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 starting 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 starting at 5 years following bioprosthetic valve replacement.
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

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° to 80°
- 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° to 90°
- 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®
- Percutaneous 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
Normal Appearance—Tissue Valves

- Stented valves
  - 3 cusps and struts with echogenic sewing ring
Normal Appearance—Mechanical Valves

Ball in cage

Single disk

Bileaflet
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

<table>
<thead>
<tr>
<th>Event</th>
<th>Mechanical</th>
<th>Bioprosthesis</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Death from any cause</td>
<td>81 ± 4%</td>
<td>79 ± 4%</td>
<td>0.30</td>
</tr>
<tr>
<td>Any valve-related complication</td>
<td>73 ± 6%</td>
<td>81 ± 5%</td>
<td>0.56</td>
</tr>
<tr>
<td>Systemic embolism</td>
<td>18 ± 5%</td>
<td>22 ± 5%</td>
<td>0.96</td>
</tr>
<tr>
<td>Bleeding</td>
<td>53 ± 7%</td>
<td>31 ± 6%</td>
<td>0.01</td>
</tr>
<tr>
<td>Endocarditis</td>
<td>11 ± 4%</td>
<td>17 ± 5%</td>
<td>0.37</td>
</tr>
<tr>
<td>Valve thrombosis</td>
<td>1 ± 1%</td>
<td>1 ± 1%</td>
<td>0.95</td>
</tr>
<tr>
<td>Perivalvular regurgitation</td>
<td>17 ± 5%</td>
<td>7 ± 4%</td>
<td>0.05</td>
</tr>
<tr>
<td>Reoperation</td>
<td>25 ± 6%</td>
<td>50 ± 8%</td>
<td>0.15</td>
</tr>
<tr>
<td>Primary valve failure (SVD)</td>
<td>5 ± 4%</td>
<td>44 ± 8%</td>
<td>0.0002</td>
</tr>
</tbody>
</table>

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


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
Non-obstructive Thrombosis

Mechanical Prosthesis

Bioprosthesis
BPVT vs. Structural Valve Deterioration

BP valve thrombosis

Structural valve deterioration

<table>
<thead>
<tr>
<th>TABLE 5 Test Performance Characteristics for the Diagnosis of BPVT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variables</td>
</tr>
<tr>
<td>-----------</td>
</tr>
<tr>
<td>A. 50% mean gradient increase</td>
</tr>
<tr>
<td>B. Increase cusp thickness</td>
</tr>
<tr>
<td>C. Abnormal cusp mobility</td>
</tr>
<tr>
<td>D. Paroxysmal AF</td>
</tr>
<tr>
<td>E. Subtherapeutic INR</td>
</tr>
<tr>
<td>Combination of variables</td>
</tr>
<tr>
<td>A and B</td>
</tr>
<tr>
<td>A, B, and C</td>
</tr>
<tr>
<td>A, B, C, and D</td>
</tr>
<tr>
<td>A, B, C, D, and E</td>
</tr>
</tbody>
</table>

Obstructive Thrombosis
Thrombus Area by TEE Predicts Clinical Outcome

Suspected Prosthetic Valve Thrombosis

TTE to evaluate hemodynamic severity (I)

CT or fluoroscopy to evaluate valve motion (IIa)

Left-sided prosthetic valve thrombosis

TEE for thrombus size (I)

NYHA class III-IV symptoms

Emergency Surgery (I)

Mobile or large (≥0.8 cm³) thrombus

Emergency Surgery (IIa)

Recent onset (<14 d) NYHA class I-II symptoms Small thrombus (<0.8 cm³)

Fibrinolytic Rx if persistent valve thrombosis after IV heparin therapy* (IIa)

Right-sided prosthetic valve thrombosis

Class I

Class IIa

Infected 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
Imaging Evaluation for Suspected Endocarditis

Patient at Risk or With Suspected NVE or PVE
- Blood cultures × 2
- TTE

Class I
Class IIa
Class IIb

Nondiagnostic TTE
Complications present or suspected
Intracardiac lead present
S. aureus bacteremia without known source
Prosthetic valve with persistent fever
Suspected paravalvular infection with inadequate TTE/TEE
Nosocomial S. aureus bacteremia with portal of entry from known extra cardiac source
Undergoing surgery for IE

TEE (Ia)
Cardiac CT (IIa)
TEE (IIb)
Intraoperative TEE (I)

* TEF
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
    - $\frac{VTI_{\text{prosthesis}}}{VTI_{\text{LVOT}}}$
Peak E-wave \( 2.6 \text{ m/sec} \)
PHT \( 166 \text{ msec} \)
\( \text{VTI}_{\text{pros}} \) \( 99 \text{ cm} \)

\( \text{VTI}_{\text{LVOT}} \) \( 17 \text{ cm} \)

\( \text{DVI} = 5.8 \)
Pannus In-growth

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

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Normal*</th>
<th>Possible stenosis†</th>
<th>Suggests significant stenosis* ‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak velocity (m/s)† §</td>
<td>&lt;1.9</td>
<td>1.9-2.5</td>
<td>≥2.5</td>
</tr>
<tr>
<td>Mean gradient (mm Hg)† §</td>
<td>≤5</td>
<td>6-10</td>
<td>&gt;10</td>
</tr>
<tr>
<td>$VTI_{PrMv}/VTI_{LVO}$† §</td>
<td>&lt;2.2</td>
<td>2.2-2.5</td>
<td>&gt;2.5</td>
</tr>
<tr>
<td>EOA (cm²)</td>
<td>≥2.0</td>
<td>1-2</td>
<td>&lt;1</td>
</tr>
<tr>
<td>PHT (ms)</td>
<td>&lt;130</td>
<td>130-200</td>
<td>&gt;200</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Normal</th>
<th>Pathological</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristic pattern</td>
<td>Asymmetric</td>
</tr>
<tr>
<td>for each valve type</td>
<td>May flow along atrial wall</td>
</tr>
<tr>
<td>Symmetric</td>
<td>Greater flow duration</td>
</tr>
<tr>
<td>Brief</td>
<td>Persists well into systole</td>
</tr>
<tr>
<td>Non-turbulent</td>
<td>Turbulent (mosaic) pattern</td>
</tr>
<tr>
<td>Lack of associated features</td>
<td>Proximal flow acceleration may be present</td>
</tr>
<tr>
<td></td>
<td>Presence of associated features</td>
</tr>
<tr>
<td>- Increased antegrade</td>
<td></td>
</tr>
<tr>
<td>velocities</td>
<td></td>
</tr>
<tr>
<td>- Effects on chamber size</td>
<td></td>
</tr>
<tr>
<td>and function</td>
<td></td>
</tr>
<tr>
<td>(hyperdynamic)</td>
<td></td>
</tr>
<tr>
<td>- Increased PASP</td>
<td></td>
</tr>
</tbody>
</table>
Evaluation of Prosthetic Regurgitation

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

Immediate Post-operative Paravalvular MR
**Table 9** Transthoracic echocardiographic findings suggestive of significant prosthetic MR in mechanical valves with normal pressure half-time

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

*PHT <130 msec*

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).

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.
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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.
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Thank you for your attention