Patient Prosthesis Mismatch

Fahad S. Al Ghofaili
PSHC, KFMC
Mismatch ???
Gradient  = \frac{Q^2}{K \times EOA^2}

<table>
<thead>
<tr>
<th></th>
<th>Mouse</th>
<th>Elephant</th>
<th>Elephant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiac Output (mL/min)</td>
<td>50</td>
<td>50 000</td>
<td>50 000</td>
</tr>
<tr>
<td>EOA (cm²)</td>
<td>0.3</td>
<td>50</td>
<td>0.3</td>
</tr>
<tr>
<td>Gradient (mmHg)</td>
<td>1</td>
<td>1</td>
<td>11 000 000</td>
</tr>
</tbody>
</table>
Are Big Valves Better?

Physics of flow through a tube:

Resistance \( \propto \frac{1}{\text{radius}^4} \)

Small increase in size causes a significant reduction in LV work.
Prosthesis-Patient Mismatch (PPM)

**Definition:** Valve Prosthesis too small relative to patient’s body size

**Consequence:** Persistence of abnormally high postoperative gradients...the reason why we operate on patients with A.S. in the first place
Table 1  Theoretical comparison of mean transvalvar pressure gradient in five hypothetical patients receiving the same prosthetic valve but having different body surface areas

<table>
<thead>
<tr>
<th>Patient number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body surface area (m²)</td>
<td>1.5</td>
<td>1.75</td>
<td>2.0</td>
<td>2.25</td>
<td>2.5</td>
</tr>
<tr>
<td>Cardiac output (l/min)</td>
<td>4.5</td>
<td>5.25</td>
<td>6.0</td>
<td>6.75</td>
<td>7.5</td>
</tr>
<tr>
<td>Valve EOA (cm²)</td>
<td>1.3</td>
<td>1.3</td>
<td>1.3</td>
<td>1.3</td>
<td>1.3</td>
</tr>
<tr>
<td>Mean pressure gradient (mm Hg)</td>
<td>13</td>
<td>17</td>
<td>22</td>
<td>28</td>
<td>35</td>
</tr>
</tbody>
</table>

For this simulation, mean pressure gradient was calculated assuming a cardiac index of 3 l/min/m², a heart rate of 65 beats/min, and a systolic ejection time of 300 ms.
EOA, effective orifice area.
Reproduced and modified from Pibarot and Dumesnil⁵ with permission of Remedica Publishing.
We are not created equal!

Patient Examples:

Bill (5'8", 180 lbs.) BSA: 2.0

Sally (5'4", 135 lbs.) BSA: 1.7
Prosthesis-Patient Mismatch: Definition
The concept of patient-prosthesis mismatch (PPM) was originally introduced by Rahimtoola in 1978 and defined “...to be present when the effective prosthetic valve area, after insertion into the patient, is less than a normal valve.”

<table>
<thead>
<tr>
<th>Parameter</th>
<th>CE-19</th>
<th>SJM-19</th>
<th>CE-21</th>
<th>SJM-21</th>
<th>CE-23</th>
<th>SJM-23</th>
</tr>
</thead>
<tbody>
<tr>
<td>GOA</td>
<td>1.96</td>
<td>1.63</td>
<td>2.9</td>
<td>2.06</td>
<td>3.9</td>
<td>2.55</td>
</tr>
<tr>
<td>EOA</td>
<td>0.9</td>
<td>1.1</td>
<td>1.1</td>
<td>1.5</td>
<td>1.5</td>
<td>2.13</td>
</tr>
</tbody>
</table>
70 years old female for AVR, BSA 1.6m², annulus is 19mm

AVR with Bioprosthesis (EOA 1.2cm²)

iEOA 1.2/1.6 = 0.75cm²/m²

((Moderate PPM))
PPM Evaluation

- **Mild** \( (0.9 < \text{iEOA} < 1 \text{ cm}^2/\text{m}^2) \)

- **Moderate** \( (0.6 < \text{iEOA} < 0.9 \text{ cm}^2/\text{m}^2) \)

- **Severe** \( (\text{iEOA} < 0.6 \text{ cm}^2/\text{m}^2) \)
Three-step Algorithm

Step 1: Calculation of the patient’s BSA.

Step 2: Reference to the specific table for identification (EOA according to BSA)

Step 3: Selection of the most appropriate type and size of valve prosthesis accordingly
# MOSAIC®
Aortic Bioprosthesis

## Valve Size

<table>
<thead>
<tr>
<th>EOA (cm²)</th>
<th>19mm (n=4)</th>
<th>21mm (n=198)</th>
<th>23mm (n=440)</th>
<th>25mm (n=317)</th>
<th>27mm (n=110)</th>
<th>29mm (n=22)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>1.20</td>
<td>1.30</td>
<td>1.50</td>
<td>1.80</td>
<td>2.00</td>
<td>2.10</td>
</tr>
<tr>
<td>1.1</td>
<td>1.09</td>
<td>1.18</td>
<td>1.36</td>
<td>1.64</td>
<td>1.82</td>
<td>1.91</td>
</tr>
<tr>
<td>1.2</td>
<td>1.00</td>
<td>1.08</td>
<td>1.25</td>
<td>1.50</td>
<td>1.67</td>
<td>1.75</td>
</tr>
<tr>
<td>1.3</td>
<td>0.92</td>
<td>1.00</td>
<td>1.15</td>
<td>1.38</td>
<td>1.54</td>
<td>1.62</td>
</tr>
<tr>
<td>1.4</td>
<td>0.86</td>
<td>0.93</td>
<td>1.07</td>
<td>1.29</td>
<td>1.43</td>
<td>1.50</td>
</tr>
<tr>
<td>1.5</td>
<td>0.80</td>
<td>0.87</td>
<td>1.00</td>
<td>1.20</td>
<td>1.33</td>
<td>1.40</td>
</tr>
<tr>
<td>1.6</td>
<td>0.75</td>
<td>0.81</td>
<td>0.94</td>
<td>1.13</td>
<td>1.25</td>
<td>1.31</td>
</tr>
<tr>
<td>1.7</td>
<td>0.71</td>
<td>0.76</td>
<td>0.88</td>
<td>1.06</td>
<td>1.18</td>
<td>1.24</td>
</tr>
<tr>
<td>1.8</td>
<td>0.67</td>
<td>0.72</td>
<td>0.83</td>
<td>1.00</td>
<td>1.11</td>
<td>1.17</td>
</tr>
<tr>
<td>1.9</td>
<td>0.63</td>
<td>0.68</td>
<td>0.79</td>
<td>0.95</td>
<td>1.05</td>
<td>1.11</td>
</tr>
<tr>
<td>2.0</td>
<td>0.60</td>
<td>0.65</td>
<td>0.75</td>
<td>0.90</td>
<td>1.00</td>
<td>1.05</td>
</tr>
<tr>
<td>2.1</td>
<td>0.57</td>
<td>0.62</td>
<td>0.71</td>
<td>0.86</td>
<td>0.95</td>
<td>1.00</td>
</tr>
<tr>
<td>2.2</td>
<td>0.55</td>
<td>0.59</td>
<td>0.68</td>
<td>0.82</td>
<td>0.91</td>
<td>0.95</td>
</tr>
<tr>
<td>2.3</td>
<td>0.52</td>
<td>0.57</td>
<td>0.65</td>
<td>0.78</td>
<td>0.87</td>
<td>0.91</td>
</tr>
<tr>
<td>2.4</td>
<td>0.50</td>
<td>0.54</td>
<td>0.63</td>
<td>0.75</td>
<td>0.83</td>
<td>0.88</td>
</tr>
<tr>
<td>2.5</td>
<td>0.48</td>
<td>0.52</td>
<td>0.60</td>
<td>0.72</td>
<td>0.80</td>
<td>0.84</td>
</tr>
<tr>
<td>2.6</td>
<td>0.46</td>
<td>0.50</td>
<td>0.58</td>
<td>0.69</td>
<td>0.77</td>
<td>0.81</td>
</tr>
<tr>
<td>2.7</td>
<td>0.44</td>
<td>0.48</td>
<td>0.56</td>
<td>0.67</td>
<td>0.74</td>
<td>0.78</td>
</tr>
</tbody>
</table>

* Hemodynamic data at 1 year

**In Vivo Indexed Effective Orifice Area (EOA)**

**Patient BSA (m²)**
HIGH TRANSPROSTHETIC GRADIENTS

1. Calculate projected indexed EOA
2. Compare measured EOA to reference value
   - Measured EOA = reference value ± 1 SD
     - Calculate indexed EOA (IEOA)
       - Aortic IEOA ≤ 0.65 cm²/m²
         - Mitral IEOA ≤ 0.9 cm²/m²
           - Severe PPM
         - Moderate PPM
           - DVI > 0.35 (aortic)
             - Evaluate leaflet mobility by TEE or cinefluoroscopy
               - Evaluate indirect signs and symptoms
               - Abnormal
                 - Consider prosthesis dysfunction:
                   - Pathologic obstruction (aortic or mitral)
                   - «Occult» mitral prosthesis regurgitation
               - Normal
                 - Consider localized high gradient
               - Consider technical pitfalls (e.g., overestimation of LVOT diameter)
           - DVI > 0.45 (mitral)
             - Evaluate leaflet mobility by TEE or cinefluoroscopy
               - Evaluate indirect signs and symptoms
               - Abnormal
                 - Consider prosthesis dysfunction
               - Normal
                 - «Occult» mitral prosthesis regurgitation
   - Measured EOA < reference EOA ± 1 SD
     - (+ EOA decreased during follow-up)
     - Bileaflet mechanical valve

- Consider: High flow states
- Subvalvular narrowing
- Aortic regurgitation
Abnormally high gradient

Measured EOA similar to reference EOA

Measured EOA indexed for patient's BSA

≤ 0.85 cm²/m²
Mild/moderate PPM

> 0.85 cm²/m²

Rule out:
- Increased LVOT velocity due to hyperdynamic state or subvalvar narrowing
- Technical pitfalls

≤ 0.65 cm²/m²
Severe PPM

Measured EOA << reference EOA

Rule out:
- Localised high gradients in bileaflet mechanical valves

Look for:
- Prosthesis dysfunction
Impact of PPM on Clinical Outcomes

- Less improvement in functional class.
- Increased incidence of late cardiac events.
- Minimal regression of LVH.
- Moderate impact on late mortality (>7 years).
- Major impact on perioperative mortality, particularly if LV dysfunction present.
389 papers were identified, 22 represent the best evidence to answer the question.

Severe mismatch (IEOA-0.65 cm²/m²) could be a predictor of overall 30-day mortality.

Moderate PPM (IEOAF 0.85 cm²/m²) is an independent risk factor of early or midterm overall mortality in the subgroup of patients with poor LV.
Impact of LV Dysfunction?
Prosthesis–patient mismatch after aortic valve replacement predominantly affects patients with preexisting left ventricular dysfunction: Effect on survival, freedom from heart failure, and left ventricular mass regression

Marc Ruel, MD, MPH,a,b Hussam Al-Faleh, MD,c Alexander Kulik, MD,a Kwan L. Chan, MD,c Thierry G. Mesana, MD, PhD,a and Ian G. Burwash, MDc

Preoperative and serial postoperative echocardiograms we in 805 adults post AVR (1990 -2003)

Preoperative left ventricular function
LN Normal (N) 548
LV impaired (N) 257
% Survival (crude)

<table>
<thead>
<tr>
<th></th>
<th>Crude HR*</th>
<th>95% CI</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impaired LV; No PPM:</td>
<td>1.4</td>
<td>0.7, 2.8</td>
<td>0.4</td>
</tr>
<tr>
<td>Normal LV; PPM:</td>
<td>2.0</td>
<td>1.0, 3.8</td>
<td>0.04</td>
</tr>
<tr>
<td>Impaired LV; PPM:</td>
<td>3.8</td>
<td>1.8, 8.0</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Interval (years) after Aortic Valve Replacement
Impact of PPM on LV Mass Regression

109 patients with a CEP bioprosthesis
53% had PPM based on an indexed EOA ≤ 0.9 cm²/m²

Impact of PPM on Short-Term Mortality after AVR (1266 pts)

Short-term mortality (%)

(Overall = 4.6%)

Impact of Valve Prosthesis-Patient Mismatch on Short-Term Mortality After Aortic Valve Replacement
Claudia Blais, BSc; Jean G. Dumesnil, MD; Richard Baillot, MD, et al.

![Graph showing the impact of valve prosthesis-patient mismatch on short-term mortality.]

- **Non significant** (iEOA > 0.85): 3% mortality, p=0.05
- **Moderate** (iEOA = 0.65 - 0.84): 7% mortality, p<0.001
- **Severe** (iEOA < 0.65): 67% mortality, p<0.001

Valve prosthesis-patient mismatch:
- LVEF < 40%
- LVEF ≥ 40%
4100 patients May 1996 - 2004 were evaluated.

1856 patients received bileaflet mechanical AVR
2275 stented AVR

**Results:**

Severe PPM was present in 97 (2.4%)
Moderate PPM in 1103 (26.7%) .
PPM occurs more frequently with xenograft AVR
Patient prosthesis mismatch affects short- and long-term outcomes after aortic valve replacement

Thomas Walther, Ardawan Rastan, Volkmar Falk, Sven Lehmann, Jens Garbade, Anne K. Funkat, Friedrich W. Mohr, Jan F. Gummert

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>5-year survival</th>
<th>8.5-year survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>no PPM (upper)</td>
<td>2927</td>
<td>84.9 ±0.7 *</td>
<td>81.4 ±1.0 *</td>
</tr>
<tr>
<td>PPM (lower)</td>
<td>1200</td>
<td>79.6 ±1.3</td>
<td>76.8 ±1.7</td>
</tr>
</tbody>
</table>

* p < 0.01
Conclusions

Value of AVR for Aortic Stenosis is relief of left ventricular outflow obstruction.

Mismatch can be avoided without increasing operative mortality by choosing the correct operation.

Strategy to maximize the EOAI in patients with impaired ventricular function can improve operative outcomes in this “high-risk” group.
Impact of Prosthesis-Patient Mismatch on Long-Term Survival After Aortic Valve Replacement

Influence of Age, Obesity, and Left Ventricular Dysfunction

Dania Mohty, MD, PhD,*† Jean G. Dumesnil, MD, FRCPC, FACC,* Najmeddine Echahidi, MD.
Impact of Prosthesis-Patient Mismatch on Cardiac Events and Midterm Mortality After Aortic Valve Replacement in Patients With Pure Aortic Stenosis

Giordano Tasca, MD; Zen Mhagna, MD; Silvano Perotti, MD; Pietro Berra Centurini, MD;

**Figure 1.** Overall survival in patients with PPM vs those with no PPM. Numbers between parentheses indicate the number of patients at each follow-up year.

**Figure 2.** Cardiac event-free survival in patients with PPM vs those with no PPM. Numbers between parentheses indicate the number of patients at each follow-up year.
Hemodynamics and Outcomes of Aortic Valve Replacement with a 17- or 19-mm Valve

Homare Okamura, MD, Atsushi Yamaguchi, MD, Kenichiro Noguchi, MD, Kazuhiro Naito, MD, Koichi Yuri, MD, Hideo Adachi, MD

<table>
<thead>
<tr>
<th>Clinical Variable</th>
<th>St. Jude Medical Regent</th>
<th>19-mm (n = 27)</th>
<th>Medtronic Mosaic (n = 15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>74.6 ± 6.3</td>
<td>65.3 ± 11.0</td>
<td>76.9 ± 3.4</td>
</tr>
<tr>
<td>Female sex</td>
<td>19 (83%)</td>
<td>8 (30%)</td>
<td>13 (87%)</td>
</tr>
<tr>
<td>NYHA class</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I–II</td>
<td>11 (48%)</td>
<td>13 (48%)</td>
<td>8 (53%)</td>
</tr>
<tr>
<td>III–IV</td>
<td>12 (52%)</td>
<td>14 (52%)</td>
<td>7 (47%)</td>
</tr>
<tr>
<td>Body surface area (m²)</td>
<td>1.41 ± 0.13 (1.19–1.63)</td>
<td>1.58 ± 0.13 (1.35–1.80)</td>
<td>1.43 ± 0.16 (1.15–1.82)</td>
</tr>
<tr>
<td>Aortic valve pathology</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Senile degeneration</td>
<td>15 (65%)</td>
<td>10 (37%)</td>
<td>11 (73%)</td>
</tr>
<tr>
<td>Bicuspid</td>
<td>6 (26%)</td>
<td>17 (63%)</td>
<td>4 (27%)</td>
</tr>
<tr>
<td>Rheumatic</td>
<td>2 (9%)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Hypertension</td>
<td>10 (43%)</td>
<td>11 (41%)</td>
<td>8 (53%)</td>
</tr>
<tr>
<td>Diabetes</td>
<td>2 (9%)</td>
<td>5 (19%)</td>
<td>3 (20%)</td>
</tr>
<tr>
<td>Ischemic heart disease</td>
<td>2 (9%)</td>
<td>0</td>
<td>4 (27%)</td>
</tr>
<tr>
<td>CPB time (min)</td>
<td>142 ± 25</td>
<td>147 ± 20</td>
<td>153 ± 32</td>
</tr>
<tr>
<td>Crossclamp time (min)</td>
<td>117 ± 22</td>
<td>123 ± 18</td>
<td>125 ± 19</td>
</tr>
<tr>
<td>Prosthesis-patient mismatch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>7 (31%)</td>
<td>4 (15%)</td>
<td>8 (53%)</td>
</tr>
<tr>
<td>Severe</td>
<td>1 (4%)</td>
<td>1 (4%)</td>
<td>3 (20%)</td>
</tr>
</tbody>
</table>
How to Avoid Mismatch

Achieve proper sizing in all patients.

Anticipate a minimum valve size that gives the patient at least $0.85 \text{ cm}^2/\text{m}^2$ of valve area

If the sizer is too big – decide on aortic root enlargement (ARE) or aortic root reconstruction (AoRR)
Valve Sizing (Stented valves)

- **size 21 or larger**: BSA approx 1.5 (50 kg)
- **size 23 or larger**: BSA approx 1.75 (75 kg)
- **at least size 25**: BSA approx 2.0 (>90 kg)
## Valve Sizing (Poor EF’s)

<table>
<thead>
<tr>
<th>Size</th>
<th>BSA Approx</th>
</tr>
</thead>
<tbody>
<tr>
<td>at least 23</td>
<td>1.5 (50 kg)</td>
</tr>
<tr>
<td>at least 25</td>
<td>1.75 (75 kg)</td>
</tr>
<tr>
<td>at least 27</td>
<td>2.0 (&gt;90 kg)</td>
</tr>
</tbody>
</table>
How do you choose AVR or ARE?
Proposal for bail-out procedures - Valves

Apico-aortic valved conduit as an alternative for aortic valve re-replacement in severe prosthesis–patient mismatch

Jamil Hajj Chahine*, Issam El-Rassi, Victor Jebra}
Patient–prosthesis mismatch post MVR

Myth or Reality?
PPM with MV

PPM
1. \( > 1.2 \text{ cm}^2/\text{m}^2 \) (NO PPM)
2. \( \leq 1.2 \text{ cm}^2/\text{m}^2 > 0.9 \text{ cm}^2/\text{m}^2 \) (Mild to Mod PPM)
3. \( \leq 0.9 \text{ cm}^2/\text{m}^2 \) (sever PPM)
Impact of Valve Prosthesis-Patient Mismatch on Pulmonary Arterial Pressure After Mitral Valve Replacement

Mingzhou Li,

Persistent PA hypertension is frequent after MVR, strongly associated with the presence of PPM.
Severe PPM is an independent predictor of mortality post-MVR.
Effect of Prosthesis-Patient Mismatch on Long-Term Survival With Mitral Valve Replacement: Assessment to 15 yrs.

W.R. Eric Jamieson

Freedom from overall mortality

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**Graph Details:**
- Log Rank Statistic
  - Overall: 0.587 (NS)
  - a vs b: 0.457 (NS)
  - a vs c: 0.307 (NS)
  - b vs c: 0.576 (NS)

**Values at 12 yrs:**
- a: 46.6 ± 3.6
- b: 47.0 ± 1.8
- c: 47.7 ± 4.7

**Values at 15 yrs:**
- a: 32.0 ± 4.4
- b: 32.9 ± 2.1
- c: 36.6 ± 6.3
Conclusion’s

PPM after MVR is not uncommon

PPM associated with recurrence of CHF and postoperative PH

PPM independently affected late survival

Implanting sufficiently large prosthesis in adult patients undergoing MVR is recommended.

PPM can largely be avoided by using a simple prospective strategy at the time of operation.