TEE Assessment of Prosthetic Valves

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Lecture Outline

• Prosthetic Valve Construction
• Echo characteristics of PVs
• Intraoperative Assessment of PVs
• 10 General Principles

Prosthetic Valve Classification

• Bioprosthetic
  – Stented
  – Stentless
  – Transcatheter
• Mechanical
  – Bileaflet
  – Monoleaflet
  – Ball-cage
• Composite
• Homograft

Stented Bioprosthetic Valves: Porcine

1. Valve tissue
   – Porcine Ao Valve(s)
2. Frame (Stent)
   – *Eugetiov Struts* (3) serve as commissure supports*
3. Sewing ring
   – Suture ring (e.g., soft silicone rubber) for stitches
   – Cloth covering (PTFE or Dacron) to promote endothelial encapsulation

Stented Bioprosthetic Valves

Porcine

Pericardial

Carpentier-Edwards
Mosaic
Biocor

Sorin Mitroflow
Ionescu-Shiley
**C-E PERIMOUNT Magna and Magna Ease**

- Supra-annular design
- “Enables up to 23% greater EOA”
- State of the art tissue treatment eliminates up to 98% of calcium binding sites

**Supra-annular Insertion**

- Supra-annular
  - Sizer should be parallel to the plane of the annulus and the lip of the sizer sits in a supraannular position
- Intra-annular
  - Entire sizer and lip should fit in the annulus

**CE Mitral vs Aortic Pericardial Valve**

Aortic valve scalloped to conform to aortic root. Oversize can cause regurgitation (esp. with RSR)

**Stented Bioprosthetic Valve: Sorin Mitroflow Valve**

- Mounting of pericardium outside the stent allows for unimpeded leaflet opening
- Supra-annular or intra-annular placement
- Only approved in US for AV position

**C-E vs Sorin Pericardial Valve**

Key differences are location of commissural supports and central aperture

**Stentless Bioprosthetic Valves**

- Allow valve 1-2 sizes larger
- Increased EOA
- Decreased Gradient
- Theoretically less stress on leaflets
- However more complicated surgery
Stentless Bioprosthetic Valves
- Medtronic Freestyle—porcine (A)
- St Jude Toronto SPV—porcine (B)
- ATS 3f—equine pericardial

Medtronic Freestyle Valve
- Porcine Aortic Root
- No Stent
- Dacron ring
- 4 insertion options

Freestyle Full Root Insertion
- 1. Annular suture line
- 2. STJ suture line
- 3. Coronary reimplantation

Freestyle Insertion—Subcoronary
Insertion steps
1. Excise R & L sinuses
2. Inflow suture line
3. Seat the bioprosthesis
4. Outflow suture line
**Note stitch issues

St Jude Toronto SPV Valve
- Porcine valve
- Stentless subcoronary design
- One insertion option
- ST Junction size determines valve size
- Vulnerable to root dilation

Toronto SPV Valve
Medtronic ATS 3f—Pericardial Stentless Valve

- Three equine pericardial leaflets shaped in the form of a tube
- Less complex implant technique
  - Annular suture line
  - 3 commissural stitches

Medtronic ATS 3f Enable Valve

- First sutureless valve
- Bioprosthesis within a self-expanding nitinol frame
- Should decrease surgical time and XC period
- In European clinical trials

Transcatheter Bioprosthetic Aortic Valves

- Edwards SAPIEN valve
- Medtronic CoreValve (not FDA approved)

Edwards Transcatheter/Apical Aortic Valve

- Edwards SAPIEN THV
  - Bovine Pericardial Tissue
  - 23 and 26mm Valves
  - ThermaFix Process
  - Leaflet Matching Technology
- Edwards SAPIEN XT THV
  - New Frame Design
  - Lower Cusp Prolapse Geometry
  - New Leaflet Design
  - Scallop-shaped Design
  - New Valve Design
  - Increased Leaflet Coaptation

Edwards Transcatheter Sapien Aortic Valve

1. PAV
2. Catheter inserted across AV
3. Slide valve into position
4. Rapid V-pacing
5. Inflate balloon to open valve

Medtronic Core Valve
### Mechanical Valves

<table>
<thead>
<tr>
<th>Bileaflet</th>
<th>Single leaflet</th>
<th>Ball-cage</th>
</tr>
</thead>
<tbody>
<tr>
<td>St Jude</td>
<td>Medtronic-Hall</td>
<td>Sturr-Edward</td>
</tr>
<tr>
<td>Carbomedics (Sorin)</td>
<td>Bjork-Shiley</td>
<td></td>
</tr>
<tr>
<td>ATS (Medtronic)</td>
<td>Omniscience</td>
<td></td>
</tr>
</tbody>
</table>

#### St Jude Valve
- 2 semicircular leaflets attached to a midline hinge
- Hinge above sewing ring (pivot guard)
- Leaflets move from 30 to 85 degrees (55 degree travel arc)
- Typically rotatable
- AVs and MVs

#### Carbomedics (Sorin) Valve

#### ATS (Medtronic) Valve
- Recently obtained by Medtronic

#### Single Tilting Disc Valves
- Key differences are leaflet retention mechanism and the central aperture
**Medtronic Hall Valve**
- Opening arc is restricted (55-70 degrees)
- Creates a major and minor orifice
- Closure occurs by backpressure on valve disc

**Bjork-Shiley Valve**
- Discs held in place by two metal struts (inflow and outflow)
- Standard design very durable
- Convexo-Concavo valve subject to extensive recall in 1986*

*619/80,000 valves fractured and 2/3 patients died

**Starr Edwards Valve**
- Stellite alloy double cage
- Silicone rubber poppet
- Teflon/polypropylene cloth sewing ring
- High profile
- High gradient
- High risk thrombosis

**Composite Root Valves: Mechanical**

St Jude Medical

*Weyman, Principles and Practice of Echocardiography*
Composite Root Valves: Tissue

• Human cadaveric aortic and pulmonary valves
• Cryopreserved
• No Stent or Dacron ring
• Good for aortic root abscess Tx

Homograft

Echo Assessment of Prosthetic Valves

• 2-D
• Color Doppler
• Hemodynamics
• Look for Collateral Damage

Step 1: 2-D Exam

• What type of valve is it?
• Is the valve well-seated?
• Are the leaflets moving appropriately?
• Are there any extraneous masses present?

Assessment of Valve Seating and Leaflet Motion

What type of valve is this?
Assessment of Leaflet Motion—Transgastric views very useful

Stentless vs Stented Valves

Stentless Valves vs Homograft

Homograft has no shadow

A Homograft does not create an acoustic shadow

Transcatheter SAPIEN Aortic Valve

St Jude Valve Mitral Position

Leaflet motion easy to assess in the esophageal views
The appearance changes with the imaging plane
Orientation of the St Jude Valve

- Anatomic?
- Anti-anatomic?

Clinical note:
Orientation of a Bileaflet valve in the mitral position

St Jude Valve Aortic Position
Long Axis View

Assessment of Leaflet Motion
Aortic valve mechanical valve leaflet motion easy to assess in TGx views
Carbomedics in the Mitral Position

Carbomedics vs St Jude

Medtronic Hall in Mitral Position

Orientation: Major Axis directed toward lateral wall

Medtronic Hall in Aortic Position

Medtronic Hall in Aortic Position

Bjork Shiley Mitral Valve

Atypical Orientation
Review
Step 1: 2-D Exam
• What type of valve is it?
• Is the valve well-seated?
• Are the leaflets moving appropriately?
• Are there any extraneous masses present?

What kind of valve is this?
Is this valve well seated?

Are these leaflets moving normally?

Are there any extraneous masses?

Step 2: Color Doppler
- Does the antegrade flow look normal?
- Are the normal washing jets present?
- Is there any intravalvular pathologic regurgitation?
- Is there a paraprosthetic leak?

Color Doppler Exam Essentials
1. Wide enough sector to see outside sewing ring
2. Omniplane 0-180 degrees
3. If confused: Freeze—slow motion replay

Is the Antegrade Flow Profile Normal?
- Limited turbulence
- Symmetric flow with most valves
**Are the Normal Washing Jets Present?**

Regurgitant Jets

1. Closure backflow
   - Short duration
2. Leakage backflow*
   - After valve closes
   - Low velocity and uniform color
   - Low signal strength with CWD

* A.K.A. Washing jets

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**Bioprosthetic Regurgitation**

- Should be minimal
- Occasionally occurs between leaflet edges
- More with C-E Perimount/Magna valves than porcine aortic valve or Mitroflow valve

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**C-E Pericardial Valves**

- Trivial / trace to mild central regurgitation arising from free space
- One or more trivial jets along coaptation edge of the leaflets originating at the stent posts
- One or more trivial jets at the base of the valve through the cloth

Courtesy Edwards Lifescience

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**Mild Central MR**

- Trace to mild central or commissural jets are commonly seen with mitral PERIMOUNT valves and are clinically insignificant

Courtesy Edwards Lifescience

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**Trivial Jets at Stent Posts**

Courtesy Edwards Lifescience

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**Other Flow Patterns: Leakage through Cloth**

- Occasionally seen on both porcine and pericardial valves
- Originates from base of stent post
- May see more than one symmetrical jet depending on view
- Unlike signature flow patterns, these jets have been observed to resolve intraoperatively following protamine

Courtesy Edwards Lifescience
Leakage through Cloth

- Pre-protamine
- Two symmetric commissural jets are noted
- Jets are low velocity, mild
- Number and direction of jets will vary depending on view

C-E Pericardial Valves

- Commissural leaks and cloth leakage jets typically improve after time and protamine

Leakage through Cloth

- Post-protamine
- Four jets visible, magnitude greatly reduced from pre-protamine view

Leakage through Cloth

- Post-protamine, 2 min later
- Commissural jets not apparent
- Only tiny central jet apparent

Tissue Valve Regurgitation

Aortic Pericardial Valve
Small Valvular Leak

What would expect in the SAx view?
Aortic Pericardial Valve Valvular Leak

Paravalvular leaks

- Small, low velocity paravalvular leaks typically resolve after protamine.

Abnormal Flow Patterns Associated with the C-E Pericardial valves

- Large, high velocity paravalvular leaks
- Eccentric jets (may be result of oversizing)
- Moderate or greater MR (may be result of suture looping, oversizing, or interference by subvalvular apparatus)

Abnormal Flow: Moderate MR

- Moderate (2+ or greater) MR is not normal flow for PERIMOUNT valves

Abnormal Flow: Oversizing

- Eccentric jets noted on echo
  - Severity of eccentric jets often underestimated
- This valve was explanted, found to be severely distorted at implant
Abnormal C-E Perimount Regurgitation

C-E PERIMOUNT vs Sorin Mitroflow Valve

Suture Looped over Post

Sorin Mitroflow
Abnormal Regurgitation in a Sorin Mitroflow valve

Transcatheter SAPIEN Valve
- May see paravalvular leaks
- Less likely to see intravalvular leaks once catheter removed

Mechanical Valve Regurgitation Sites

Two Key Principles Regarding Washing Jets for Mechanical Valves
- Dependent on the valve type
- Dependent on the imaging plane
Classic St Jude Color Jets

St Jude Valve in Aortic Position

Post MVR Color Doppler II

St Jude Washing Jets while on CPB

Notice more dominant central jets in this St Jude valve
Key: No paravalvular leak

Washing jets may be exaggerated while on bypass

Prosthetic Valve Regurgitation
Medtronic Hall
Medtronic Hall color Jets

Medtronic Hall in Aortic Position

Medtronic Hall

Deep Transgastric View

Bjork Shiley Mitral Valve

Medtronic Hall vs Bjork Shiley

St Jude vs Bjork Shiley
Starr Edwards Valve

There may be a transient closing jet, but no washing jet associated with a Starr-Edwards valve.

Summary of Mechanical Valve Washing Jets

- **St Jude**: 1 leaflet: 2 lateral jets
  2 leaflets: small central and lateral jets
- **Medtronic Hall**: 1 large central jet, 2 lateral
- **Bjork Shiley**: 2 lateral jets
- **Starr Edwards**: 2 curved closing jet
  no washing jets

Normal vs Pathologic Regurgitation

- **Normal (expected) Regurgitation**
  - Short duration
  - Low velocity and uniform color
  - Low signal strength with CWD
- **Pathologic Regurgitation**
  - Deeply penetrating jets
  - High velocity
  - Non-homogenous jets
  - PISA in the proximal chamber
  - Anything outside the sewing ring

Intraprosthetic vs Paraprosthetic?

- Use multiple views
- Use color suppress
- Use zoom and slow motion replay
- 3-D

Mapping a Paraprosthetic Leak

- 64 degrees
- 84 degrees
- 107 degrees

Mitral Valve Mapping

Also see my handout
1. Start at 0 degrees and center the valve
2. “Omniplane” until see PV leak
3. Check Omniplane angle
4. If jet on left (bottom)
5. If jet on right (top)
6. Rotate to surgeon’s view

**Step 3: Hemodynamics**

- Valve Specific Assessment
  - Velocity
  - Gradients
  - Area calculation

**Hemodynamics: Aortic Valve**

- Peak Velocity
- Peak and Mean Gradient
- Doppler Velocity Index (DVI)
- Effective Orifice Area (EOA) and Index (EOAI)

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**ASE PV Guidelines Document**

**Assessment of Prosthetic AV stenosis**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Normal</th>
<th>Post</th>
<th>Possible stenosis</th>
<th>Significant stenosis</th>
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</thead>
<tbody>
<tr>
<td>Peak velocity (m/s)</td>
<td>&lt;6</td>
<td>&lt;6</td>
<td>&gt;6</td>
<td>&gt;6</td>
</tr>
<tr>
<td>Peak gradient (mm Hg)</td>
<td>&lt;5</td>
<td>&lt;5</td>
<td>&gt;5</td>
<td>&gt;5</td>
</tr>
<tr>
<td>Stenosis</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

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**Post Aortic St Jude Valve**

Transgastric View with CWD

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**Review**

**Step 2: Color Doppler**

- Does the antegrade flow look normal?
- Are the normal washing jets present?
- Is there any intravalvular pathologic regurgitation?
- Is there a paraprosthetic leak?
Peak AV Velocity

<table>
<thead>
<tr>
<th>Valve</th>
<th>Size</th>
<th>Peak Grad</th>
<th>Mean Grad</th>
<th>EOA</th>
</tr>
</thead>
<tbody>
<tr>
<td>#23 CE Pericardial Valve</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Peak LVOT velocity

- DVI = LVOT velocity
- AV velocity

= 1.1 m/s
2.4 m/s
= .46

Effective Orifice Area

- EOA = .785 D^2 \times \frac{VTI_{LVOT}}{VTI_{AV}}
- EOA = .785(2.1^2) \times \frac{1.1}{2.4}
- EOA = 1.58 cm^2

Effective Orifice Area Index

- EOA/BSA = \frac{1.58 \text{ cm}^2}{1.8 \text{ m}^2}
- EOA/BSA = .88 \text{ cm}^2/\text{m}^2

Acceptable EOAI > .85
Marginal EOAI .75 - .85
Unacceptable EOAI < .75
ASE PV Guidelines Document
Assessment of Prosthetic AV stenosis

Hemodynamics: Mitral Valve

- Peak Velocity
- Peak and Mean Gradient
- Pressure Half-Time (PHT)
- Effective Orifice Area (EOA)

Mitral Valve Gradients

Mitral Valve PHT
Expected values for C-E MV

<table>
<thead>
<tr>
<th>Valve</th>
<th>Size</th>
<th>Peak gradient (mm Hg)</th>
<th>Mean gradient (mm Hg)</th>
<th>Peak velocity (m/s)</th>
<th>Pressure half-time (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edwards Non-Valved Bioprosthesis</td>
<td>29</td>
<td>4.7 ± 2</td>
<td>1.76 ± 0.27</td>
<td>92 ± 14</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>4.4 ± 2</td>
<td>1.54 ± 0.15</td>
<td>92 ± 19</td>
<td></td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>6.4 ± 3</td>
<td></td>
<td>93 ± 15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Edwards-Valved Heart Bioprosthesis</td>
<td>27</td>
<td>3.6</td>
<td>1.6</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>5.26 ± 2.36</td>
<td>1.67 ± 0.3</td>
<td>116 ± 11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>1.6 ± 0.85</td>
<td>1.53 ± 0.1</td>
<td>86 ± 11</td>
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</tr>
</tbody>
</table>

Hemodynamics: Tricuspid Valve

- Peak Velocity
- Mean Gradient
- Pressure Half-Time (PHT)

ASE PV Guidelines Document: Assessment of Prosthetic TV stenosis

Table 15: Doppler parameters of prosthesis tricuspid valve function

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak velocity (m/s)</td>
<td>&gt;1.7</td>
</tr>
<tr>
<td>Mean gradient (mm Hg)</td>
<td>&gt;8</td>
</tr>
<tr>
<td>Pressure half-time (ms)</td>
<td>230</td>
</tr>
<tr>
<td>EOA and V in cc/pulse</td>
<td>Varies depending on valve type</td>
</tr>
<tr>
<td>PHTV, Prosthetic tricuspid valve</td>
<td>Varies depending on valve type</td>
</tr>
</tbody>
</table>

Review

Step 3: Hemodynamics

- Valve Specific Assessment
  - Velocity
  - Gradients
  - Area calculation
- Use ASE PV Guidelines Document

Echo Assessment of Prosthetic Valves

- 2-D
- Color Doppler
- Hemodynamics
  - Look for Collateral Damage

Step 4: Rule Out Collateral Damage

- Non-operative valve damage
  - Suture through AML during AVR
  - Suture through the AV during MVR
- Coronary obstruction
  - Valve too large in aortic position
  - Misplaced suture
- LV or RV dysfunction
- VSD
- LVOT obstruction
  - High profile tissue valve in mitral position
- LV rupture
Case #11

- 74 yo woman s/p bioprosthetic valve 13 years ago
- Presented with CHF

What do you see?

What is the diagnosis?

• #27 mm Medtronic Mosaic valve inserted into mitral position
• PFO closed
• While warming, after cardiac rhythm returned, noted a lot of ejection
• What is the differential?

Post op—Notice anything wrong?
Clinical Prosthetic Valve Exam
Post-Bypass
1. Sewing ring well-seated
2. Leaflet(s) demonstrate normal excursion
3. Normal valvular leak present
4. No significant pathologic valvular or paravalvular leak (0-180 degrees)
5. Hemodynamics (grad, velocities, EOA, etc)
6. R/O collateral damage

10 General Principles
- Know the prosthetic valves used in your hospital (2D and washing jet pattern)
- Record baseline (pre-bypass) loops of all cardiac structures
- Listen to/watch the surgeons during bypass period
- Begin post-op assessment BEFORE separation from bypass
- Use ME LAx view during de-airing
- Become an expert at obtaining TGx views
- Use zoom and slow motion replay
- Get a second opinion if any question
- Have a copy of the HDs reference in OR
- Use the same exam sequence every time
What should you do if you really want to become an expert in Prosthetic Valve Assessment?

1. Read a comprehensive chapter on Prosthetic Valves
2. Get samples of the different valve types and study their construction and mechanism
3. Read the ASE Guidelines for Prosthetic Valve Assessment JASE 2009