Prosthetic Valve Assessment

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Types of Prosthetic Heart Valves

- Biological
  - Stented
    - Porcine Xenograft
    - Pericardial Xenograft
  - Stentless
    - Porcine Xenograft
    - Pericardial Xenograft
    - Homograft (allograft)
    - Autograft
  - Percutaneous
- Mechanical
  - Bileaflet
  - Single tilting disk
  - Caged Ball

25 Different Brand Names worldwide.....

> 44 Different Models

Sizes 19 – 35 mm
Types of Prosthetic Heart Valves
Stented bioprosthetic valves consist of a base ring and stent with supporting parts. Radiographic appearance of various stented bio-prosthetic valves.
• Different flow profiles and hemodynamics thru these 3 valves even though all same size
• “Different flow profiles and effective orifice area for similar “size” valves
Look at structure and function

• **Structural**
  - Mobility of occluder / leaflets
  - Valve thrombus, pannus
  - Vegetations and associated complications

• **Functional**
  - Velocity
  - Gradients
  - Effective Orifice Area
  - Regurgitation
Mechanisms of Prosthetic Valve Dysfunction

A: Wear and tear
B: Calcification
C: Pannus
D: Endocarditis
E: Thrombus
Mechanisms of Prosthetic Valve Dysfunction

Table 3  Early and late complications of prosthetic valves

<table>
<thead>
<tr>
<th>PPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geometric mismatch</td>
</tr>
<tr>
<td>Dehiscence</td>
</tr>
<tr>
<td>Primary failure</td>
</tr>
<tr>
<td>Thrombosis and thromboembolism</td>
</tr>
<tr>
<td>Pannus formation</td>
</tr>
<tr>
<td>Pseudoaneurysm formation</td>
</tr>
<tr>
<td>Endocarditis</td>
</tr>
<tr>
<td>Hemolysis</td>
</tr>
</tbody>
</table>
• 81 yo with progressive dyspnea on exertion
• PMHx: Rheumatic valve disease, CABG, Mechanical AVR 2003 (19 St Jude Regent Valve), A Fib, DM Type 2
• TTE: Difficult to visualize mechanical AV
Mean Grad 24

3.2 m/s
What is your diagnosis?

- A) Patient – Prosthesis Mismatch
- B) Normal Prosthetic Valve Function
- C) High Flow State
- D) Prosthetic Valve Stenosis
- E) Improper LVOT Velocity
Evaluation of Prosthetic Valves

- Large range in what is considered normal
- Larger valves produce lower mean gradients
- For any particular patient... it is difficult to differentiate normal from abnormal
- Therefore... additional tools are needed
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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Suita, Japan; Toronto, Ontario, Canada; Cleveland, Ohio; Durham, North Carolina; St Louis, Missouri;
Washington, DC; Springfield, Illinois

JASE September 2009
Table 4  Doppler echocardiographic evaluation of prosthetic aortic valves

<table>
<thead>
<tr>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doppler echocardiography of the valve</td>
</tr>
<tr>
<td>Peak velocity/gradient</td>
</tr>
<tr>
<td>Mean gradient</td>
</tr>
<tr>
<td>Contour of the jet velocity; AT DVI EOA</td>
</tr>
<tr>
<td>Presence, location, and severity of regurgitation</td>
</tr>
<tr>
<td>Pertinent cardiac chambers</td>
</tr>
<tr>
<td>LV size, function, and hypertrophy</td>
</tr>
</tbody>
</table>
• Peak Velocity: 3.2 m/sec
• Peak gradient: 42 mmhg
• Mean gradient: 24 mmhg
Doppler Velocity Index

Normal > 0.25

\[ \text{Doppler Velocity Index} = \frac{V_{LVO}}{V_{jet}} \]
DVI = Velocity LVO / Velocity Jet
DVI = 0.58 / 3.24
DVI = 0.18
An approach to prosthetic AV stenosis

Peak Prosthetic Aortic Jet Velocity $> 3$ m/s

- DVI $\geq 0.30$
- DVI $0.25 - 0.29$
- DVI $< 0.25$

Jet Contour

- AT (ms) $>100$
- AT (ms) $<100$
- AT (ms) $>100$
- AT (ms) $<100$
Where did this data come from?

Red – obstructed valves
General trend is to increase ratio as valves get bigger, however all normal valves > 0.25
Pulsed Doppler LVO

Normal: 1.1 m/s

Obstructed: 1.0 m/s

CW Doppler Prosthetic AV

MG = 22 mmHg
DVI = 0.4
AT = 75 ms

MG = 80 mmHg
DVI = 0.18
AT = 180 ms
• Acceleration Time (AT): 0.15 sec
• Contour of jet: Rounded
Effective Orifice Area = \( \frac{\text{CSA}_{\text{LVO}} \times \text{VTI}_{\text{LVO}}}{\text{VTI}_{\text{JET}}} \)
An approach to prosthetic AV stenosis

Peak Prosthetic Aortic Jet Velocity > 3 m/s

- DVI ≥ 0.30
- DVI 0.25 – 0.29
- DVI < 0.25

Jet Contour

AT (ms)

- >100
- <100

Normal PrAV

EOA Index

High Flow

PPM
An approach to prosthetic AV stenosis

- Peak Prosthetic Aortic Jet Velocity $> 3$ m/s
  - DVI $\geq 0.30$
  - DVI $0.25 - 0.29$
  - DVI $< 0.25$

Jet Contour

- AT (ms)
  - $>100$
  - $<100$

- EOA Index
  - High Flow
  - PPM

Suggests PrAV Stenosis

Consider Improper LVOT velocity
An approach to prosthetic AV stenosis

Peak Prosthetic Aortic Jet Velocity > 3 m/s

- DVI \( \geq 0.30 \)
- DVI 0.25 – 0.29
- DVI < 0.25

Jet Contour

AT (ms)
- >100
- <100

Consider PrAV stenosis with
- Sub-valve narrowing
- Underestimated gradient
- Improper LVOT velocity

Normal PrAV
EOA Index
- High Flow
- PPM

Suggests PrAV Stenosis

Consider Improper LVOT velocity
An approach to prosthetic AV stenosis

Peak Prosthetic Aortic Jet Velocity > 3 m/s

- DVI ≥ 0.30
- DVI 0.25 – 0.29
- DVI < 0.25

Jet Contour

AT (ms)

- >100
- <100

Consider PrAV stenosis with
- Sub-valve narrowing
- Underestimated gradient
- Improper LVOT velocity*

Normal PrAV

EOA Index

- High Flow
- PPM

Suggests PrAV Stenosis◊

Consider Improper LVOT velocity**
Additional Studies Needed?
Fluoroscopy

Fluoroscopy Parameters

Table 1. Cine-Fluoroscopic Functional Parameters.

<table>
<thead>
<tr>
<th>Device Valve</th>
<th>Opening Angle (°)</th>
<th>Closing Angle (°)</th>
<th>Travel Angle (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>f (n = 64)</td>
<td>11.5 ± 1.1 (10-13)*</td>
<td>121.6 ± 1.4 (120-124)*</td>
<td>55.0 ± 0.6 (54.0-56.5)*</td>
</tr>
<tr>
<td>f (n = 69)</td>
<td>27.0 ± 1.4 (25-29)*</td>
<td>131.7 ± 2.1 (130-135)*</td>
<td>60.2 ± 1.4 (57.5-62.5)*</td>
</tr>
<tr>
<td>4V (n = 109)</td>
<td>35.1 ± 1.9 (32-38)*</td>
<td>148</td>
<td>63.3 ± 0.9 (55.0-58.0)*</td>
</tr>
<tr>
<td>n = 78</td>
<td>21.7 ± 1.5 (20-25)</td>
<td>138.0 ± 1.5 (136-141)</td>
<td>58.2 ± 1.0 (56.5-60.0)</td>
</tr>
<tr>
<td>n = 27</td>
<td>21.8 ± 1.3 (20-26)</td>
<td>111.0 ± 2.0 (108-115)</td>
<td>50.8 ± 0.7 (42.0-46.5)</td>
</tr>
</tbody>
</table>

Montorsli P, et al. Am J Card Imag Jan, 1996. 10(1); 29-41
Is TEE Needed?

Fluoro vs. TTE +/- TEE

<table>
<thead>
<tr>
<th></th>
<th>Fluoro</th>
<th>TTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>87</td>
<td>75</td>
</tr>
<tr>
<td>Specificity</td>
<td>78</td>
<td>64</td>
</tr>
<tr>
<td>PPV</td>
<td>80</td>
<td>57</td>
</tr>
<tr>
<td>NPV</td>
<td>91</td>
<td>78</td>
</tr>
</tbody>
</table>

- Together correctly identify thrombosis in 85%
- Suspected valve thrombosis of bileaflet prosthesis, CF and TTE both positive → defer TEE
- High Doppler gradients with normal leaflet motion by CF → TEE
Thank You
### Doppler Parameters of Normal Prosthetic Aortic Valve Function

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak velocity</td>
<td>&lt; 3 m/s</td>
</tr>
<tr>
<td>Mean gradient</td>
<td>&lt; 20 mmHg</td>
</tr>
<tr>
<td>Doppler velocity index</td>
<td>≥ 0.30</td>
</tr>
<tr>
<td>Effective orifice area</td>
<td>&gt;1.2 cm²</td>
</tr>
<tr>
<td>Contour of the jet</td>
<td>Triangular, Early peaking</td>
</tr>
<tr>
<td>Acceleration time</td>
<td>&lt; 80 ms</td>
</tr>
</tbody>
</table>

MG = 22 mmHg  
DVI = 0.4  
AT = 75 ms

Zoghbi W et al. JASE 22: 975 2009
# Doppler Parameters of Abnormal Prosthetic Aortic Valve Function

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak velocity</td>
<td>$&gt; 4 \text{ m/s}$</td>
</tr>
<tr>
<td>Mean gradient</td>
<td>$&gt;35 \text{ mmHg}$</td>
</tr>
<tr>
<td>Doppler velocity index</td>
<td>$&lt; 0.25$</td>
</tr>
<tr>
<td>Effective orifice area</td>
<td>$&lt; 0.8 \text{ cm}^2$</td>
</tr>
<tr>
<td>Contour of the jet</td>
<td>Rounded, symmetrical contour</td>
</tr>
<tr>
<td>Acceleration time</td>
<td>$&gt; 100 \text{ ms}$</td>
</tr>
</tbody>
</table>

![Flow profile with annotations](image)

- **MG:** $80 \text{ mmHg}$
- **DVI:** $0.18$
- **AT:** $180 \text{ ms}$
What else is important?

Key component to evaluation of prosthetic valves is: comparison with old studies and changes from baseline.
<table>
<thead>
<tr>
<th></th>
<th>NORMAL</th>
<th>POSSIBLE STENOSIS</th>
<th>SUGGESTS STENOSIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak velocity</td>
<td>&lt; 3 m/s</td>
<td>3-4 m/s</td>
<td>&gt; 4 m/s</td>
</tr>
<tr>
<td>Mean gradient</td>
<td>&lt; 20 mmHg</td>
<td>20-35 mmHg</td>
<td>&gt;35 mmHg</td>
</tr>
<tr>
<td>Doppler velocity index</td>
<td>≥ 0.30</td>
<td>0.29-0.25</td>
<td>&lt; 0.25</td>
</tr>
<tr>
<td>Effective orifice area</td>
<td>&gt;1.2 cm²</td>
<td>1.2- 0.8 cm²</td>
<td>&lt; 0.8 cm²</td>
</tr>
<tr>
<td>Contour of the jet</td>
<td>Triangular, Early peaking</td>
<td>Triangular to Intermediate</td>
<td>Rounded, symmetrical contour</td>
</tr>
<tr>
<td>Acceleration time</td>
<td>&lt; 80 ms</td>
<td>80-100 ms</td>
<td>&gt; 100 ms</td>
</tr>
</tbody>
</table>

Zoghbi W et al. JASE 22: 975, 2009
Prosthetic Aortic Regurgitation
Similar Criteria for Assessment of Native Aortic Valve Regurgitation

### Evaluation of the Severity of Prosthetic Aortic Valve Regurgitation

<table>
<thead>
<tr>
<th>Doppler Parameters Semi-Quantitative</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jet width in central jets LVO diameter (Color*)</td>
<td>Narrow ($\leq 25%$)</td>
<td>Intermediate ($26% - 64%$)</td>
<td>Large ($\geq 65%$)</td>
</tr>
<tr>
<td>Jet density -CW</td>
<td>Incomplete or faint</td>
<td>Dense</td>
<td>Dense</td>
</tr>
<tr>
<td>Jet deceleration rate (PHT, ms) -CW§</td>
<td>Slow ($&gt; 500$)</td>
<td>Variable ($200 - 500$)</td>
<td>Steep ($&lt; 200$)</td>
</tr>
<tr>
<td>LVO flow compared to pulmonary flow - PW</td>
<td>Slightly increased</td>
<td>Intermediate</td>
<td>Greatly increased</td>
</tr>
<tr>
<td>Diastolic flow reversal in the descending aorta - PW</td>
<td>Absent or brief early diastolic</td>
<td>Intermediate</td>
<td>Prominent, holodiastolic</td>
</tr>
</tbody>
</table>

### Doppler Parameters Quantitative

<table>
<thead>
<tr>
<th></th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regurgitant Volume</td>
<td>$&lt; 30$ ml/beat</td>
<td>$30 - 59$ ml/beat</td>
<td>$\geq 60$ ml/beat</td>
</tr>
<tr>
<td>Regurgitant Fraction</td>
<td>$&lt; 30%$</td>
<td>$30 - 50%$</td>
<td>$\geq 50%$</td>
</tr>
</tbody>
</table>

_JASE 22: 975, 2009_
Prosthetic Aortic Regurgitation
TEE helps identify systolic expansion, endocarditis, etc

Table 6 Parameters for evaluation of the severity of prosthetic aortic valve regurgitation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valve structure and motion</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3 D Echocardiography

- Bioprostheses
- Bi-Leaflet Valve
- Prosthetic Regurgitation
Prosthetic Valve Functional Imaging

- Many different valves
- Spectral and Color Doppler
- Be suspicious – look for clues and changes
- Know the imaging limitations – by valve position and imaging method
- Mitral Valve – think 3D TEE
- Aortic Valve stenosis? Think CT (or fluoro)
- Large ventricle or Volumes – think CMRI
Valve Imaging by Cardiac CT

- Echocardiography is the gold standard
- Advantages
  - Acquisition of a 4D dataset that the reader can interact with to create numerous perspectives
  - Excellent anatomic depiction of native, bio-prosthetic and mechanical valves
  - Excellent depiction of peri-valvular abnormalities
  - Displays extent of valvular/peri-valvular calcification
- Disadvantages
  - Radiation exposure (10-20 msV)
  - Iodinated contrast administration
  - Anatomic assessment only (cannot assess blood flow)
Aortic Valve Regurgitation
Different Perspectives by CT

Fused AV cusps; 3 case examples

Courtesy Dr Entrikin, Wake Forest University
Prosthetic Valvular Evaluation
HPI – 81 year old male

- 8/2005: 2V CABG and 27 mm stented bioprosthetic AVR for obstructive CAD and degenerative AS
- 8/2010: Developed prosthetic valve IE, severe para-valvular AI and NYHA 2 heart failure
  - Treated with prolonged antibiotics
  - Re-do AVR with 23mm stented bioprosthesis, bovine pericardial patch
- 3/2011: Presented with two week history of back pain, confusion
Pseudoaneurysm of the Mitral-Aortic Intervalvular Fibrosa
3D Volume Rendered Image with Blood Pool Inversion Technique
Large Pseudoaneurysm (Preop Planning)
**Multislice Computed Tomography in Infective Endocarditis**

Comparison With Transesophageal Echocardiography and Intraoperative Findings

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Thomas Schertler, MD,§ Johannes Bonatti, MD, FECTS,‡ Hans Scheffel, MD,§
Silvana Mueller, MD,† André Plass, MD,|| Ludwig Mueller, MD,‡ Thomas Bartel, MD, PD,†
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*Innsbruck and Vienna, Austria; and Zurich, Switzerland

**Objectives**
The aim of this study was to assess the value of multislice computed tomography (CT) for the assessment of valvular abnormalities in patients with infective endocarditis (IE) in comparison with transesophageal echocardiography (TEE) and intraoperative findings.

**Background**
Multislice CT has recently shown promising data regarding valvular imaging in a 4-dimensional fashion.

**Methods**
Thirty-seven consecutive patients with clinically suspected IE were examined with TEE and 64-slice CT or dual-source CT. Twenty-nine patients had definite IE and underwent surgery.

**Results**
The diagnostic performance of CT for the detection of evident valvular abnormalities for IE compared with TEE was: sensitivity 97%, specificity 88%, positive predictive value (PPV) 97%, and negative predictive value (NPV) 88% on a per-patient basis (n = 37); excellent intermodality agreement κ = 0.84. CT correctly identified 26 of 27 (96%) patients with valvular vegetations and 9 of 9 (100%) patients with abscesses/pseudoaneurysms compared with the intraoperative specimen. On a per-valve–based analysis, diagnostic accuracy for the detection of vegetations and abscesses/pseudoaneurysms compared with surgery was: sensitivity 96%, specificity 97%, PPV 96%, NPV 97%, and sensitivity 100%, specificity 100%, PPV 100%, NPV 100%, respectively, without significant differences as compared with TEE. Vegetation size measurements by CT correlated (r = 0.95; p < 0.001) with TEE (mean 7.6 ± 5.6 mm). The mobility of vegetations was accurately diagnosed in 21 of 22 (96%) patients with CT, but all of 4 leaflet perforations (≤2 mm) were missed. CT provided more accurate anatomic information regarding perivalvular extent of abscess/pseudoaneurysms than TEE.

**Conclusions**
Multislice CT shows good results in detecting valvular abnormalities in IE and could be applied in pre-operative planning and exclusion of coronary artery disease before surgery.  
(J Am Coll Cardiol 2009;53:436–44) © 2009 by the American College of Cardiology Foundation
Table 3: Diagnostic Performance of CT

For the Detection of Vegetations, Paravalvular Abscesses, and Pseudoaneurysms (37 Patients, 73 Valves) in Patients With Possible and Definite IE: Comparison With TEE

<table>
<thead>
<tr>
<th></th>
<th>Percent</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Per-patient-based analysis</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensitivity (28/29)</td>
<td>97</td>
<td>82%–100%</td>
</tr>
<tr>
<td>Specificity (7/8)</td>
<td>88</td>
<td>47%–100%</td>
</tr>
<tr>
<td>Positive predictive value (28/29)</td>
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<td>Negative predictive value (7/8)</td>
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<td></td>
<td></td>
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<tr>
<td>Sensitivity (28/29)</td>
<td>97</td>
<td>82%–100%</td>
</tr>
<tr>
<td>Specificity (42/44)</td>
<td>95</td>
<td>85%–99%</td>
</tr>
<tr>
<td>Positive predictive value (28/30)</td>
<td>93</td>
<td>78%–99%</td>
</tr>
<tr>
<td>Negative predictive value (41/42)</td>
<td>98</td>
<td>88%–100%</td>
</tr>
<tr>
<td>Diagnostic accuracy (70/73)</td>
<td>96</td>
<td>88%–99%</td>
</tr>
</tbody>
</table>
Conclusions

Results from this preliminary study show a good diagnostic value of multislice CT for the detection of valvular abnormalities associated with IE. Vegetations, abscesses, and pseudoaneurysms were detected with a similar accuracy with CT compared with TEE. CT could be used as an alternative imaging tool in patients with clinical suspicion of IE after an initial negative or inconclusive TEE. In detail, these could be patients in whom a chest CT scan is clinically indicated because of fever of unknown origin in the presence of other pre-disposing factors for IE (3 minor criteria) or a positive hemoculture (1 major).
Complex Prosthetic Mitral Valve Disease

Prosthetic MV Disease
MV Endocarditis
Evaluation for abscess
Surgical approach
66F, 23 mm St Jude Valve Conduit (2002, hx severe AI), COPD, admitted with DOE
- DVI = 0.83/3.64
- DVI = 0.23
- Mean 30 mmHg
- Indexed EOA 0.62
An approach to prosthetic AV stenosis

Peak Prosthetic Aortic Jet Velocity > 3 m/s

- DVI ≥ 0.30
- DVI 0.25 – 0.29
- DVI < 0.25

Jet Contour

- AT (ms)
  - >100
  - <100

Consider PrAV stenosis with:
- Sub-valve narrowing
- Underestimated gradient
- Improper LVOT velocity

EOA Index

High Flow

PPM

Normal PrAV

Suggests PrAV Stenosis

Consider Improper LVOT velocity
GUIDELINES AND STANDARDS

Recommendations for Evaluation of Prosthetic Valves With Echocardiography and Doppler Ultrasound

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