Assessing Prosthetic Valves: Differentiating Normal From Stenotic or Regurgitant

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74M with #23 CE Perimount Magna AVR
LVOT Diameter 20 mm
LVOT (PW):
  Peak velocity 1.0 m/s
  VTI 20 cm
PrAV (CW):
  Peak velocity 2.4 m/s
  Mean gradient 12 mm Hg
  VTI 46 cm
  Acceleration Time 90 ms
DVI 20cm/46cm = 0.43 or 1m/s/2.4m/s = 0.42
Effective Orifice Area:
\[
EOA_{PrAV} = \frac{(CSA_{LVOT} \times VTI_{LVOT})}{VTI_{PrAV}}
\]
\[
EOA_{PrAV} = \frac{63 \text{ mL}}{46 \text{ cm}} = 1.4 \text{ cm}^2
\]

What’s your echo interpretation?

1. Normal prosthetic aortic valve
2. Mild stenosis
3. Moderate stenosis
4. Severe stenosis
5. Patient prosthesis mismatch
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\]

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Best Reference: Expected Performance Values

Doppler Echocardiography in Normally Functioning Replacement Aortic Valves: A Review of 129 Studies
Ronak Rajani, Dayal Mukherjee, John B. Chambers

Valve Study Group, Guy’s and St. Thomas’ Foundation Trust, London, United Kingdom

Echocardiography is the technique of choice for the assessment of replacement aortic valves. Hemodynamic function depends on the design and size of the valve. This review summarizes the published information available to the end of 2005. The most obstructive valve was the caged-ball, followed by the stented porcine and single tilting-disc valves. The stented bovine pericardial valves were slightly less obstructive than these, and similar to the intrannular bileaflet mechanical valves. Stentless valves appeared slightly less obstructive still, and similar to reduced-cuff mechanical bileaflet valves. Homografts were the least obstructive. Approximate guide thresholds suggesting obstruction were derived.

The Journal of Heart Valve Disease 2007;16:519-535
Best Reference: Expected Performance Values

<table>
<thead>
<tr>
<th>Size</th>
<th>n</th>
<th>BSA (m²)</th>
<th>LVOT (mm)</th>
<th>PG max (mmHg)</th>
<th>PG mean (mmHg)</th>
<th>DVI</th>
<th>EOA (cm²)</th>
<th>EOAI (cm³/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>30</td>
<td>1.59 ± 0.15</td>
<td>15.16 ± 1.16</td>
<td>17.67 ± 4.63</td>
<td>0.46 ± 0.14</td>
<td>1.22 ± 0.49</td>
<td>0.77 ± 0.29</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>43</td>
<td>1.77 ± 0.16</td>
<td>16.16 ± 1.16</td>
<td>15.79 ± 5.01</td>
<td>0.60 ± 0.46</td>
<td>1.42 ± 0.59</td>
<td>0.80 ± 0.32</td>
<td></td>
</tr>
<tr>
<td><strong>23</strong></td>
<td><strong>24</strong></td>
<td><strong>1.90 ± 0.18</strong></td>
<td><strong>20.49 ± 2.61</strong></td>
<td><strong>23.90 ± 7.06</strong></td>
<td><strong>13.04 ± 4.40</strong></td>
<td><strong>0.48 ± 0.12</strong></td>
<td><strong>1.64 ± 0.42</strong></td>
<td><strong>0.79 ± 0.36</strong></td>
</tr>
<tr>
<td>25</td>
<td>13</td>
<td>1.89 ± 0.13</td>
<td>22.17 ± 2.71</td>
<td>17.30 ± 6.40</td>
<td>0.49 ± 0.14</td>
<td>2.11 ± 0.58</td>
<td>1.12 ± 0.36</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>2</td>
<td>1.93 ± 0.04</td>
<td>22.50 ± 1.53</td>
<td>18.60 ± 1.24</td>
<td>0.71</td>
<td>2.45 ± 0.21</td>
<td>1.27 ± 0.14</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>3</td>
<td>1.86 ± 0.12</td>
<td>26.33 ± 2.89</td>
<td>15.67 ± 1.53</td>
<td>9 ± 1</td>
<td>0.37 ± 0.01</td>
<td>1.99 ± 0.36</td>
<td>1.07 ± 0.18</td>
</tr>
</tbody>
</table>

Minardi et al. Cardiovascular Ultrasound 2011;9:37

Next Best Thing: Comparison to Prior Study

First Post-Operative Study:
PrAV:
- Peak velocity 1.7 m/s
- VTI 33 cm
- AT 80-90 ms (estimated)
EOA 1.7 cm²
When All Else Fails:  
*A Normal Prosthesis Acts Like Mild Native Valve Stenosis*

<table>
<thead>
<tr>
<th>Stage</th>
<th>Definition</th>
<th>Valve Anatomy</th>
<th>Valve Hemodynamics</th>
<th>Hemodynamic Consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>At risk of AS</td>
<td>• Bicuspid aortic valve (or other congenital valve anomaly)</td>
<td>• Aortic V&lt;sub&gt;max&lt;/sub&gt; &lt; 2 m/s</td>
<td>• None</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Aortic valve sclerosis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Progressive AS</td>
<td>• Mild-to-moderate leaflet calcification of a bicuspid or trileaflet valve with some reduction in systolic motion or • Rheumatic valve changes with commissural fusion</td>
<td>• Mild AS: Aortic V&lt;sub&gt;max&lt;/sub&gt; 2.0–2.9 m/s or mean ΔP &lt; 20 mm Hg</td>
<td>• Early LV diastolic dysfunction may be present • Normal LVEF</td>
</tr>
</tbody>
</table>

61 year old man received a #25 St Jude bileaflet metallic aortic valve 9 years ago for aortic valve endocarditis. He misses about 1/3 anticoagulation clinic appointments and recently decided Coumadin just wasn’t “worth the trouble”

HR 86, BP 140/88, RR 14, SpO2 98%. He has a loud systolic murmur and soft heart sounds. Lungs are clear. 1+ bilateral ankle edema.
LVOT Diameter 24 mm

LVOT (PW):
- Peak velocity 1.0 m/s
- VTI 19 cm

PrAV (CW):
- Peak velocity 4.5 m/s
- Mean gradient 41 mm Hg
- VTI 108 cm
- Acceleration Time 114 ms

DVI 19cm/108cm = 0.18 or 1m/s/4.5m/s = 0.22

Effective Orifice Area:
\[ EOA_{PrAV} = \frac{CSA_{LVOT} \times VTI_{LVOT}}{VTI_{PrAV}} \]
\[ EOA_{PrAV} = \frac{(86 \text{ mL})/108 \text{ cm}}{108 \text{ cm}} = 0.8 \text{ cm}^2 \]

What’s your echo interpretation?
1. Paravalvular regurgitation
2. Prosthetic stenosis
3. Doppler error
4. Mismeasurement of the LVOT
5. Patient prosthesis mismatch
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2. Prosthetic stenosis

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Effective Orifice Area: 

\[ EOA_{PrAV} = \frac{86 \text{ mL}}{108 \text{ cm}} \approx 0.8 \text{ cm}^2 \]

PrAV Peak Velocity >3 m/s

Jet contour

AT (ms)

DVI ≥0.30

DVI 0.25-0.29

DVI <0.25

Consider PrAV stenosis with:
- Subvalvular narrowing
- Underestimated gradient
- Error in LVOT velocity measurement

Normal PrAV

EOA Index

High flow state

PPM

Suggests PrAV stenosis

Consider error in LVOT Doppler

From Zoghbi J Am Soc Echocardiogr 2009
### Differential Diagnosis of An Elevated Prosthetic Valve Velocity/Gradient

<table>
<thead>
<tr>
<th>Condition</th>
<th>LVOT Velocity</th>
<th>PrAV Velocity</th>
<th>DVI</th>
<th>Acceleration Time</th>
<th>EOA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>Normal (1 m/s)</td>
<td>&lt;3 m/s</td>
<td>&gt;0.30</td>
<td>&lt;100 ms</td>
<td>&gt;1.2 cm²</td>
</tr>
<tr>
<td>PrAV Stenosis</td>
<td>Normal or low</td>
<td>&gt;3 m/s</td>
<td>&lt;0.25</td>
<td>&gt;100 ms</td>
<td>&lt;0.8 cm²</td>
</tr>
<tr>
<td>Aortic Regurgitation</td>
<td>High (&gt;1 m/s)</td>
<td>≥3 m/s</td>
<td>&gt;0.25</td>
<td>&lt;100 ms</td>
<td>&gt;1.2 cm²</td>
</tr>
<tr>
<td>Patient prosthesis mismatch</td>
<td>Normal</td>
<td>&gt;3 m/s</td>
<td>&lt;0.30</td>
<td>&lt;100 ms</td>
<td>&lt;1.2 cm² &lt;0.65 cm²/m²</td>
</tr>
</tbody>
</table>

*LVOT: Left Ventricular Outflow Tract, PrAV: Prosthetic Aortic Valve, EOA: Effective Orifice Area*
76 year old man with a #23 CE Standard aortic valve replacement 13 years ago. Has not seen a doctor in 7 years. Now admitted with shortness of breath and palpitations.

Temperature 98.4°F, P90 and irregular, BP 106/44, RR 22. There is a loud diastolic murmur best heard when leaning forward.

Blood cultures were negative, WBC normal. ESR 27 and CRP 3.
### Useful Parameters for Evaluating Severity of Prosthetic Aortic Valve Regurgitation

<table>
<thead>
<tr>
<th></th>
<th>Mild PrAR</th>
<th>Moderate PrAR</th>
<th>Severe PrAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaflet Structure &amp; Motion</td>
<td>Usually normal</td>
<td>Usually abnormal</td>
<td>Abnormal</td>
</tr>
<tr>
<td>LV size</td>
<td>Usually normal</td>
<td>Normal to mildly dilated</td>
<td>Dilated</td>
</tr>
<tr>
<td>Doppler parameters</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Circumferential extent</td>
<td>&lt;10-20%</td>
<td>20-30%</td>
<td>&gt;30%</td>
</tr>
<tr>
<td>Color jet width (% LVOT)</td>
<td>&lt;25%</td>
<td>25-65%</td>
<td>&gt;65%</td>
</tr>
<tr>
<td>Spectral Doppler jet density</td>
<td>Faint</td>
<td>Dense</td>
<td>Dense</td>
</tr>
<tr>
<td>Pressure half time (ms)</td>
<td>&gt;500</td>
<td>200-500</td>
<td>&lt;200</td>
</tr>
<tr>
<td>LVOT flow vs RVOT flow</td>
<td>Slightly increased</td>
<td>Intermediate</td>
<td>Markedly increased</td>
</tr>
<tr>
<td>Diastolic flow reversal (Desc Ao)</td>
<td>Brief</td>
<td>Intermediate</td>
<td>Marked</td>
</tr>
<tr>
<td>Quantitative parameters</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regurgitant volume (mL/beat)</td>
<td>&lt;30</td>
<td>30-59</td>
<td>&gt;60</td>
</tr>
<tr>
<td>Regurgitant fraction (%)</td>
<td>&lt;30</td>
<td>30-50</td>
<td>&gt;50</td>
</tr>
</tbody>
</table>

73 year old woman with a #27 St Jude bileaflet mechanical mitral valve placed 16 years ago sent in from clinic for TEE because of increase in transmitral gradient

She feels fine, vital signs normal. Crisp valve sounds, soft murmur

Previous echo: Transmitral gradient 6-8 mm Hg

Current echo: Transmitral gradient 14 mm Hg
PrMV: Peak Velocity 2.1 m/s
Mean gradient 8 mm Hg
VTI 59 cm
PHT 90-100 ms

LVOT: Diameter 21 mm
Peak velocity 1.1 m/s
VTI 29 cm

DVI 2.0

PrMV EOA 1.7 cm²
### Doppler Parameters of Prosthetic Mitral Valve Function

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Normal</th>
<th>Possible Stenosis</th>
<th>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>&gt;2.5</td>
</tr>
<tr>
<td>Mean gradient (mm Hg)</td>
<td>&lt;6</td>
<td>6-10</td>
<td>&gt;10</td>
</tr>
<tr>
<td>DVI: VTiPmV/VTiLVO</td>
<td>&lt;2.2</td>
<td>2.2-2.5</td>
<td>&gt;2.5</td>
</tr>
<tr>
<td>EOA (cm²)</td>
<td>&gt;2</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>

42 year old man with a bioprosthetic mitral valve, unknown size and type, placed 5 years ago for endocarditis. Recurrent IVDU and now admitted with fevers and respiratory failure.
What’s the status of this prosthetic mitral valve?

1. Normal prosthetic valve
2. Severe prosthetic regurgitation
3. Severe prosthetic stenosis
4. Can’t tell from this information
What’s the status of this prosthetic mitral valve?

1. Normal prosthetic valve
2. Severe prosthetic regurgitation
3. Severe prosthetic stenosis
4. Can’t tell from this information
For Your Consideration:

- Peak E velocity 2.5 m/s
- Mean gradient 18 mm Hg
- DVI: PrMV/LVOT = 2.5
- Pressure Half Time 150 ms

Tips for Differentiating PrMS from PrMR

- Normal (<130 ms) pressure half time with:
  - High E velocity (>1.9 m/s)
  - DVI: VTI$_{PrMV}$/VTI$_{LVOT}$ >2.5
  - Mean gradient >5 mm Hg

- Obvious dehiscence of the prosthesis, prolapse of biologic leaflet, or immobile (open) occluder

- Hyperdynamic LV function (LVEF >65%) with low forward stroke volume (VTI$_{LVOT}$ <16 cm)
Role of Transesophageal Echo

TEE, with transducer on the left atrial side of the mitral valve, is very specific for prosthetic mitral regurgitation

When MR is suggested but not seen ...
- hyperdynamic LVEF with low LVOT flow,
- high E velocity or gradient with normal pressure half time,
- valve leaflets not obviously stenotic

... get a TEE!

Summary & Wrap Up

• Valve “size” and model, patient’s prior studies, or parameters for mild native stenosis are key references for prosthetic valve performance

• DVI and AT are key parameters to understanding prosthetic aortic valves
• Prosthetic aortic regurgitation is easy to see but hard to quantify

• DVI and PHT are key parameters to understanding prosthetic mitral valves
• You won’t diagnose prosthetic mitral regurgitation if you don’t think of it