Assessing Prosthetic Valve Function: Differentiating Normal from Stenotic or Regurgitant

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Canada Research Chair in Valvular Heart Diseases
Disclosure
Philippe Pibarot

Financial relationship with industry:
- Edwards Lifesciences: Echo CoreLab - SAPIEN 3
- V-Wave: Echo CoreLab
- Cardiac Phoenix: Research Grant for Echo CoreLab
- Ionis Pharmaceuticals

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- Research and Heart & Stroke Foundation of Quebec
Doppler-Echo Evaluation of Prosthetic Valves

- Doppler-echocardiography is the primary imaging modality to evaluate prosthetic valve function

- Structural evaluation (TTE and TEE)
  - Valve position and shape
  - Leaflet morphology and mobility
  - Paravalvular region

- Functional evaluation
  - Transprosthetic gradients, EOA, and DVI
  - Localization (central vs. para) and degree of regurgitation

- LV/RV size and function, Pulmonary Arterial Pressure
Recommendations for Timing of Echo Follow-up in Prosthetic Valves

- Preoperative
- Predischarge / 2-4 weeks postdischarge
- Routine annual clinical follow-up and echo if there is a change in clinical status
- After 5 years:
  - Annual echo in patients with bioprosthetic valves
  - Annual echo not indicated in patients with mechanical valves in the absence of change in clinical status

*J Am Soc Echocardiogr, 22:975-1014, 2009*
Doppler-Echo Evaluation of Prosthetic Valve Regurgitation

- Mild regurgitations, central or paravalvular are frequent, sometimes transient and rarely progressive
- Mechanical prostheses usually show small regurgitation due to normal closing volume
- Mitral regurgitation may be underestimated by TTE due to acoustic shadowing: look for indirect signs
- Severity: use same criteria as for native valves
- If significant regurgitation suspected, look for underlying pathology and proceed to TEE
Physiological vs. Pathological Regurgitation

Physiological

Pathological (Paravalvular)
# Doppler-Echo Criteria to Assess the Severity of Prosthetic Aortic Valve Regurgitation

<table>
<thead>
<tr>
<th></th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2D/3D TTE / TEE / Cinefluoroscopy / CT</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Valve structure / leaflet mobility</td>
<td>Normal</td>
<td>Often abnormal</td>
<td>Abnormal</td>
</tr>
<tr>
<td><strong>Doppler qualitative or semi-quantitative parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vena contracta width</td>
<td>&lt;3</td>
<td>3-6</td>
<td>&gt;6</td>
</tr>
<tr>
<td>Jet width in central jets (% LVOT diameter)</td>
<td>≤25</td>
<td>26-64</td>
<td>≥65</td>
</tr>
<tr>
<td>Pressure half time (ms)</td>
<td>Slow &gt;500</td>
<td>200-500</td>
<td>Steep &lt;200</td>
</tr>
<tr>
<td>Diastolic flow reversal in descending aorta</td>
<td>Absent- brief</td>
<td>Intermediate</td>
<td>Holodiastolic</td>
</tr>
<tr>
<td>Circumferential extent (paravalvular) (%)</td>
<td>&lt;10</td>
<td>10-29</td>
<td>≥30</td>
</tr>
<tr>
<td><strong>Doppler quantitative parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regurgitant volume (ml)</td>
<td>&lt;30</td>
<td>30-59</td>
<td>≥60</td>
</tr>
<tr>
<td>Regurgitant fraction (%)</td>
<td>&lt;30</td>
<td>30-49</td>
<td>≥50</td>
</tr>
</tbody>
</table>

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
**Criteria for Definition of Aortic Prosthesis-Patient Mismatch**

PPM is defined as: normal EOA but small indexed EOA

<table>
<thead>
<tr>
<th></th>
<th>None/Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indexed EOA (cm²/m²)</td>
<td>&gt;0.85</td>
<td>0.85-0.65</td>
<td>&lt;0.65</td>
</tr>
<tr>
<td>Indexed EOA (cm²/m²) in obese patients (BMI ≥30 kg/m²)</td>
<td>&gt;0.70</td>
<td>0.70-0.60</td>
<td>&lt;0.60</td>
</tr>
</tbody>
</table>

*VARC 2 - Kappetein et al. Eur Heart J 2012*
Localized High Gradient in Bileaflet Mechanical Valves

# Doppler-Echo Criteria to Assess the Severity of Prosthetic Aortic Valve Stenosis

<table>
<thead>
<tr>
<th></th>
<th>Normal</th>
<th>Possible Stenosis</th>
<th>Significant Stenosis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2D/3D TTE/TEE / Cinefluoroscopy / CT</strong></td>
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<tr>
<td>Valve structure / leaflet mobility</td>
<td>Normal</td>
<td>Often abnormal</td>
<td>Abnormal</td>
</tr>
<tr>
<td><strong>Doppler quantitative parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak velocity (m/s)</td>
<td>&lt;3</td>
<td>3-4</td>
<td>≥4</td>
</tr>
<tr>
<td>Mean gradient (mmHg)</td>
<td>&lt;20</td>
<td>20-35</td>
<td>≥35</td>
</tr>
<tr>
<td>Doppler velocity index</td>
<td>≥0.35</td>
<td>0.25-0.35</td>
<td>&lt;0.25</td>
</tr>
<tr>
<td>Effective orifice area (cm²)</td>
<td>&gt;1.1</td>
<td>0.8-1.1</td>
<td>&lt;0.8</td>
</tr>
<tr>
<td>Difference (Normal EOA - Measured EOA)</td>
<td>&lt;0.25</td>
<td>0.25-0.35</td>
<td>&gt;0.35</td>
</tr>
<tr>
<td><strong>Doppler semi-quantitative parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acceleration time (ms)</td>
<td>&lt;80</td>
<td>80-100</td>
<td>&gt;100</td>
</tr>
<tr>
<td>Acceleration time / LV ejection time</td>
<td>&lt;0.32</td>
<td>0.32-0.37</td>
<td>&gt;0.37</td>
</tr>
<tr>
<td><strong>Changes in echo parameters during FU</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase in mean gradient (mmHg)</td>
<td>&lt;10</td>
<td>10-19</td>
<td>≥20</td>
</tr>
<tr>
<td><strong>Changes in echo parameters during stress echo</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase in mean gradient (mmHg)</td>
<td>&lt;10</td>
<td>10-19</td>
<td>≥20</td>
</tr>
</tbody>
</table>

Zoghbi JASE 2009
Lancellotti EHJ CV Img 2016
Calculation of Prosthetic Valve EOA by Continuity Equation Method

Doppler Velocity Index = $\frac{V_{LV0}}{V_{jet}}$
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

Abnormal

Bioprosthesis

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

Normal

Abnormal
High Gradient after AV R

Step 1
Predicted Indexed EOA < 0.85 cm²/m²?

- Yes
  - Consider:
    - High Flow state / aortic regurgitation
    - Subvalvular obstruction
    - Technical error
    - Localized high gradient (bileaflet valve)

- No
  - Prosthesis-Patient Mismatch
    Severity? <0.65: severe
  - Consider:
    - Prosthesis Stenosis

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

Pibarot & Dumesnil
Heart ; 98:69-78, 2012

TEE Cine-fluoro
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

EOA = 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 valve size (mm)</th>
<th>19</th>
<th>21</th>
<th>23</th>
<th>25</th>
<th>27</th>
<th>29</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stentless bioprosthetic valves</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±0.4</td>
<td>2.0±0.4</td>
</tr>
<tr>
<td>Hancock II</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>1.5±0.2</td>
<td>1.6±0.2</td>
<td>1.6±0.2</td>
</tr>
<tr>
<td>Carpentier-Edwards Perimount</td>
<td>1.1±0.3</td>
<td>1.3±0.4</td>
<td>1.50±0.4</td>
<td>1.80±0.4</td>
<td>2.1±0.4</td>
<td>2.2±0.4</td>
</tr>
<tr>
<td>Carpentier-Edwards Magna</td>
<td>1.3±0.3</td>
<td>1.5±0.3</td>
<td>1.8±0.4</td>
<td>2.1±0.5</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>BicOR (Epic)</td>
<td>1.0±0.3</td>
<td>1.1±0.5</td>
<td>1.4±0.5</td>
<td>1.8±0.7</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Microflow</td>
<td>1.1±0.2</td>
<td>1.2±0.3</td>
<td>1.4±0.2</td>
<td>1.6±0.3</td>
<td>1.8±0.3</td>
<td>—</td>
</tr>
<tr>
<td>Medtronic Freestyle</td>
<td>1.2±0.2</td>
<td>1.4±0.2</td>
<td>1.5±0.3</td>
<td>2.0±0.4</td>
<td>2.3±0.5</td>
<td>—</td>
</tr>
<tr>
<td>St Jude Medical Toronto SPV</td>
<td>—</td>
<td>1.3±0.3</td>
<td>1.5±0.6</td>
<td>1.7±0.8</td>
<td>2.1±0.7</td>
<td>2.7±1.0</td>
</tr>
<tr>
<td>Mechanical valves</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Medtronic Hall</td>
<td>1.2±0.2</td>
<td>1.3±0.2</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>St Jude Medical Standard</td>
<td>1.0±0.2</td>
<td>1.4±0.2</td>
<td>1.5±0.5</td>
<td>2.1±0.4</td>
<td>2.7±0.6</td>
<td>3.2±0.3</td>
</tr>
<tr>
<td>St Jude Medical Regent</td>
<td>1.6±0.6</td>
<td>2.0±0.7</td>
<td>2.2±0.9</td>
<td>2.5±0.9</td>
<td>3.6±1.3</td>
<td>4.4±0.6</td>
</tr>
<tr>
<td>Medtronic On-X</td>
<td>1.5±0.2</td>
<td>1.7±0.4</td>
<td>2.0±0.6</td>
<td>2.4±0.8</td>
<td>3.2±0.6</td>
<td>3.2±0.6</td>
</tr>
<tr>
<td>Carbomedics Standard and Top List</td>
<td>1.0±0.4</td>
<td>1.6±0.3</td>
<td>1.7±0.3</td>
<td>2.0±0.4</td>
<td>2.5±0.4</td>
<td>2.6±0.4</td>
</tr>
<tr>
<td>Carpentier-Edwards</td>
<td>1.1±0.3</td>
<td>1.6±0.4</td>
<td>1.8±0.5</td>
<td>1.9±0.3</td>
<td>2.3±0.8</td>
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<tr>
<td>ATS Medical</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

Reference

Pibarot & Dumesnil Heart; 98:69-78, 2012
Dumesnil & Pibarot, Curr Cardiol Rev 2011
Question no. 2

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

Measured EOA = 1.06 cm²

BSA = 1.95 m²

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

Step 1
Predicted Indexed EOA < 0.85 cm²/m²?

Yes

No

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

Consider:
High Flow state / subvalvular obstruction
Technical error
Localized high gradient (bileaflet valve)

Consider Prosthesis Dysfunction

Prosthesis-Patient Mismatch
Severity? < 0.65: severe

Normal reference EOA / BSA

Cine-fluoro

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: High Doppler Gradient in Aortic Valve Prosthesis

72 y.o. patient with Carbomedic # 19 aortic:

Reoperated 3 years postop.

Prosthesis is functioning normally

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: $\text{VTI}_{mvp} / \text{VTI}_{lvot}$

- EOA calculated using continuity equation as follows: $\text{EOA} = \frac{\text{SV}_{lvot}}{\text{VTI}_{mvp}}$
  (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
# Doppler-Echo Criteria to Assess the Severity of Prosthetic Mitral Valve Stenosis

<table>
<thead>
<tr>
<th></th>
<th>Normal</th>
<th>Possible Stenosis</th>
<th>Significant Stenosis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2D/3D TTE / TEE / Cinefluoroscopy / CT</strong></td>
<td></td>
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<tr>
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<td>Abnormal</td>
</tr>
<tr>
<td><strong>Doppler quantitative parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak velocity (m/s)</td>
<td>&lt;1.9</td>
<td>1.9-2.5</td>
<td>≥2.5</td>
</tr>
<tr>
<td>Mean gradient (mmHg)</td>
<td>≤5</td>
<td>6-10</td>
<td>≥10</td>
</tr>
<tr>
<td>Doppler velocity index</td>
<td>&lt;2.2</td>
<td>2.2-2.5</td>
<td>&gt;2.5</td>
</tr>
<tr>
<td>Effective orifice area (cm²)</td>
<td>≥2</td>
<td>1-2</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Difference (Normal EOA - Measured EOA)</td>
<td>&lt;0.25</td>
<td>0.25-0.35</td>
<td>&gt;0.35</td>
</tr>
<tr>
<td><strong>Doppler semi-quantitative parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure half time (ms)</td>
<td>&lt;130</td>
<td>130-200</td>
<td>&gt;200</td>
</tr>
<tr>
<td>Changes in echo parameters during FU</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase in mean gradient (mmHg)</td>
<td>&lt;5</td>
<td>5-9</td>
<td>≥10</td>
</tr>
</tbody>
</table>

Zoghbi et al. JASE, 22:975-1014, 2009
High Gradient after MVR

Step 1
Predicted Indexed EOA < 1.2 cm²/m²?

Yes

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

No

Step 2
Abnormal leaflet morphology/mobility
DVI > 2.2
EOA < reference EOA (Δ > 0.35 cm²)
Gradient increased during FU
EOA decreased during FU

Normal reference EOA / BSA

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

Consider:
- Prosthesis Stenosis a/o Regurgitation

TEE Cine-fluoro

Prosthesis-Patient Mismatch

Pibarot & Dumesnil
Heart ; 98:69-78, 2012
Is valve prosthesis-patient mismatch a consideration in this case?

Case # 2 - Question no. 1

Peak Gradient = 11 mmHg
Mean Gradient = 6 mmHg
DVI : 2.4
Measured EOA = 1.1 cm²
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>
<td></td>
<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>
<td></td>
<td></td>
<td></td>
<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

0.9

MODERATE

1.2

MILD/NONE (non significant)

2.2 cm²

BSA = 1.30 m²

Predicted Indexed EOA = 1.7 cm²/m²
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!!

DVI : 2.4
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

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

No

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

Prosthesis-Patient Mismatch
Severity? < 0.9: severe

Prosthesis Stenosis & Regurgitation

Normal reference EOA / BSA

TEE Cine-fluoro

Pibarot & Dumesnil
Heart ; 98:69-78, 2012
Answer

The cause of the small EOA in this patient was:

a- Valve prosthesis dysfunction: thrombus and pannus

b- Prosthesis-patient mismatch

c- Central high velocity jet bileaflet prosthesis
Case #1
- 3 yr. post AVR
- Carbomedics 19
- NYHA III
- Echo
  - Gradients: 69/40
  - EOA: 1.1 cm$^2$
- Severe PPM

Case #2
- 1 yr. Post MVR
- OnX 25
- Asymptomatic
- Echo
  - Gradients: 11/6
  - EOA: 1.1 cm$^2$
- Severe dysfunction: Thrombus
Key Points

- 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 (stenosis and/or regurgitation)
<table>
<thead>
<tr>
<th></th>
<th>PPM</th>
<th>Stenosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Gradient</td>
<td>➢</td>
<td>➢ High Gradient</td>
</tr>
<tr>
<td>No change in gradient during FU</td>
<td>➢</td>
<td>➢ Increase in gradient during FU (&gt;10 mmHg)</td>
</tr>
<tr>
<td>Small indexed EOA (&lt;0.85)</td>
<td>➢</td>
<td>➢ Small indexed EOA (&lt;0.85)</td>
</tr>
<tr>
<td>EOA ~ normal (~0.35)</td>
<td>➢</td>
<td>➢ EOA &lt;&lt; normal</td>
</tr>
<tr>
<td>Variable DVI</td>
<td>➢</td>
<td>➢ Small DVI (&lt;0.30)</td>
</tr>
<tr>
<td>Variable AT/LVET</td>
<td>➢</td>
<td>➢ High AT/LVET (&gt;0.37)</td>
</tr>
<tr>
<td>Normal leaflet morphology / mobility</td>
<td>➢</td>
<td>➢ Abnormal leaflet morphology / mobility</td>
</tr>
</tbody>
</table>
Mitral Prostheses

PPM
- High Gradient
- No change in gradient during FU
- Small indexed EOA (<1.2)
- EOA ~ normal (~0.35)
- Variable DVI
- Variable PHT
- Normal leaflet morphology / mobility

Stenosis
- High Gradient
- Increase in gradient during FU (>5 mmHg)
- Small indexed EOA (<1.2)
- EOA << normal
- High DVI (>2.2)
- PHT (>200)
- 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 Cardiology, the Japanese Society of Echocardiography, and Canadian Society of Echocardiography

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Recommendations for the imaging assessment of prosthetic heart valves: a report from the European Association of Cardiovascular Imaging endorsed by the Chinese Society of Echocardiography, the Inter-American Society of Echocardiography, and the Brazilian Department of Cardiovascular Imaging†

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Lancellotti, EHJ Cardiovascular Imaging, 2016