Anatomy of the Aortic Valve & Root

Reconstruction of the Aortic Valve and Root

Frank Langer

Sept 13-15, 2017
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<tbody>
<tr>
<td>A</td>
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**SCORE: 1234**
Aortic Valve/Root Anatomy

- Location / Co-Location
- Anatomic Components
- Dimensions
- Dysfunction
- Congenital Variations
Aortic Root: Location

- Posterior / right relative to the subpulmonary infundibulum
- Wedged between the orifices of the two AV-valves
Co-Location

Wilcox Cook Anderson Cambridge 3rd ed
Aortic Annulus

- Unites aortic cusps and sinuses
- Scalloped shape
- Fibrous throughout its course
- Strands extend into myocardium and the fibrous continuity with AML
Aortic Annulus = Ring ???

- **Crown**-shaped hemodynamic junction marked by semilunar attachments of the aortic cusps
- **Ring**-like ventriculo-arterial junction
- **Ring**-like joining base line of semilunar attachments (virtual) basal ring

Courtesy of E. Lansac
Sinus Valsalvae

Non-coronary sinus fibrous (aorto-mitral continuity)

Crescents of LV musculature at base of left and right sinus (variably)

Anderson Heart 2000
Aortic Cusps

- Consist of collagen, elastin, glycosaminoglycans
- Attached to aortic annulus
- Semilunar shape - base 1.5 x free margin
- Cusps meet at commissures - immediately below sinotubular junction
A cross section of the geometry in the region of the aortic valve is sketched in Figure 2. Dimensions are shown as fractions of base aortic diameter (approximately the annulus diameter at the base of the aortic valve). The coaptation ratio of 0.2 at the apex of the leaflets is of interest. The maximum coaptation ratio of 0.4 is about midway along the contact or the free edge of the leaflets. The leaflet length ratio is 0.75–0.8. The maximum diameter ratio of the sinus cavities is about 1.5. The area-averaged diameter ratio of the sinus region calculated from the measured maximum cross-sectional area through the sinuses is 1.36. These measurements are the averages of measurements on silicone rubber casts of nine human valves (made by the authors) at pressures from 0 to 100 mm Hg corresponding to those during the pulse cycle.

No change in leaflet dimensions occurs following the time when left ventricular pressure reaches aortic pressure, since there is no longer any pressure gradient across the valve.
10 normal cryopreserved tricuspid homografts

**Human aortic root measurements**

<table>
<thead>
<tr>
<th>Level</th>
<th>Orifice area (cm²)</th>
<th>Diameter (mm)*</th>
<th>Diameter (mm)†</th>
<th>Thickness (mm)</th>
<th>Interlevel distance (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>STJ₁</td>
<td>3.40 ± 0.38</td>
<td>21.1 ± 1.0</td>
<td>20.6 ± 1.0</td>
<td>1.9 ± 0.2</td>
<td>10.0 ± 0.0</td>
</tr>
<tr>
<td>STJ₀</td>
<td>2.98 ± 0.32‡</td>
<td>18.9 ± 0.9‡</td>
<td>19.3 ± 0.9‡</td>
<td>1.8 ± 0.2</td>
<td>7.3 ± 0.4</td>
</tr>
<tr>
<td>SINUS</td>
<td>4.49 ± 0.40§</td>
<td>22.4 ± 1.7§</td>
<td>23.7 ± 1.0§</td>
<td>1.3 ± 0.1</td>
<td>62.4 ± 0.4</td>
</tr>
<tr>
<td>BASE</td>
<td>4.24 ± 0.44</td>
<td>23.4 ± 1.2</td>
<td>23.0 ± 1.1</td>
<td>0.8 ± 0.1</td>
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</table>

Valves given as mean plus or minus standard error of the mean.
Dimensions

\[ a^2 + b^2 = c^2 \rightarrow c = \sqrt{a^2 + b^2} \]

e.g. \[ 12^2 + 10^2 = c^2 \rightarrow c = \sqrt{244} = 15.62 \]

<table>
<thead>
<tr>
<th>Human aortic leaflet dimensions</th>
<th>Right</th>
<th>Left</th>
<th>Noncoronary</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (cm)</td>
<td>1.33 ± 0.06</td>
<td>1.39 ± 0.08</td>
<td>1.37 ± 0.04</td>
<td>1.36 ± 0.06</td>
</tr>
<tr>
<td>Free margin length (cm)</td>
<td>3.30 ± 0.14</td>
<td>3.15 ± 0.14*</td>
<td>3.27 ± 0.13</td>
<td>3.24 ± 0.13</td>
</tr>
<tr>
<td>Attached edge length (cm)</td>
<td>4.64 ± 0.20</td>
<td>4.76 ± 0.22</td>
<td>4.81 ± 0.16</td>
<td>4.74 ± 0.19</td>
</tr>
<tr>
<td>Perimeter (cm)</td>
<td>7.94 ± 0.33</td>
<td>7.91 ± 0.35</td>
<td>8.08 ± 0.28</td>
<td>7.98 ± 0.31</td>
</tr>
<tr>
<td>Area (cm²)</td>
<td>2.97 ± 0.17</td>
<td>3.09 ± 0.27</td>
<td>3.17 ± 0.18</td>
<td>3.07 ± 0.21</td>
</tr>
</tbody>
</table>

Values given as mean plus or minus standard error of the mean.

* \( p < 0.05 \), left < right, left < noncoronary, one-way ANOVA.
Dimensions

Effective height measured in 130 healthy volunteers (TTE: 100 adults, 30 children)

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<tr>
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<th>Adults, $n = 100$</th>
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<tbody>
<tr>
<td>Age (years)</td>
<td>$33.8 \pm 14$ (19–76)</td>
</tr>
<tr>
<td>Body height (m)</td>
<td>$1.75 \pm 0.09$ (1.5–2)</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>$71.9 \pm 12.6$ (42–105)</td>
</tr>
<tr>
<td>Body surface area ($m^2$)</td>
<td>$1.87 \pm 0.2$ (1.35–2.4)</td>
</tr>
<tr>
<td>Effective height (mm)</td>
<td>$9.5 \pm 1.4$ (7–12)</td>
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<tr>
<td>Aortoventricular diameter (mm)</td>
<td>$21 \pm 2.8$ (13.5–30.6)</td>
</tr>
<tr>
<td>Sinus Valsalva diameter (mm)</td>
<td>$28.5 \pm 3.5$ (21.1–40)</td>
</tr>
<tr>
<td>Sinutubular junction (mm)</td>
<td>$25 \pm 3.7$ (16–36.6)</td>
</tr>
<tr>
<td>Sinus height (mm)</td>
<td>$22.4 \pm 4.2$ (33.9)</td>
</tr>
</tbody>
</table>

Bierbach Eur JCTS 2010
Dimensions

Geometric height measured intraoperatively in 621 patients:

BAV non-fused cusp  23.8 ± 2.0 mm

TAV NCC 20.7 ± 2.2 mm, LCC & RCC 20.0 ± 2.1 mm
Dysfunction of Aortic Cusps

- Prolapse
- Perforation
- Retraction
- Congenital Malformation
- Fenestration
Congenital Variations

Valve specimens after AVR

TAV 45 %

BAV 49 %

UAV 5 %
Congenital Variations: BAV

- Prevalence 1 – 2 %
- Aortopathy in 40 – 60 %

Nistri Heart 1999
Masri Heart 2017
Congenital Variations: BAV

Cusp fusion

Commissural orientation

Congenital Variations: BAV

Partial Fusion (?)

Complete Fusion
Congenital Variations: BAV
**Congenital Variations: UAV**

- Prevalence 0.02%

- Unicommissural variant:
  - 1 fully developed commissure commonly in posterior location
  - Rudimentary commissures lower

- Congenital fusion:
  - RCC-LCC
  - RCC-NCC

- Acommissural variant (rare)

- Critical AS in infancy or childhood

- AS or AR in 3rd or 4th decade of life

- Prevalence of aortopathy?
Congenital Variations: UAV
Congenital Variations

- Type 0 and 1 = bicuspid
- Type 1: commissural orientation? fusion complete / partial?
- Type 2 = unicuspid
Congenital Variations: QAV

- Prevalence 0.01 - 0.04%
- Seven different types (A-G)
- LCA displaced leftward/upward
- AR in 5th or 6th decade of life
- AS rare
Congenital Variations: QAV
Failure Modes

- prolapse
- retraction
- annular dilatation

- prolapse of fused cusp
- annular dilatation

- calcification
- commissural height
- annular dilatation

- restriction
Conclusions

• The normal aortic valve function depends on correct interactions between root and cusp configuration.
• The natural aortic valve is ideally designed for unobstructed LV ejection and valve closure.
• Different cusp pathologies and morphological variants exist and may lead to aortic valve dysfunction.
• In reconstruction of the aortic valve the different cusp configurations and failure modes have to be considered as part of the repair strategy.