paroxysmal AF	1	63	73	54	80
E. Subtherapeutic INR	1	30	92	67	73
Combination of variables					
A and B	2	86	57	50	89
A, B, and C	3	72	90	78	87
A, B, C, and D	4	70	94	87	86
A, B, C, D, and E	5	66	93	85	89

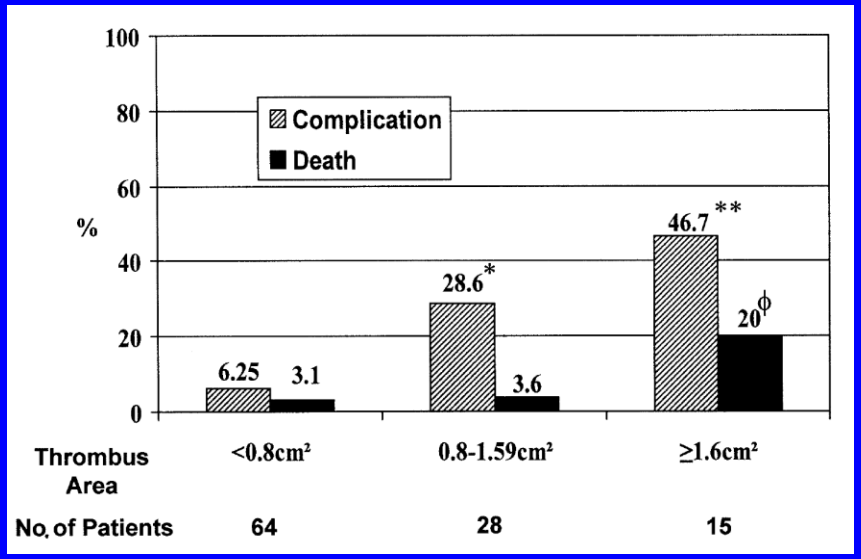
Egbe AC et al. J Am Coll Cardiol 2015;66:2285.

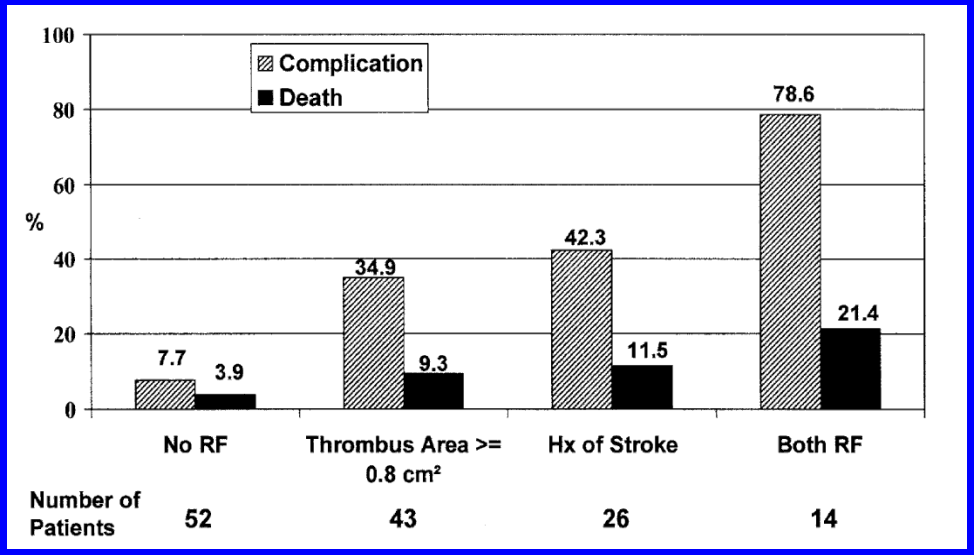
Obstructive Thrombosis



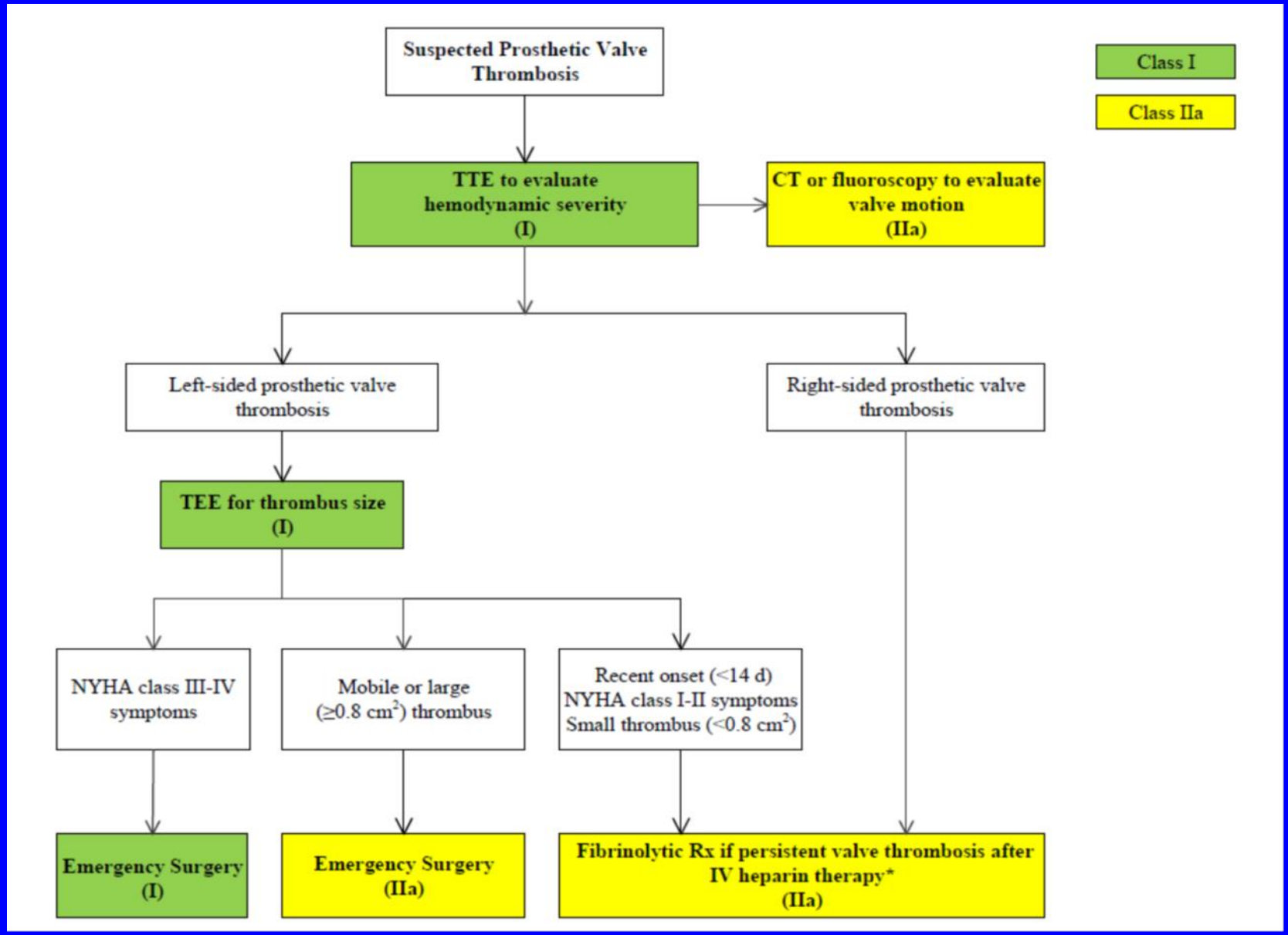


Thrombus Area by TEE Predicts Clinical Outcome





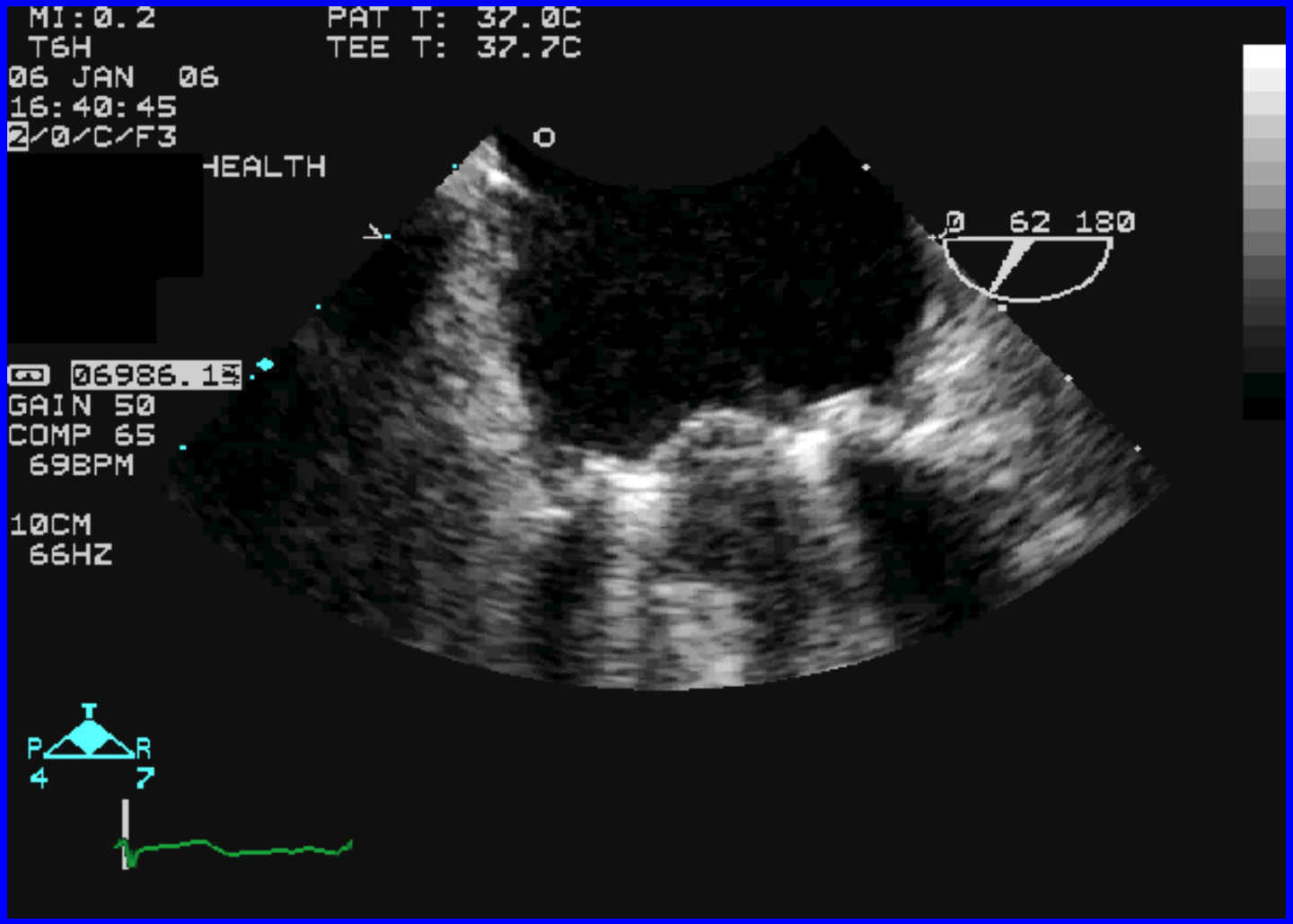
Tong AT et al. J Am Coll Cardiol 2004;43:77.



Nishimura RA et al. Circulation 2014 ;129:e586.

Infective Endocarditis

- Risk approximately 0.5%/year
- Early versus late pathogens
- Mechanical valves
  - Usually involves the sewing ring
  - Rare to visualize vegetation on discs
- Tissue valves
  - Vegetations seen both at sewing ring and leaflets
- Complications
  - Heart failure
  - Abscess/fistula formation
  - Regurgitation: paravalvular or valvular
  - Stenosis
  - Embolism
  - Conduction defects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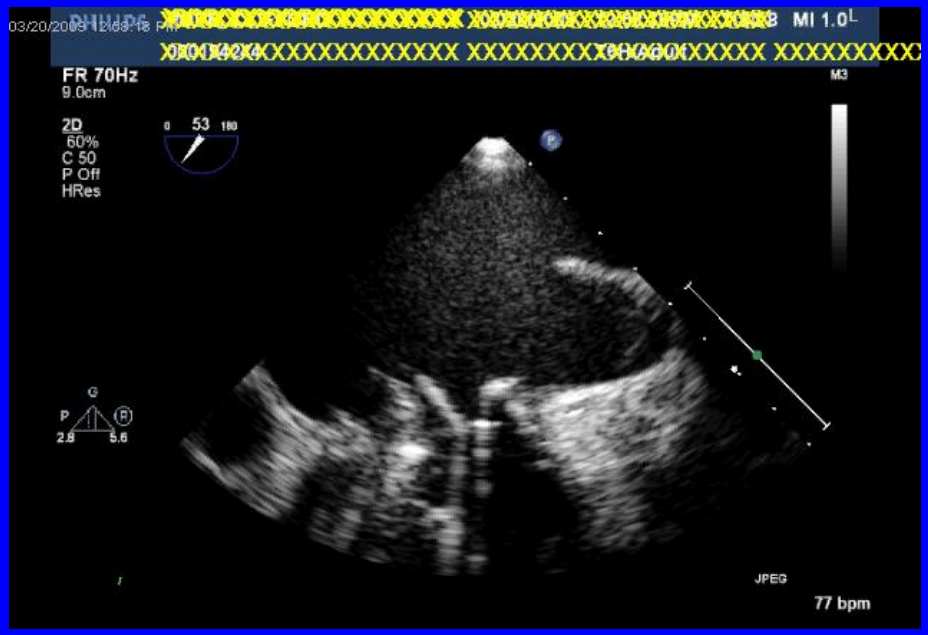
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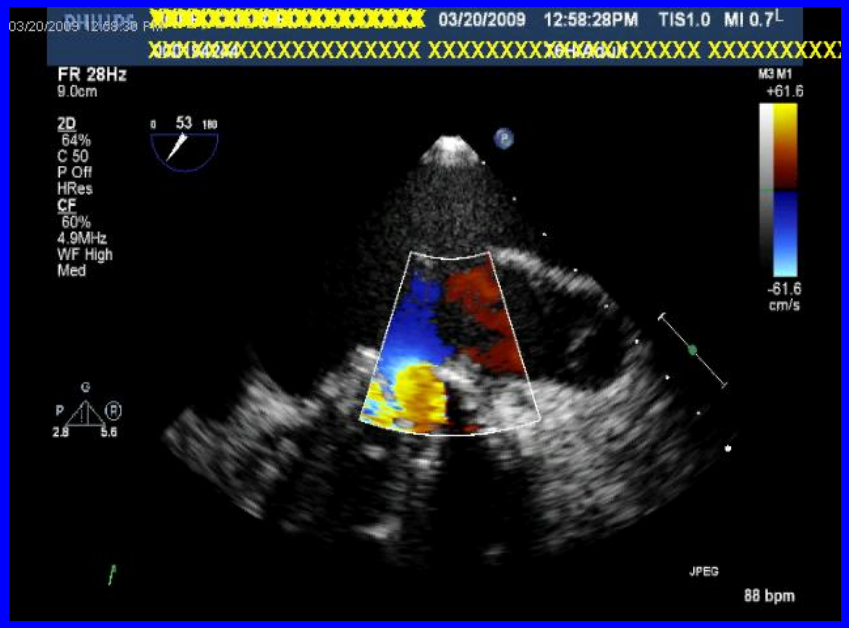
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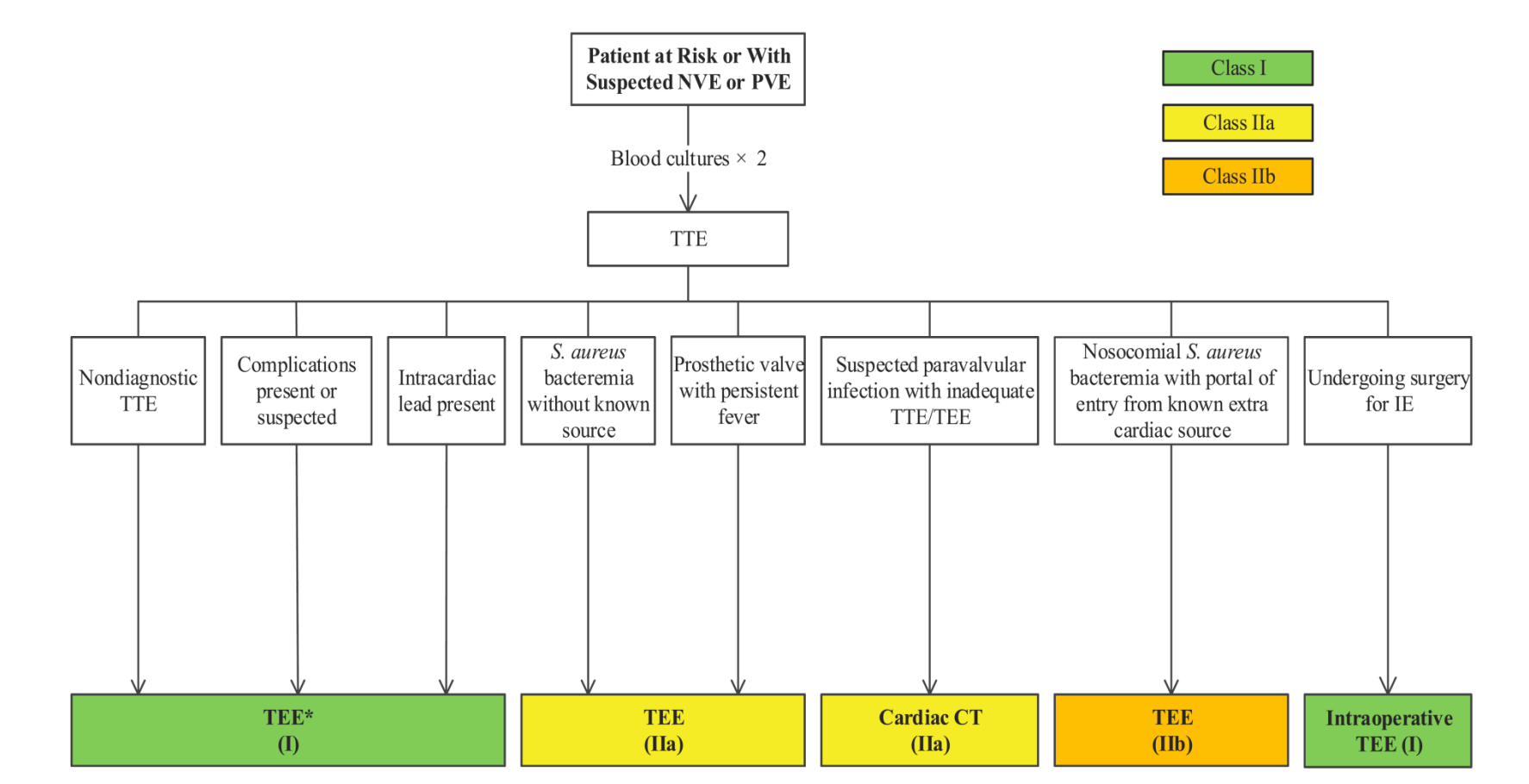
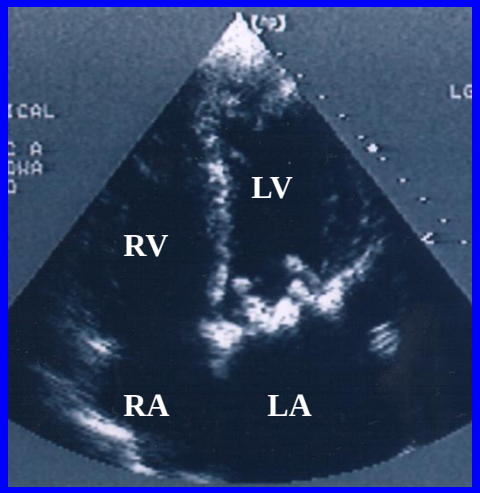
Imaging Evaluation for Suspected Endocarditis

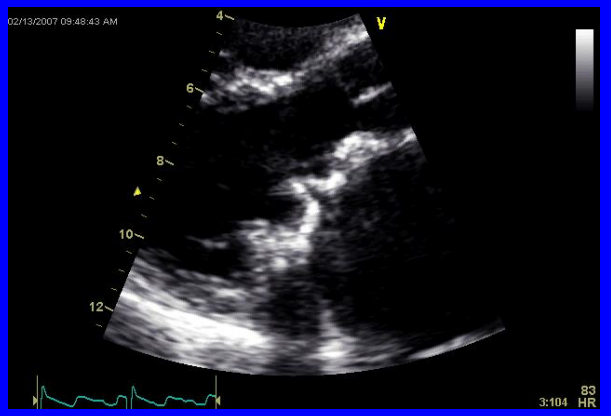


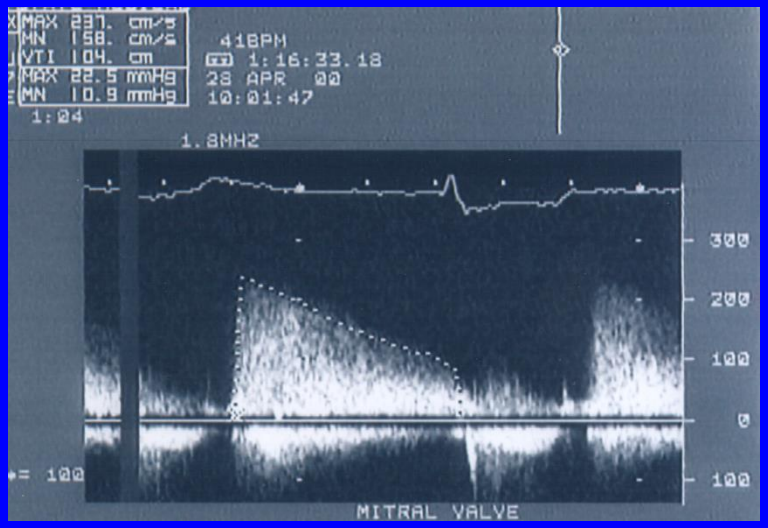
Nishimura RA et al. Circulation 2014;129:e590.

Valve Stenosis/Obstruction

- Tissue valves
  - Thickening, calcification and restricted motion
  - Pannus in-growth
  - Thrombosis
- Mechanical valves
  - Restriction of disc/ball motion
    - Thrombus
    - Pannus in-growth
    - Combination
    - Vegetations
  - Restriction of annular area
    - Pannus in-growth

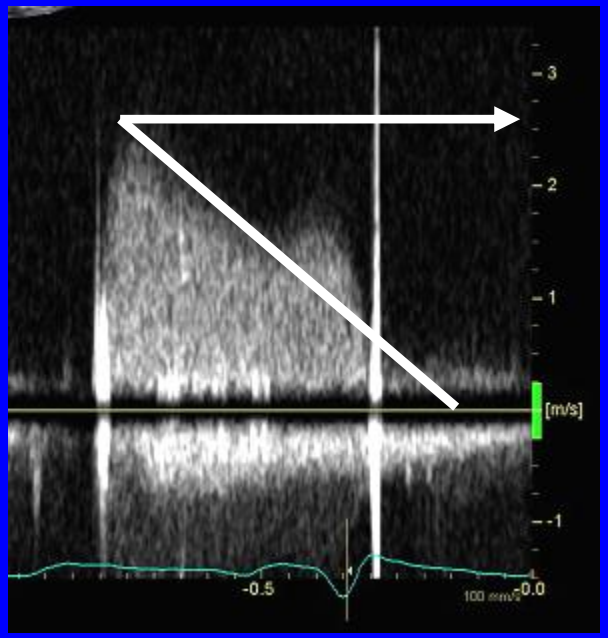




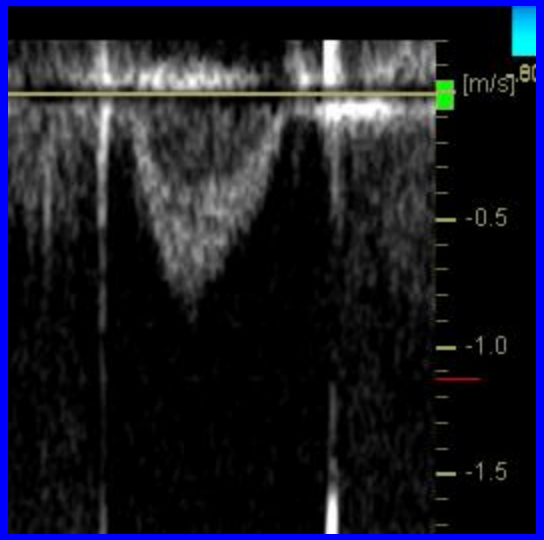


Valve Stenosis/Obstruction

- Mitral valve parameters
  - Peak E-wave velocity
  - Mean gradient
  - Pressure half-time
  - Effective orifice area
    - Continuity equation area
  - DVI
    - $VTI_{prosthesis}$/ VTI_{LVOT}

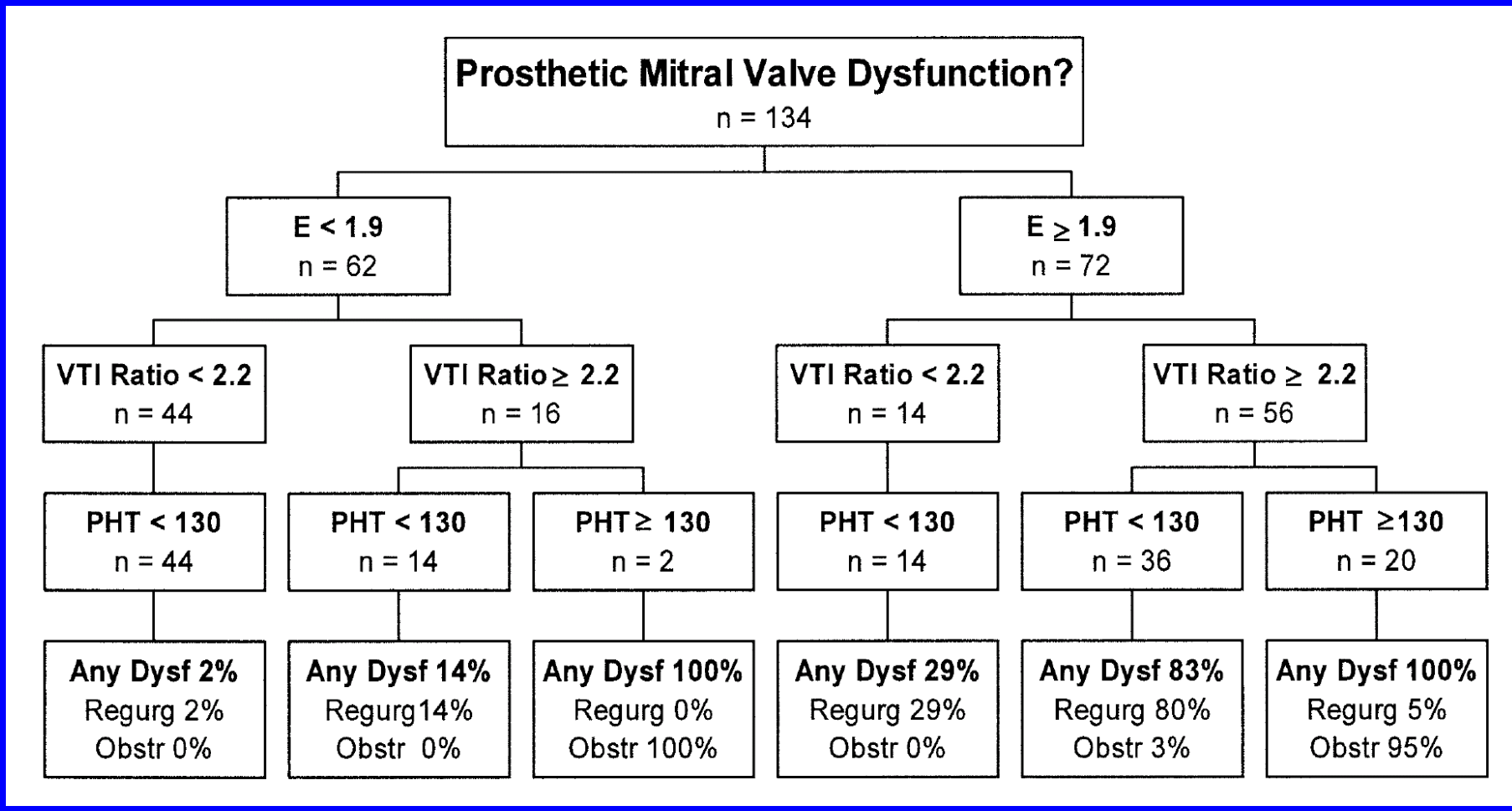


Peak E-wave **2.6 m/sec**
PHT **166 msec**
VTI_{pros} **99 cm**

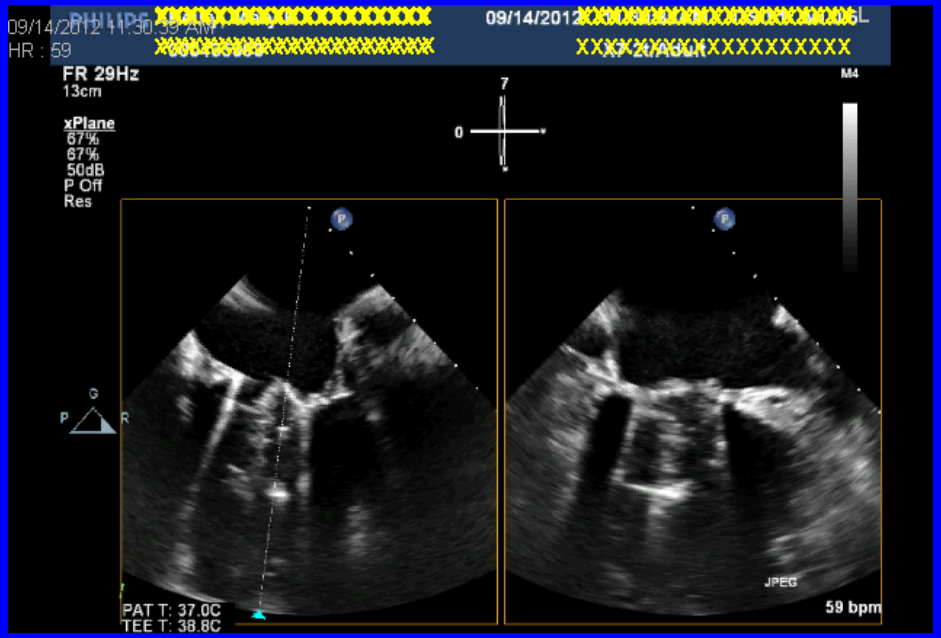


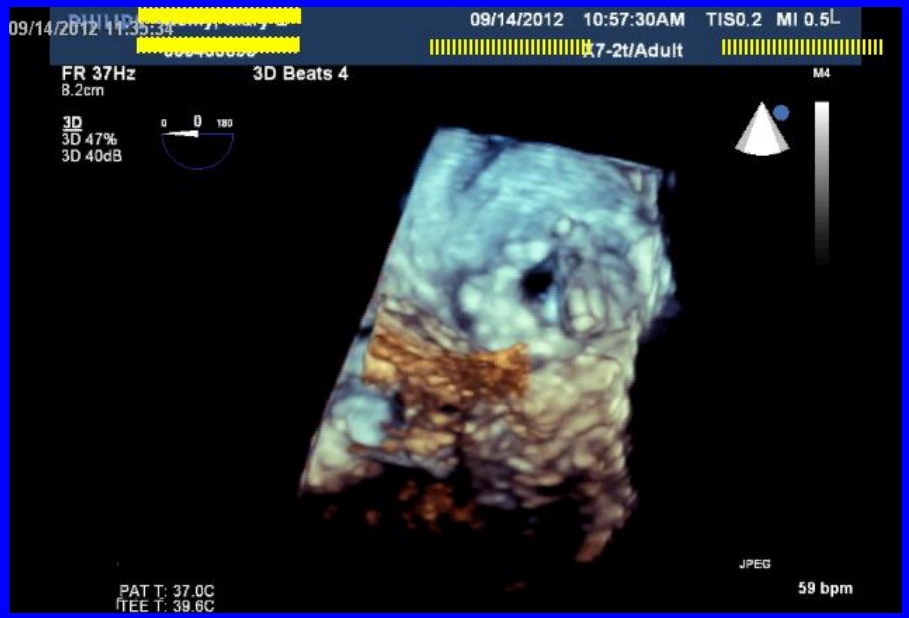
VTI_{LVOT} **17 cm**

DVI = 5.8



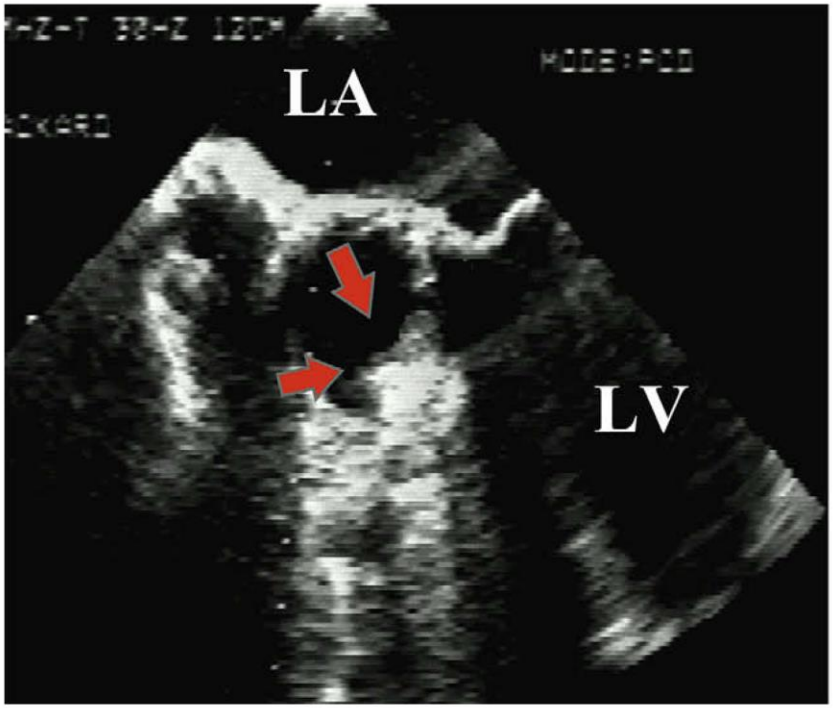
Fernandes V et al. Am J Cardiol 2002;89:704.

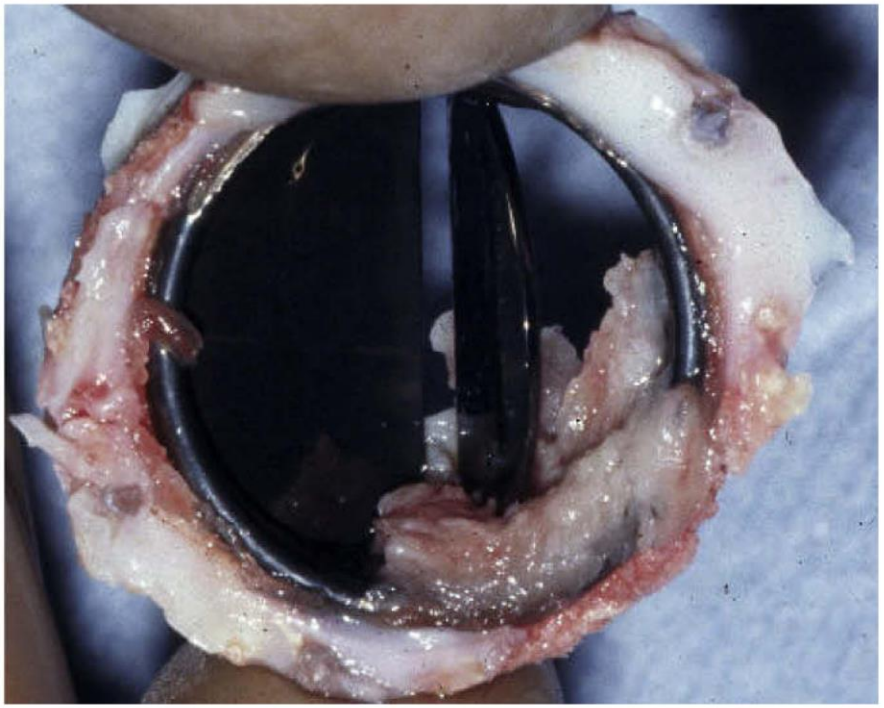

09/14/2012 11:30:39 AM
HR : 59
FR 29Hz
13cm
xPlane
67%
67%
50dB
P Off
Res
M4
JPEG
PAT T: 37.0C
TEE T: 38.8C
59 bpm


09/14/2012 10:57:30AM TIS0.2 MI 0.5
X7-2t/Adult
FR 37Hz
3D Beats 4
8.2cm
3D
3D 47%
3D 40dB
M4
JPEG
PAT T: 37.0C
TEE T: 39.6C
59 bpm


CM
1
2
3

Pannus In-growth





Versus Thrombosis

-Anticoagulation usually adequate
-Greater time from implant to presentation
-More echo-dense
-Aortic position more common

Zoghbi WA et al. J Am Soc Echocardiogr 2009;22:975.

Valve Stenosis/Obstruction

- Differential Diagnosis
  - High cardiac output states
    - Anemia, fever, hypovolemia, thyrotoxicosis
  - Significant regurgitation
  - Patient-prosthesis mismatch
  - Pressure recovery
- Caveats
  - Compare to baseline study
  - Take into account:
    - Size/type of prosthesis
    - Cardiac output
    - Heart rate
  - Be aware of pressure recovery
    - Bileaflet mechanical valves primarily in aortic position

Valve Stenosis/Obstruction

Table 8 Doppler parameters of prosthetic mitral valve function

	Normal*	Possible stenosis‡	Suggests significant stenosis*‡
Peak velocity (m/s)†§	<1.9	1.9-2.5	≥2.5
Mean gradient (mm Hg)†§	≤5	6-10	>10
VTI_{PrMv}/VTI_{LVO}†§	<2.2	2.2-2.5	>2.5
EOA (cm^2)	≥2.0	1-2	<1
PHT (ms)	<130	130-200	>200

Zoghbi WA et al. J Am Soc Echocardiogr 2009;22:975.

Note: PHT is not a valid measure of EOA

Prosthetic Regurgitation

- Tissue valves
  - Degenerative/calcific changes
  - Infective endocarditis
  - Pannus in-growth
  - Paravalvular
- Mechanical valves
  - Paravalvular
    - Dehiscence
    - Poor seating
    - Infection
  - Incomplete closure
    - Pannus in-growth
    - Thrombosis

Prosthetic Regurgitation

Differentiating "Normal" from Pathological Regurgitation

Normal

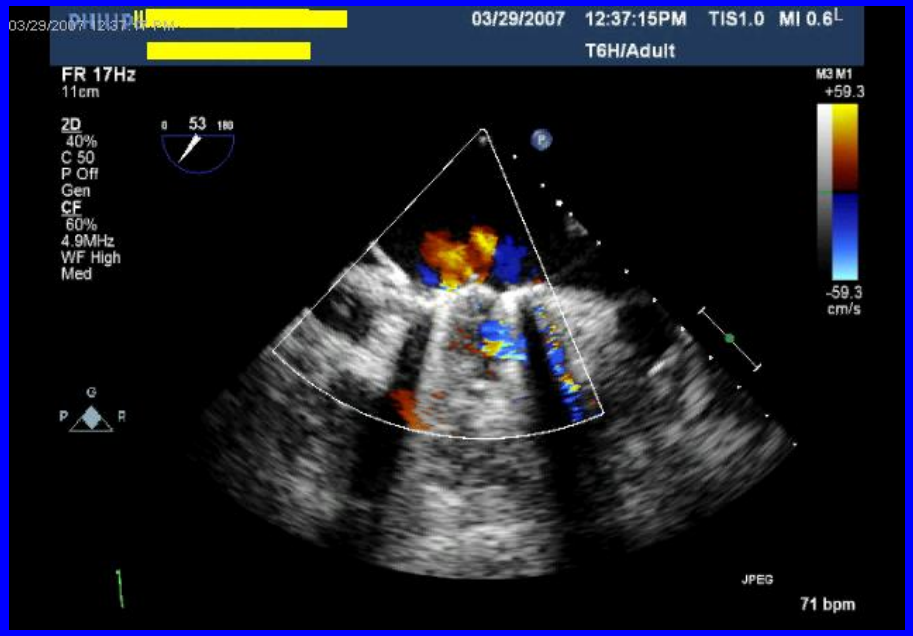
- Characteristic pattern for each valve type
- Symmetric
- Brief
- Non-turbulent
- Lack of associated features
  - Increased antegrade velocities
  - Effects on chamber size and function (hyperdynamic)
  - Increased PASP

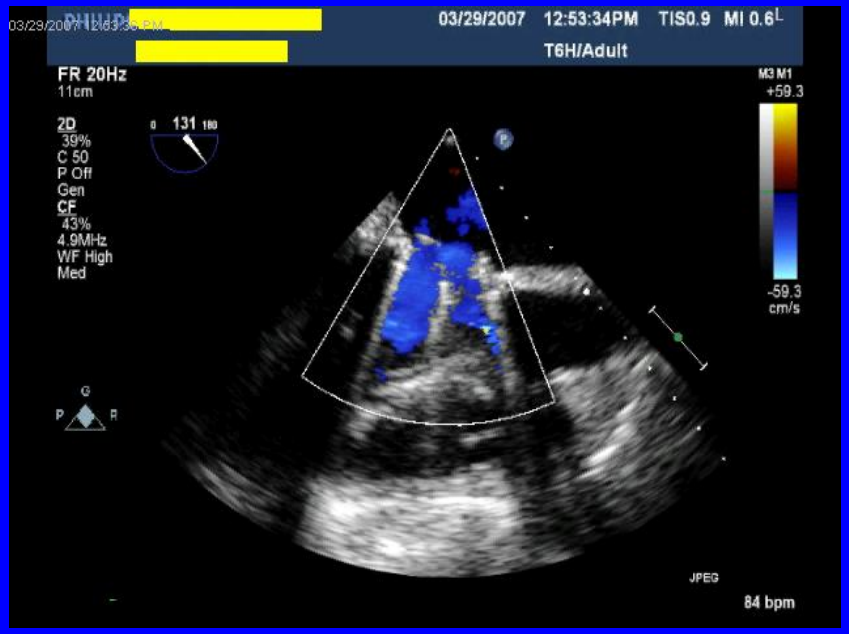
Pathological

- Asymmetric
  - May flow along atrial wall
- Greater flow duration
  - Persists well into systole
- Turbulent (mosaic) pattern
- Proximal flow acceleration may be present
- Presence of associated features

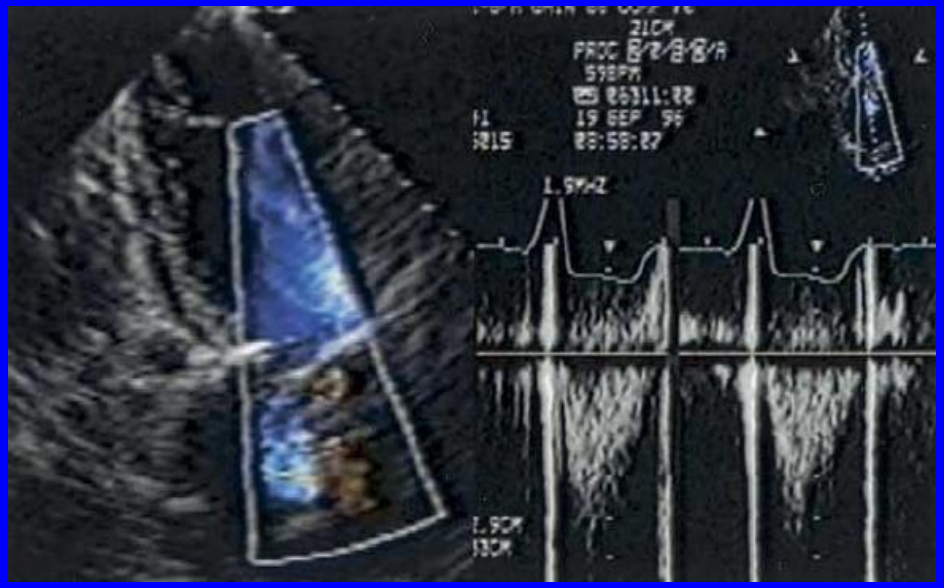
Evaluation of Prosthetic Regurgitation

- Similar to native valve evaluation
- Prosthetic shadowing limits evaluation
  - Mitral: TEE superior to evaluate LA aspect
- “Pseudo-regurgitation”

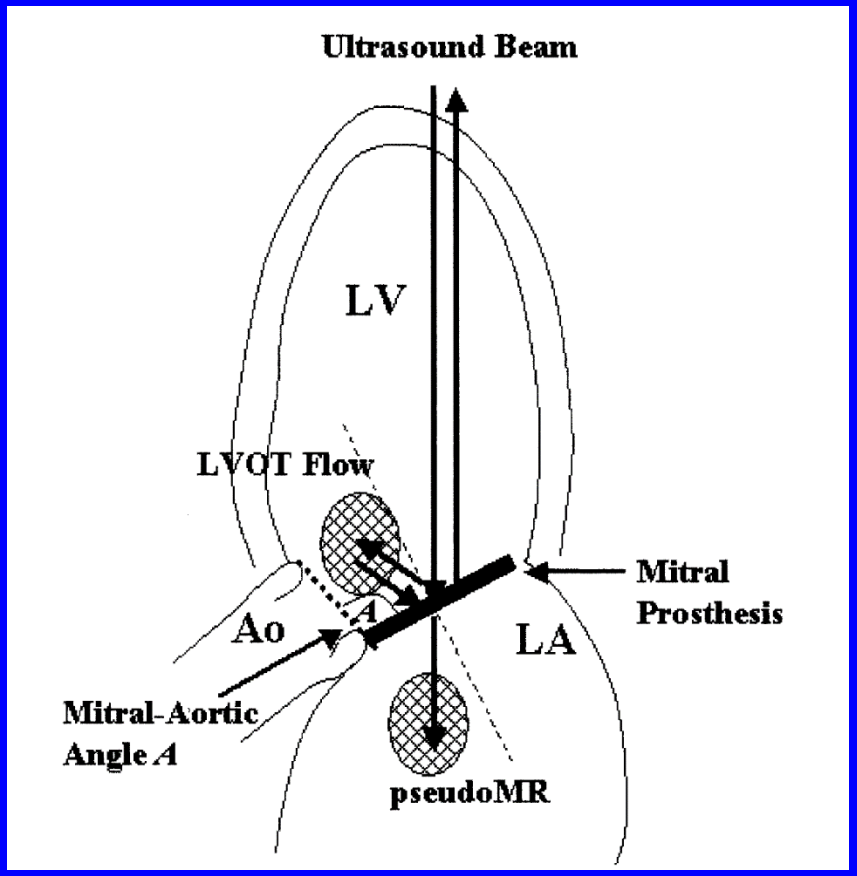

03/29/2007 12:37:15PM TIS1.0 MI 0.6
T6H/Adult
FR 17Hz
11cm
2D
40%
C 50
P Off
Gen
CF
60%
4.9MHz
WF High
Med
53
M3 M1
+59.3
-59.3
cm/s
JPEG
71 bpm


03/29/2007 12:53:34PM TIS0.9 MI 0.6
T6H/Adult
FR 20Hz
11cm
2D
39%
C 50
P Off
Gen
CF
43%
4.9MHz
WF High
Med
131
M3 M1
+59.3
-59.3
cm/s
JPEG
84 bpm

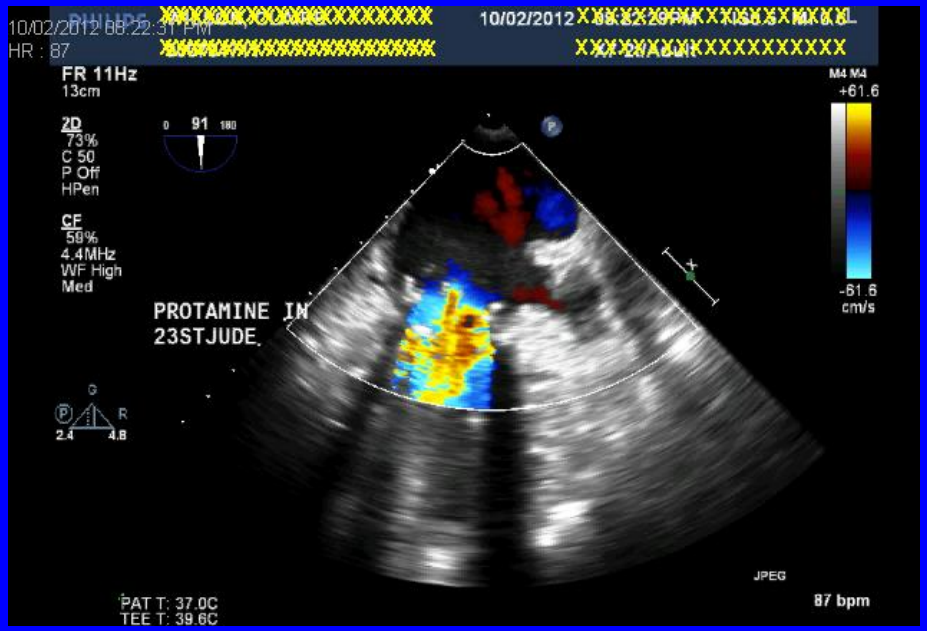
Pseudo-regurgitation

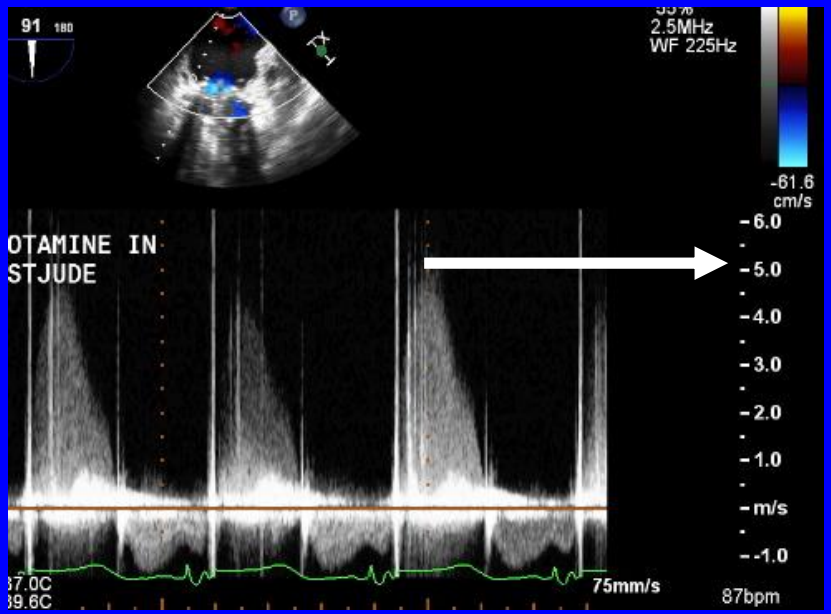


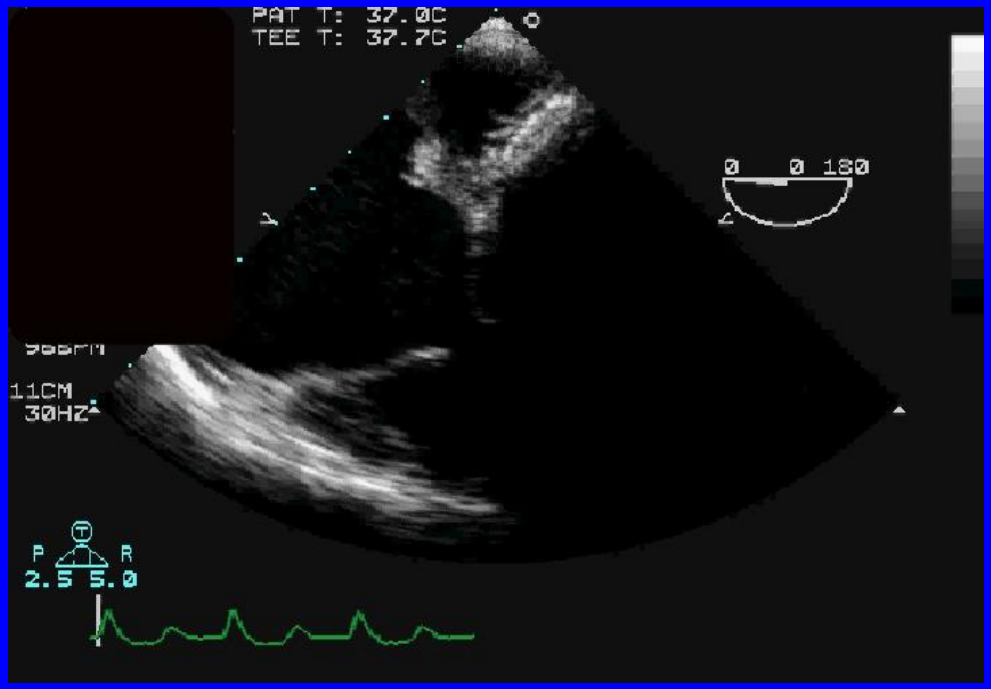
Rudski LG et al. J Am Soc Echocardiogr 2004;17:829.

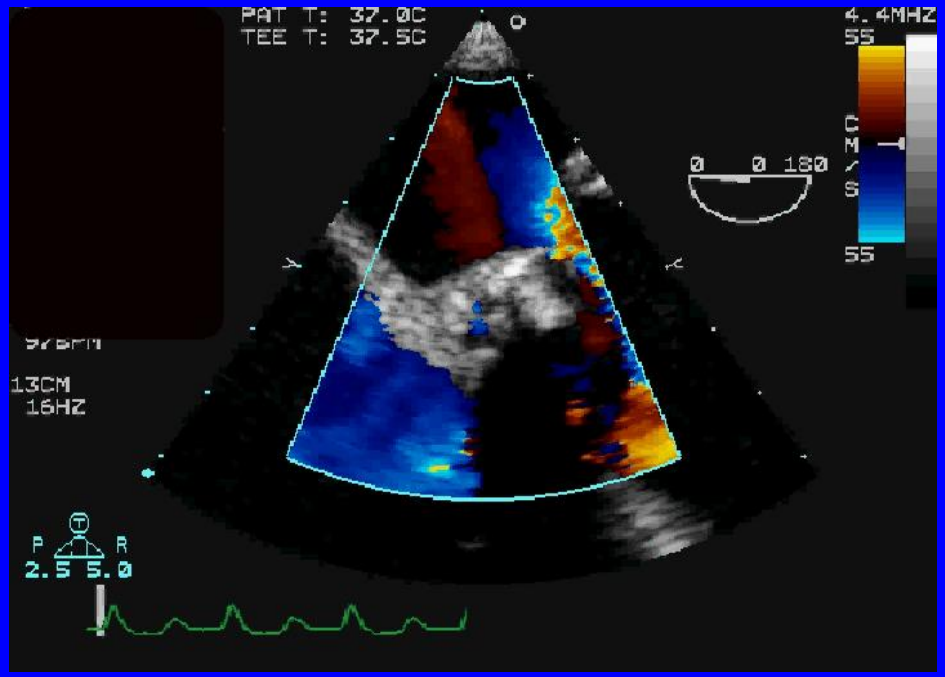


Immediate Post-operative Paravalvular MR






PAT T: 37.0C
TEE T: 37.7C
0 0 180
11CM
30HZ
P R
2.5 5.0


PAT T: 37.0C
TEE T: 37.5C
4.4MHZ
55
C
M
/
S
55
0 0 180
13CM
16HZ
P R
2.5 5.0

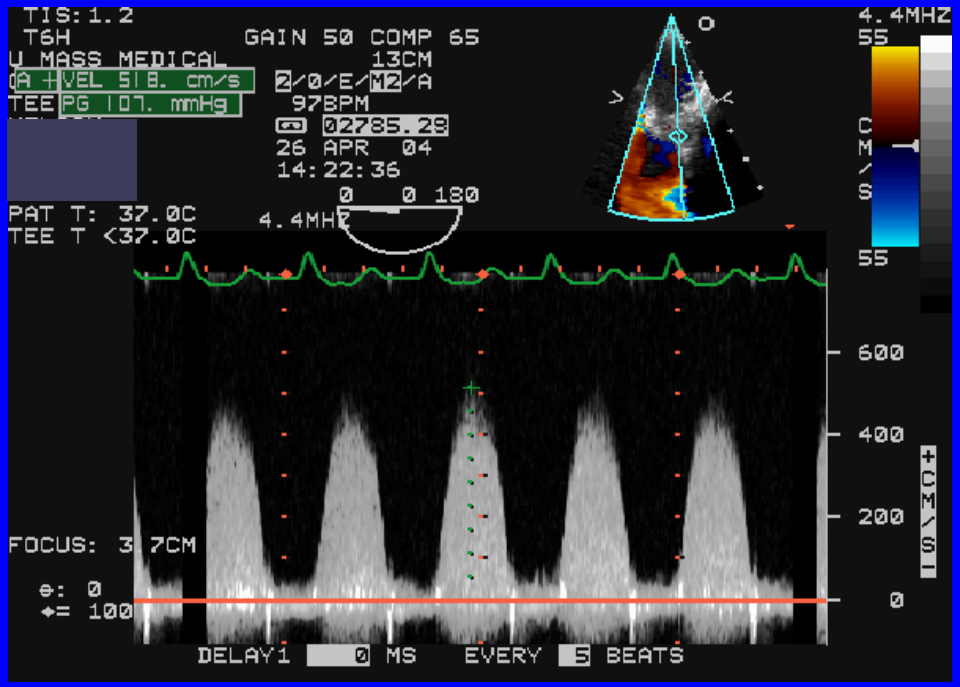

TIS: 1.2
T6H
GAIN 50 COMP 65
U MASS MEDICAL
13CM
VEL 518. cm/s
2/0/E/M2/A
TEE PG 107. mmHg
97BPM
02785.28
26 APR 04
14:22:36
0 0 180
PAT T: 37.0C
TEE T <37.0C
4.4MHZ
4.4MHZ
55
C
M
/
S
55
600
400
200
0
FOCUS: 3 7CM
0: 0
100
DELAY1 0 MS EVERY 5 BEATS

Table 9 Transthoracic echocardiographic findings suggestive of significant prosthetic MR in mechanical valves with normal pressure half-time

Finding	Sensitivity	Specificity	Comments
Peak mitral velocity ≥1.9 m/s*	90%	89%	Also consider high flow, PPM
$VTI_{PrMV}/VTI_{LVO} \geq 2.5$*	89%	91%	Measurement errors increase in atrial fibrillation due to difficulty in matching cardiac cycles; also consider PPM
Mean gradient ≥ 5 mmHg*	90%	70%	At physiologic heart rates; also consider high flow, PPM
Maximal TR jet velocity > 3 m/s*	80%	71%	Consider residual postoperative pulmonary hypertension or other causes
LV stroke volume derived by 2D or 3D imaging is >30% higher than systemic stroke volume by Doppler	Moderate sensitivity	Specific	Validation lacking; significant MR is suspected when LV function is normal or hyperdynamic and VTI_{LVO} is <16 cm
Systolic flow convergence seen in the left ventricle toward the prosthesis	Low sensitivity	Specific	Validation lacking; technically challenging to detect readily

***PHT <130 msec**

Zoghbi WA et al. J Am Soc Echocardiogr 2009;22:975.

Prosthesis-Patient Mismatch

- Effective orifice area (EOA) of the prosthetic valve is less than that of the normal native valve
  - PPM occurs when EOA is smaller than expected for BSA
- High transvalvular gradients in normally functioning valves
- EOA indexed to body surface area (EOAi)
  - Mitral valve:
    - Non-significant >1.2 cm^2/m^2
    - Moderate >0.9 cm^2/m^2 to ≤1.2 cm^2/m^2
    - Severe ≤0.9 cm^2/m^2
- Consequences may include:
  - Exercise intolerance
  - Higher pulmonary artery pressures
  - Heart failure
  - Increased mortality

Follow-up of Prosthetic Heart Valves
ACC/AHA Guidelines

- Class I
  - Initial TTE is recommended after prosthesis implantation (6 wks to 3 mos) for assessment of valve hemodynamics (LOE: B).
  - Repeat TTE is recommended with a change in clinical symptoms or signs suggesting prosthetic valve dysfunction (LOE: C).
  - TEE is recommended when clinical symptoms or signs suggest prosthetic valve dysfunction (LOE: C).
- Class IIa
  - Annual TTE is reasonable in patients with a bioprosthetic valve after the first 10 years, even in the absence of a change in clinical status (LOE: C).

Nishimura RA et al. Circulation 2014;129:e577-e578.

Which of the following statements regarding the obstructed/thrombosed prosthetic mitral valve is correct?

- 1. A pressure half-time >130 msec is the single best indicator of prosthetic obstruction.
- 2. Taking into account heart rate is not necessary when assessing trans-mitral gradients.
- 3. Pannus in-growth is more common in the mitral position than with aortic PHVs.
- 4. A peak velocity ≥2.5 m/sec suggests significant stenosis.
- 5. Randomized, controlled trials have demonstrated that bolus infusion of rt-PA is the fibrinolytic regimen of choice.

Which of the following statements concerning prosthetic mitral regurgitation is correct?

- 1. Pseudo-regurgitation is an issue most often encountered during performance of TEE.
- 2. Any degree of regurgitation indicates dysfunction of a mechanical valve.
- 3. Structural valve deterioration is an uncommon cause of pathological regurgitation.
- 4. Mitral bioprostheses are less prone to suffer structural valve deterioration than are aortic bioprostheses.
- 5. Annular dehiscence most often is a consequence of infective endocarditis.

As recommended by the 2014 AHA/ACC Valvular Heart Disease Guideline, which of the following statements regarding follow-up of prosthetic heart valves by echocardiography is true?

- 1. Annual TTE is reasonable staring at 5 years following mechanical valve replacement.
- 2. An initial TEE should be performed routinely to assess valve hemodynamics within 2 months of implantation.
- 3. Change in clinical status should prompt early echocardiography.
- 4. Annual TTE is reasonable staring at 5 years following bioprosthetic valve replacement.

Thank you for your attention