Prosthesis-Patient Mismatch or Prosthetic Valve Valve Stenosis?

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Disclosure Statement

- Edwards Life Science: Research grant for Echo Core Lab, transcatheter aortic and mitral valve replacement

- V Wave Ltd.
Etiology of High Doppler Gradients in Prosthetic Heart Valves

- Prosthesis-patient mismatch i.e. too small a prosthesis in too large a patient
- Prosthesis dysfunction due to an acute (e.g. thrombus), subacute (e.g. endocarditis) or chronic process (e.g. pannus, calcific degeneration in bioprosthesis)
- Central localized high velocity jet in bileaflet prosthesis
- Occult mitral prosthesis regurgitation
Transvalvular Flow Pattern in Bioprosthetic Valve vs. Mechanical Prosthesis

Peak Prosthetic Aortic Jet Velocity > 3 m/s

DVI ≥ 0.30

DVI 0.25 – 0.29

DVI < 0.25

Jet Contour

AT (ms)

>100

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

<100

<100

>100

Normal PrAV

EOA Index

High Flow

PPM

Suggests PrAV Stenosis

Consider Improper LVOT velocity**

Zoghbi et al.
Gradient, EOA, and DVI for Evaluation of Aortic Prosthetic Valve Function

Peak Gradient (mmHg)

EOA (cm²)

DVI

Zekry et al.
*J Am Coll Cardiol Img*
2011;4:1161–70
Ratio of Acceleration Time to Ejection Time for Aortic Prosthetic Valve Function

Criteria for PV stenosis:
- AT > 100 ms
- AT/LVET > 0.37

Zekry et al.
J Am Coll Cardiol Img
2011;4:1161–70
Dysfunction of Bileaflet Aortic Valves: Doppler-Echo vs. Cinefluoroscopy

Muratori et al. JACC Img 2013; 6:196–205
Evaluation of Leaflet Morphology & Mobility: A Cornerstone of Identification of Prosthetic Valve Dysfunction

Normal

Bioprosthesis

Mechanical

Abnormal
Evaluation of Leaflet Mobility: Usefulness of Cinefluoroscopy in Mechanical Valves

Normal

Abnormal
High Gradient after AVR

Step 1
Predicted Indexed EOA < 0.85 cm²/m²?

- Yes
  - Prosthesis-Patient Mismatch
    - Severity? < 0.65: severe

- No
  - Consider:
    - High Flow state / aortic regurgitation
    - Subvalvular obstruction
    - Technical error
    - Localized high gradient (bileaflet valve)

Step 2
Abnormal leaflet morphology/mobility
DVI < 0.30 (< 0.25)
EOA < reference EOA (Δ > 0.35 cm²)
Gradient increased during FU
EOA & DVI decreased during FU
AT/ET > 0.37

- Yes
  - Consider Prosthesis Stenosis

- No
  - Normal reference EOA / BSA

Cine-fluoro

Pibarot & Dumesnil
Heart; 98:69-78, 2012
Case Study: High Doppler Gradient in Aortic Valve Prosthesis

72 y.o. patient with Carbomedic #19 aortic prosthesis (3 years):

- NYHA class II-III
- Moderate diastolic dysfunction
- Pulmonary arterial hypertension (systolic PA pressure: 50 mmHg)

Peak Gradient = 69 mm Hg
Mean Gradient = 40 mmHg

Question no. 1

What is the cause of the high gradient in this patient?

a. Valve prosthesis dysfunction (thrombus / pannus)?
b. Valve prosthesis-patient mismatch?
c. Central localized high velocity jet?
Step 1
Predicted Indexed EOA < 0.85 cm²/m²?

BSA = 1.95 m²

EOA = 1.0 cm²

= 0.51 cm²/m²

Severe Prosthesis-Patient Mismatch!

Table 2: Normal reference values of effective orifice areas for the prosthetic valves

<table>
<thead>
<tr>
<th>Prosthetic aortic valves</th>
<th>19</th>
<th>21</th>
<th>23</th>
<th>25</th>
<th>27</th>
<th>29</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stented bioprosthetic valves</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mosaic</td>
<td>1.1±0.2</td>
<td>1.2±0.2</td>
<td>1.4±0.3</td>
<td>1.7±0.4</td>
<td>1.8±0.6</td>
<td>2.0±0.4</td>
<td>w8</td>
</tr>
<tr>
<td>Hancock II</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carpentier-Edwards Perimount</td>
<td>1.1±0.3</td>
<td>1.3±0.4</td>
<td>1.5±0.4</td>
<td>1.8±0.4</td>
<td>2.1±0.4</td>
<td>2.2±0.4</td>
<td>w8</td>
</tr>
<tr>
<td>Carpentier-Edwards Magna</td>
<td>1.3±0.3</td>
<td>1.6±0.3</td>
<td>1.8±0.4</td>
<td>2.1±0.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biccor (Epic)</td>
<td>1.0±0.3</td>
<td>1.1±0.5</td>
<td>1.4±0.5</td>
<td>1.9±0.7</td>
<td></td>
<td></td>
<td>w9, w10</td>
</tr>
<tr>
<td>Medtronic Freestyle</td>
<td>1.1±0.2</td>
<td>1.4±0.3</td>
<td>1.4±0.2</td>
<td>1.6±0.3</td>
<td>1.8±0.3</td>
<td></td>
<td>w10, w12</td>
</tr>
</tbody>
</table>

Stentless bioprosthetic valves

Medtronic Hall            | 1.2±0.2 | 1.4±0.2 | 1.5±0.3 | 2.0±0.4 | 2.5±0.5 |    | w8        |
| St Jude Medical Standard | 1.0±0.1 | 1.4±0.5 | 1.5±0.5 | 2.1±0.4 | 2.7±0.6 | 3.2±0.3 | w8        |
| St Jude Medical Regent   | 1.6±0.8 | 2.0±0.7 | 2.2±0.9 | 2.5±0.9 | 3.6±1.3 | 4.4±0.6 | w14       |

Medtronic On-X            | 1.5±0.2 | 1.7±0.4 | 2.0±0.6 | 2.4±0.8 | 3.2±0.6 | 3.2±0.6 | w15       |

Carbomedics Standard and Top Flat | 1.0±0.4 | 1.5±0.3 | 1.7±0.3 | 2.0±0.4 | 2.5±0.4 | 2.6±0.4 | w8        |
| ATS Medical              | 1.1±0.3 | 1.6±0.4 | 1.8±0.5 | 1.9±0.3 | 2.3±0.6 |    | w16       |
Is there any intrinsic dysfunction in addition to prosthesis-patient mismatch?
Case Study: High Doppler Gradient in Aortic Valve Prosthesis

68 y.o. patient
3 Years post AVR
Carbomedic # 19

Reference EOA
1.0±0.4

Predicted
Indexed EOA: 0.51 cm²/m²

BSA = 1.95 m²

Measured EOA = 1.06 cm²

Measured Indexed EOA: 0.55 cm²/m²
High Gradient after AVR

Prosthesis-Patient Mismatch
Severity? <0.65: severe

Step 1
Predicted Indexed EOA < 0.85 cm²/m²?

No
Consider:
High Flow state / subvalvular obstruction
Technical error
Localized high gradient (bileaflet valve)

Yes

Step 2
Abnormal leaflet morphology / mobility
DVI < 0.30 (<0.25)
EOA < reference EOA (Δ > 0.35 cm²)
Gradient increased during FU
EOA & DVI decreased during FU
AT/ET > 0.37

Yes

Cine-fluoro

Normal reference EOA / BSA

Consider Prosthesis Dysfunction

Pibarot & Dumesnil
Heart; 98:69-78, 2012
Intraoperative echo after prosthesis implantation

St. Jude Regent # 21
Suprannular
(reference EOA: 2.0 cm²)

Stroke volume: 64 mL
Heart rate: 98 bpm
Peak gradient: 21 mmHg
Mean gradient: 14 mmHg

Dumesnil & Pibarot, in Book:
Transesophageal Echocardiography
Multimedia Manual: 361, 2005
Case Study #2

- 62 y.o. woman
- BSA: 1.3 m²
- History of Barlow disease
- MVR 1 year ago with a MCRI OnX #25 mechanical valve
- INR within target since MVR
- Asymptomatic
- Recruited for a research project
Echocardiogram

Peak Gradient = 11 mmHg
Mean Gradient = 6 mmHg
DVI : 2.4
Measured EOA = 1.1 cm²
Doppler-Echo Evaluation of Mitral Prosthesis - Specifics

- Doppler Velocity Index: $\text{VTI}_{\text{mvp}} / \text{VTI}_{\text{lvot}} (>2.2)$

- EOA calculated using continuity equation as follows: $\text{EOA} = \frac{\text{SV}_{\text{lvot}}}{\text{VTI}_{\text{mvp}}}$ (Not valid if significant aortic or mitral regurgitation)

- Pressure half-time not valid to calculate EOA (grossly overestimates) but may be useful for serial comparisons or if delayed (>130 msec)
Question no. 1

Is valve prosthesis-patient mismatch a consideration in this case?
High Gradient after MVR

Step 1
Predicted Indexed EOA < 1.2 cm²/m²?

Yes

Prosthesis-Patient Mismatch
Severity? <0.9: severe

Consider:
High flow state
Technical error
Localized high gradient (bileaflet valve)

No

Consider:
Prosthesis Stenosis a/o Regurgitation

Step 2
Abnormal leaflet morphology/mobility
DVI > 2.2
EOA < reference EOA (Δ > 0.4 cm²)
Gradient increased during FU
EOA decreased during FU

Normal reference EOA / BSA

Cine-fluoro
# Normal Reference Values of EOAs for Mitral Prostheses

<table>
<thead>
<tr>
<th>Prosthetic Valve Size, mm</th>
<th>25 mm</th>
<th>27 mm</th>
<th>29 mm</th>
<th>31 mm</th>
<th>33 mm</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stented bioprosthesis</strong></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medtronic Mosaic</td>
<td>1.5±0.4</td>
<td>1.7±0.5</td>
<td>1.9±0.5</td>
<td>1.9±0.5</td>
<td>...</td>
<td>15, 28</td>
</tr>
<tr>
<td>Hancock II</td>
<td>1.5±0.4</td>
<td>1.8±0.5</td>
<td>1.9±0.5</td>
<td>2.6±0.5</td>
<td>2.6±0.7</td>
<td>29</td>
</tr>
<tr>
<td>Carpentier-Edwards Perimount*</td>
<td>1.6±0.4</td>
<td>1.8±0.4</td>
<td>2.1±0.5</td>
<td>...</td>
<td>...</td>
<td>28</td>
</tr>
<tr>
<td><strong>Mechanical prostheses</strong></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>St Jude Medical Standard</td>
<td>1.5±0.3</td>
<td>1.7±0.4</td>
<td>1.8±0.4</td>
<td>2.0±0.5</td>
<td>2.0±0.5</td>
<td>28</td>
</tr>
<tr>
<td>MCRI On-X†</td>
<td><strong>2.2±0.9</strong></td>
<td>2.2±0.9</td>
<td>2.2±0.9</td>
<td>2.2±0.9</td>
<td>2.2±0.9</td>
<td>28</td>
</tr>
</tbody>
</table>

Pibarot & Dumesnil  
Circulation, 119:1034-1048, 2009
Answer: Calculate predicted indexed EOA to exclude PPM

Predicted EOA for OnX #25

Indexed EOA (cm²/m²)

Severe

Moderate

Mild/None (non significant)

BSA = 1.30 m²

Predicted Indexed EOA = 1.7 cm²/m²

2.2 cm²

Predicted Indexed EOA = 1.7 cm²/m²

0.9

1.2
Question no. 2

Should we suspect a prosthesis dysfunction?
Answer: Compare the measured EOA to the normal reference EOA.

Measured EOA = 1.1 cm²
Reference value = 2.2 cm²!!
Question no. 3

Differential diagnosis:

a- Prosthesis dysfunction in this case?

b- Central high velocity jet in bileaflet mechanical prosthesis?
Answer

Evaluate leaflet mobility using either TEE / fluoroscopy / CT
Leaflet Mobility by TTE
Cinefluoroscopy
Transthoracic Echocardiogram
Transesophageal Echocardiogram
High Gradient after MVR

Step 1
Predicted Indexed EOA < 1.2 cm²/m²?

- Yes
- Prosthesis-Patient Mismatch
  Severity? < 0.9: severe

- No
  Consider:
  - High flow state
  - Technical error
  - Localized high gradient (bileaflet valve)

Step 2
Abnormal leaflet morphology/mobility
DVI > 2.2
EOA < reference EOA (Δ > 0.4 cm²)
Gradient increased during FU
EOA decreased during FU

Normal reference EOA / BSA

Cine-fluoro

Prosthesis Stenosis & Regurgitation

Pibarot & Dumesnil
Heart; 98:69-78, 2012
3D Echo for Evaluation of Prosthetic Valve Function
Case #1
- 3 yr. post AVR
- Carbomedics 19
- NYHA III
- Echo
  - Gradients: 69/40
  - EOA: 1.1 cm²
- Severe PPM

Case #2
- 1 yr. Post MVR
- OnX 25
- Asymptomatic
- Echo
  - Gradients: 11/6
  - EOA: 1.1 cm²
- Severe dysfunction: Thrombus
High gradient does not always mean prosthesis dysfunction

Low gradient does not always mean normal prosthesis function

Multi-parametric approach is key to appropriately differentiate normal function vs. PPM vs. dysfunction
Key Points

PPM

- High Gradient
- Small indexed EOA
- EOA ~ normal
- Intermediate DVI
- Intermediate AT/LVET
- Normal leaflet morphology / mobility

Dysfunction

- High Gradient
- Small indexed EOA
- EOA << normal
- Small DVI
- Low AT/LVET
- Abnormal leaflet morphology / mobility
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
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Useful References


Zamorano JL; J Am Soc Echocardiogr 2011;24:937-65