Echocardiographic Assessment of Prosthetic Heart Valves

Dennis A. Tighe, M.D., FACC, FACP
Cardiovascular Medicine
University of Massachusetts Medical School
Worcester, MA

Overview

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

Prosthetic Heart Valves

- Mechanical valves
- Tissue (biological) valves
- Valved conduits
- 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

Ball-in Cage
Starr Edwards Valve

- Circular sewing ring
- Silastic ball
- Cage with arches
- Durable
- High profile
- Flow occurs around the ball
- Normal 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
- Normal regurgitant volume of 5-9 mL
Bileaflet Tilting Disc Valves

- 2 pyrolytic carbon semicircular discs attached to rigid valve ring by small hinges
- Opening angle 75° to 90°
- 3 orifices—small central and 2 larger lateral orifices
- Normal regurgitant volume of 5-10 mL

Tissue Valves

- Stented heterograft valves
  - Porcine
  - Bovine pericardium
- Stentless heterograft valves
- Homografts
- Autografts

Stented Heterograft Valves

- Sewing ring with 3 semirigid stents or struts
- Trileaflet—opens to a circular orifice
- Suboptimal hemodynamic performance compared to native valves
- Normal regurgitant volume of about 1 mL
- 10% exhibit a small degree of regurgitation by color flow imaging
**Stentless Heterograft Valves**

- Manufactured from intact porcine aortic valves
- Aortic position primarily
- No rigid stents—larger effective orifice area
- Better hemodynamic performance as compared to stented biological valves

**Homograft Valves**

- Antibiotic-sterilized, cryogenically preserved, harvested from human cadavers
- Favorable hemodynamics, resistant to infection, no anticoagulation requirement
- Usually implanted as a complete root replacement with coronary artery reimplantation

**Autograft Valves**

- **Ross Procedure**
  - Native pulmonary valve replaces diseased aortic valve
  - Stentless homograft used in pulmonary position
  - Reconstruct RV outflow tract
  - Reimplant coronary arteries
- **Benefits**
  - Stentless
  - No anticoagulation requirement
  - May grow
Echocardiographic Approach to 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 imaging
  - Reverberations/shadowing
- Calculate transvalvular pressure gradient (mean)
- Calculate valve orifice area
  - Continuity equation
  - Pressure half-time
  - Dimensionless (velocity) index
- Estimate degree of regurgitation
- Estimate pulmonary artery systolic pressure
- Assess ventricular size and function
- Evaluate other valves
- COMPARE TO BASELINE STUDY

Echocardiographic Approach to Prosthetic Heart Valves—Caveats

- “Normal” Doppler values based on prosthesis size and type, and valve position
- All prosthetic valves have higher gradients compared to native valves
- Include the proximal velocity in continuity equation calculation if it exceeds 1 m/sec
- Differential diagnosis of high valve gradients:
  - True stenosis
  - High cardiac output state
  - Significant regurgitation
  - Patient-prosthesis mismatch
  - Pressure recovery
Normal Appearance—Tissue Valves

• Stented valves
  – 3 cusps and struts with echogenic sewing ring
• Stentless valves
  – Thickening of aortic root/annulus
• Homograft/autograft
  – Increased echogenicity at the annular level
Normal Appearance—Mechanical Valves

Materials on this slide cannot be shown due to copyright issues.

---

Doppler Parameters

<table>
<thead>
<tr>
<th>Type</th>
<th>Peak velocity (m/s)</th>
<th>Mean gradient (mm Hg)</th>
<th>Area mean (cm²)</th>
<th>Area range (cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>St. Jude Mosaic</td>
<td>2.4 ± 0.4</td>
<td>12 ± 0.3</td>
<td>2.2</td>
<td>2.2 - 2.3</td>
</tr>
<tr>
<td>Edwards</td>
<td>2.4 ± 0.4</td>
<td>13 ± 0.3</td>
<td>2.2</td>
<td>2.2 - 2.3</td>
</tr>
<tr>
<td>Medtronic</td>
<td>2.4 ± 0.4</td>
<td>13 ± 0.3</td>
<td>2.2</td>
<td>2.2 - 2.3</td>
</tr>
<tr>
<td>Hancock</td>
<td>2.4 ± 0.4</td>
<td>13 ± 0.3</td>
<td>2.2</td>
<td>2.2 - 2.3</td>
</tr>
<tr>
<td>St. Jude Medtronic</td>
<td>2.4 ± 0.4</td>
<td>13 ± 0.3</td>
<td>2.2</td>
<td>2.2 - 2.3</td>
</tr>
</tbody>
</table>

Prosthetic Valve Dysfunction

- Structural valve failure
- Thrombosis
- Infective endocarditis
- Stenosis
- Regurgitation
- Patient-prosthesis mismatch
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 catheterization
  - Stress echocardiography

Structural Failure

- Mechanical valves
  - Rare today
  - Ball variance
    - Starr-Edwards
  - Strut fracture
    - Bjork-Shiley
  - Disc embolization
Structural Failure

- Tissue Valves
  - Much more common
  - Younger patients
  - Renal failure
  - Calcification, perforation, or spontaneous tissue degeneration of leaflets
  - Regurgitation
  - Usually gradual—may be acute and massive
  - Doppler may show “stripes”

Valve Thrombosis

- Risk much more common with mechanical valves
- Highest risk: tricuspid and mitral positions
- Often associated with inadequate anticoagulation
- Clinical manifestations
  - Peripheral embolization
  - Stenosis or regurgitation
  - Heart failure
- Gradual or acute symptom onset
- TEE often needed especially in mitral position
Infective Endocarditis

- Early versus late
- Risk approximately 0.5%/year
- Mechanical valves
  - Usually involves the sewing ring
  - Rare to visualize vegetation on discs
- Tissue valves
  - Vegetations seen most often on leaflets
- Complications
  - Heart failure
  - Abscess/fistula formation
  - Regurgitation: valvular or paravalvular
  - Stenosis
  - Embolism
  - Conduction defects
Infective Endocarditis

Valve Stenosis/Obstruction

- Tissue valves
  - Calcification and restricted motion
- Mechanical valves
  - Restriction of disc/ball motion
    - Thrombus
    - Vegetations
    - Pannus formation
  - Restriction of annular area
    - Pannus ingrowth
Valve Stenosis/Obstruction

- Aortic Valve
  - Continuity equation
  - Dimensionless index
- Mitral valve
  - Pressure half-time
  - Continuity equation
- Tricuspid valve
  - Pressure half-time
Valve Stenosis/Obstruction

- **Differential Diagnosis**
  - High cardiac output states
    - Anemia, fever, hypovolemia, thyrotoxicosis, etc.
  - Significant regurgitation
  - Patient-prosthesis mismatch
  - Pressure recovery

- **Caveats**
  - Compare to baseline study
  - Take into account size/type of prosthesis and cardiac output
  - Beware pressure recovery
  - Bileaflet mechanical valves in aortic position

Valve Stenosis/Obstruction

- **Aortic valve**
  - Favors stenosis
    - Peak velocity >4.5 m/sec
    - Mean gradient >50 mm Hg
    - Effective orifice area <0.8 cm²
    - Dimensionless index <0.20-0.25

- **Mitra valve**
  - Favors stenosis
    - Increased peak E-wave velocity (>2 m/sec)
    - PHT >200 msec
    - MVA <1.0-1.5 cm²
    - \( E_{peak} >1.9 \text{ m/sec, } \frac{VTI_{pmv}}{VTI_{lvot}} >2.2, \text{ PHT } >130 \text{ msec} \)

**Prosthetic Regurgitation**

- **Tissue valves**
  - Degenerative changes
  - Infective endocarditis
  - Paravalvular

- **Mechanical valves**
  - Paravalvular: dehiscence, poor seating, infection
  - Incomplete closure
    - Pannus formation
    - Thrombosis
Prosthetic Regurgitation
Differentiate “Normal” from Pathological Regurgitation

<table>
<thead>
<tr>
<th>Normal</th>
<th>Pathological</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Characteristic pattern for each valve type</td>
<td>• Asymmetric</td>
</tr>
<tr>
<td>• Symmetric</td>
<td>• Flow along atrial/aortic wall</td>
</tr>
<tr>
<td>• Brief</td>
<td>• Long duration</td>
</tr>
<tr>
<td>• Nonturbulent</td>
<td>- Persists well into systole or diastole</td>
</tr>
<tr>
<td>• Absence of associated features</td>
<td>- Turbulent (mosaic) pattern</td>
</tr>
<tr>
<td>- increased integrative velocity</td>
<td>- Proximal flow acceleration may be present</td>
</tr>
<tr>
<td>- effects on chamber size and function (hyperdynamic)</td>
<td>- Presence of associated features</td>
</tr>
<tr>
<td>- pulmonary hypertension</td>
<td></td>
</tr>
</tbody>
</table>

Evaluation of Prosthetic Regurgitation

• Similar to native valve evaluation
• Prosthetic shadowing limits evaluation
  – Mitral: TEE superior
  – Aortic: TTE superior in most situations
    • TEE superior for suspected abscess
    • TEE LVOT, gastric and deep gastric views helpful
• “Pseudoregurgitation”
Valve-Prosthesis Patient Mismatch

- Effective orifice area of the prosthetic valve is less than that of the normal native valve
  - EOA is smaller than expected for BSA
- High transvalvular gradients in normally functioning valve
- Indexed to body surface area
  - Aortic valve: <0.85 cm²/m²
  - Mitral valve: <1.2 cm²/m²
- Consequences may include exercise intolerance, impaired regression of LV hypertrophy, higher pulmonary artery pressures, increased 30 day (and possibly late) mortality after AVR

Miscellaneous Findings

- Microbubble cavitation
  - Most common with bileaflet mechanical valves
- Fibrinous strands
- Post-op aortic root thickening
### An Algorithm for Follow-up of Prosthetic Heart Valves

<table>
<thead>
<tr>
<th>Patient Characteristics</th>
<th>Recommended Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early post-operative (bioprosthetic valves)</td>
<td>Usually in all patients</td>
</tr>
<tr>
<td>Long-term follow-up (bioprosthetic valves)</td>
<td>Every 4 years for the first 6 years, then every 3 years</td>
</tr>
<tr>
<td>Mechanical valves</td>
<td>Every 2 years</td>
</tr>
<tr>
<td>Clinical suspicion of prosthetic valve dysfunction</td>
<td>Bedside transthoracic and transesophageal echocardiography</td>
</tr>
<tr>
<td>Aortic position</td>
<td>Transthoracic and/or transesophageal echocardiography</td>
</tr>
</tbody>
</table>

Adapted from: Zabalgoitia M. Curr Prob Cardiol 1992;17:312