Transoesophageal echocardiography and decision making in valve surgery
Intraoperative evaluation of the surgical results in aortic valve / root surgery

Catherine Szymanski
Disclosures

None
The aortic annulus: a 3D structure

Inter leaflets triangle

Membranous septum

Sino-tubular junction

Aortic annular base

Sutton et al. ATS 1995

Anderson et al. ATS 1991
Dynamic anatomy of the aortic root

Supravalvular: aortic dynamics
Subvalvular: LV dynamics

Aortic Root = 2 functional compartments

Aortic valve opening starts prior to ejection (2.1±0.5%)
Lansac 2002

Systolic expansion of root volume + 37.7±2.7%

Stressless opening of the aortic valve
Maximise ejection

Supravalvular: aortic dynamics
Subvalvular: LV dynamics

Clover shaped aortic valve orifice
Lansac 2001

Da Vinci 1508

ISOVOLUMIC CONTRACTION

D1
D2
RVOT
RVCT
ET

Leyh Circulation 1999

Kilner Circulation 1993

Vortices = stressless valve closure

Stressless opening of the aortic valve
Maximise ejection

Lansac 2002

Aortic valve opening starts prior to ejection (2.1±0.5%)
Pre-operative TEE

4 diameters

STJ > Annulus
Ratio = 1.2 (1.1-1.3)

cH= 4-5 mm
eH= 9-10 mm

Dilated ≥25 mm

Dilated ≥35 mm

Long Axis
120-140°

Transgastric
0 et 120°

Short Axis
45°

Cusp number
Origine of the jet
Commissure Analysis

4 diameters Coaptation Direction of the jet
Root phenotype

Root aneurysm
- Valsalva ≥45 mm

Supra coronary aneurysm
- Valsalva ≤ 40 mm

Isolated AR
- All Ø ≤ 40 mm

Cusp motion

Normal (I)
- AR zero
- Central jet

Prolaps (II)
- Eccentric jet

Retracted (III)

Coaptation and cusp motion

Direction of the jet

Central

Excentric septum

NC or LC prolaps

Eccentric towards MV

RC prolaps

Bicuspid or tricuspid?
Coaptation and cusp motion

Origin of the jet

Central

Large central jet
Trivalvular prolaps

Eccentric
Rupture fenestration

Central
At whole coaptation

Raphe calcified
Bicuspid classification

0 raphe - Type 0

1 raphe - Type 1

2 raphes - Type 2

Sievers et al. JTCVS 2007
### Expansibility of the aortic root

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<tr>
<td>Annular base</td>
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<td></td>
<td>5.7% (2.5-9.6)</td>
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<td>SoV</td>
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<td>4.3% (0.5-10.3)</td>
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<tr>
<td>STJ</td>
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<td>5.4% (1.7-9.8)</td>
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**Aortic annulus and STJ expansion**
## What are the normal diameters of the aortic root?

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<td>1132</td>
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<td>Annular Ø</td>
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<td>22.3±1,4</td>
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<td>(20.5-32.4)</td>
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<td>STJ Ø</td>
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<td>26.7±2.2</td>
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<td>(31.2-23.4)</td>
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<tr>
<td>STJ/annulus</td>
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<td></td>
<td>1.2±0.1</td>
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<td>(1.1-1.3)</td>
</tr>
</tbody>
</table>

**STJ> Annulus Ratio = 1.2 (1.1-1.3)**

**Dilated ≥25 mm**

**Dilated ≥35 mm**
Parameters for valve coaptation

- $c_H = 4-5 \text{ mm}$
- $e_H = >9 \text{ mm}$

STJ

Aortic annular base

Bierbach EJTCVS 2010
Tamas JHVD 2007
When to repair the aortic valve?

**Ascending aorta aneurysms**

- **Root aneurysm**
  - Ø ≥ 55 mm idiopathic aneurysm
  - Ø ≥ 50 mm bicuspid, coarctation, familial history
  - Ø 45-50 mm Marfan
  - ↑ 2-5 mm/y

- **Supra coronary aneurysm**
  - Ø ≥ 45 mm aortic valve disease requiring surgery

**Isolated AR**

- Asymptomatic and LVEF<50%
  - and/or LVESD> 50 mm (25 mm/m²)
  - and/or LVEDD>70 mm

Valve sparing procedures

Remodeling of the aortic root
Yacoub 1983

- Supravalvular annuloplasty

+ Treatment of STJ dilatation
+ Sinuses of Valsalva

Aortic Root expansibility (interleaflet triangles)

- Treatment of aortic annular base dilatation

Sub and supravalvular annuloplasty

Reimplantation of the aortic valve
David 1992
Aortic valve dynamics after valve sparing

Cusp motion and expansibility of the aortic root is best preserved

1) after Remodeling than after Reimplantation

2) with graft with neo- sinuses of Valsalva than without
Influence of valve sparing procedure on cusp coaptation?

Coaptation level is lowered towards aortic annular base after both types of valve sparing procedures.

Reduction of STJ induces symmetrical prolapse.

Resuspension of the cusp effective height.

Soncini. MEP 2009, Pr C. Antona, with permission.

Schäfers et al. JTCVS 2006.
Goals for aortic valve repair

- Treat annular base and STJ dilated Ø
- Preserve root dynamics (neosinus of Valsalva)
- Preserve root expansibility (interleaflet triangles)
- Restore cusp effective height

Need for standardization
An aortic ring: From physiologic reconstruction of the root to a standardized approach for aortic valve repair

Emmanuel Lansac, MD, PhD, a Isabelle Di Centa, MD, b Ghassan Sleilaty, MD, b Eric Arnaud Crozat, MD, c Olivier Bouchot, MD, PhD, d Rachid Hacini, MD, e Dominique Blin, MD, e Fabien Doguet, MD, PhD, f Jen-Paul Bessou, MD, PhD, f Bernard Albat, MD, PhD, g Roland De Maria, MD, PhD, g Jean-Pierre Villemot, MD, PhD, h Eric Portocarrero, MD, h Christophe Acar, MD, PhD, i Didier Chatel, MD, i Stéphane Lopez, MD, k Thierry Folliguet, MD, PhD, a and Mathieu Debauchez, MD a
Standardization based on aortic annulus Ø

Tube graft for remodelling = aortic annulus Ø

<table>
<thead>
<tr>
<th>Valsalva graft® Ø (mm)</th>
<th>25-27</th>
<th>28-30</th>
<th>31-33</th>
<th>≥34</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
<td>Extra aortic ring® Ø (mm)</td>
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<td></td>
<td></td>
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<tr>
<td></td>
<td>25</td>
<td>27</td>
<td>29</td>
<td>31</td>
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</table>

Subvalvular ring = down size from one size
187 patients with Remodeling + External subvalvular aortic ring annuloplasty

<table>
<thead>
<tr>
<th></th>
<th>“Eye Balling”</th>
<th>Alignment of cusp free edges</th>
<th>Measurement of cusp effective height</th>
</tr>
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<tbody>
<tr>
<td>N</td>
<td>74</td>
<td>62</td>
<td>51</td>
</tr>
<tr>
<td>Bicuspid</td>
<td>10 (13.5%)</td>
<td>11 (17.7%)</td>
<td>19 (37.3%) *</td>
</tr>
<tr>
<td>Pre-op annulus Ø</td>
<td>28 (26 – 28)</td>
<td>26 (25 – 28)</td>
<td>28 (26 – 29)</td>
</tr>
<tr>
<td>Cusp repair</td>
<td>15 (20.3%)</td>
<td>19 (30.6%)</td>
<td>36 (70.6%) *</td>
</tr>
<tr>
<td>Ring Ø</td>
<td>28 (26 – 28)</td>
<td>28 (25 – 28)</td>
<td>27 (25 – 27)</td>
</tr>
<tr>
<td>Residual AR≥ 2</td>
<td>6 (8.1%)</td>
<td>8 (12.9%)</td>
<td>1 (1.9%) *</td>
</tr>
<tr>
<td>Re-repair</td>
<td>-</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Conversion</td>
<td>2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Post-op annulus Ø</td>
<td>-24.9% diameter, gradient 5.2±2.3 mmHg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Op. mortality</td>
<td>2 (2.7%)</td>
<td>2 (3.2%)</td>
<td>2 (3.9%)</td>
</tr>
</tbody>
</table>

## Follow-up events

<table>
<thead>
<tr>
<th></th>
<th>1 year follow up</th>
<th>Latest follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Al ≥ 2</td>
<td>Reoperation</td>
</tr>
<tr>
<td>“Eye Balling”</td>
<td>16 (25.0%)</td>
<td>2 (3.1%)</td>
</tr>
<tr>
<td>Alignment of cusp free edges</td>
<td>9 (15.0%)</td>
<td>1 (1.7%)</td>
</tr>
<tr>
<td>Measurement of cusp effective height</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
</tbody>
</table>

## Risk factors for AR recurrence

- **“Eye Balling”**
- Residual AR
- Tricuspid valve

Phenotypes of the ascending aorta

- Aortic root aneurysm
  - Valsalva ≥45 mm

- Supra-coronary aneurysm
  - Valsalva < 40 mm
  - Supra coronary Aorta > 45 mm

- Isolated AI
  - Valsalva < 40 mm
  - Supra coronary Aorta < 40 mm

Standardized and physiological approach to aortic valve repair

- Root reconstruction
  - Remodeling
    - + sub-valvular annuloplasty
  - Supra-coronary graft
    - + sub-valvular annuloplasty
    - (annulus > 25 mm)

- Subvalvular annuloplasty

Cusp repair

- Resuspension of cusp effective height

- Subvalvular aortic annuloplasty
Post aortic valve repair TEE analysis

What is a good result?
A good result

• Patient may expect at -10 years postop
  – 85-95% survival
  – 90-95% freedom from reoperation
  – 80-90% freedom from moderate to severe AR
A good result is related to

- A proper patient selection
- A standardized approach
- A good immediate result
AR > grade I

Risk factor for reoperation

Eccentric jet

Prolapsing cusps

Tip of coaptation at the level of the aortic annulus or below

AR ≤ grade I

Satisfactory results

Tip of coaptation above the plane of aortic annulus

Coaptation height > 5 mm
Decision to rerepair / replace

- **Valvular factors**
  - Mechanism of residual AR
  - Quality of valve tissue
  - Aggressiveness of attempted repairs

- **Patient factors**
  - Age
  - Comorbidities
  - LV function
  - Choice of prosthesis
Effective height

- Correlates with
  - Size of individuals
  - Aortic root diameters
- $\geq 9$ mm = excellent predictor for a good hemodynamic outcome
  (residual AR < 2)

Bierbach BO. Eur J Cardiothorac Surg 2010; 38: 400-406
BAV: dilated AVJ

- 316 patients, 49 ± 14 years, 268 male, reconstruction of regurgitant BAV
- Hosp. Mortality 0.63%
- Survival 92% at 10 years
- Freedom from reoperation
  - 88% at 5 years
  - 81% at 10 years
- Freedom from aortic valve replacement
  - 95% at 5 years
  - 84% at 10 years

Aicher D. Circulation 2011; 123:178-185
BAV: dilated AVJ

Aicher D. Circulation 2011; 123:178-185
BAV: need for pericardial patch

- For raphe repair

Aicher D. Circulation 2011; 123:178-185

Boodhwanni M. J Thorac Cardiovasc Surg 2010; 140: 276-284
• Circumferential orientation of the commissures determines outcome
BAV: freedom from reoperation

Follow-up (months)

% 100 90 80 70 60 50 40 30 20 10 0

- eH ≥ 9mm
- eH < 9mm

P=0.003

Aicher D. Circulation 2011; 123:178-185
AV repair: effect of AR type

- 163 patients AV surgery, 117 males, 58 ± 14 years
- 125 valve repair or sparing
- 38 valve replacement
- Type 1: aortic dilatation
- Type 2: cusp prolapse
- Type 3: restrictive cusp motion or endocarditis

le Polain de Waroux JB, Circulation 2007; 116: I 264
AV repair: effect of AR type

![Graph showing event free survival over time for different types of AR.](image)

- **Type 1**: n = 36
  - Initial: 22
  - Final: 16, 8

- **Type 2**: n = 55
  - Initial: 37
  - Final: 18, 10

- **Type 3**: n = 30
  - Initial: 24
  - Final: 14, 8

Log rank p = 0.04
Death
AR > grade 2
reoperation

le Polain de Waroux JB, Circulation 2007; 116: I 264
Height of resuspension and early valve failure

- 101 patients aortic root reconstruction by reimplantation of the native valve
- 52 males, 49.1 ± 20.6 years
Height of resuspension and early valve failure

Mechanisms of Recurrent AR after Aortic Valve Repair

Aortic Valve Repair (Severe AR) N=244

- Included N=186
- Excluded:
  - No Follow up Data: N=6
  - Missing TEE Data: N=50
  - No AR at 2nd Surg: N=2

- No or Trivial AR N=122
- Grade 1-2 AR N=23
- Severe AR N=41
  - Redo N=23

Le Polain de Waroux JB. J Am Coll Cardiol 2009; 2: 931-939
### Table 4. Intraoperative TEE Predictors of ≥3+ Recurrent AR With the Cox Multivariate Analysis

<table>
<thead>
<tr>
<th>Multivariate Analysis</th>
<th>HR</th>
<th>95% Confidence Interval</th>
<th>Cox p Value</th>
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<tbody>
<tr>
<td>Coaptation length</td>
<td>0.82</td>
<td>0.63–1.00</td>
<td>0.05</td>
</tr>
<tr>
<td>Tips below the level of the aortic annulus</td>
<td>7.9</td>
<td>6.52–9.28</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Diameter of aortic annulus</td>
<td>1.18</td>
<td>1.03–2.45</td>
<td>0.01</td>
</tr>
<tr>
<td>Residual AR</td>
<td>5.3</td>
<td>1.47–6.57</td>
<td>0.01</td>
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</tbody>
</table>

HR = hazard ratio; other abbreviations as in Tables 1 and 3.
No Residual AR
Residual AR, coapt > 4mm
Residual AR, coapt < 4mm
Coaptation below annulus

**Figure 5.** 4-Year Survival Free From Redo According to TEE
Risk of aortic repair failure

Coaptation Tips Below the Annulus?
- Yes
  - Recurrence Rate 20/28 (71%)
  - Redo Rate 12/28 (48%)
- No
  - Residual AR?
    - Yes
      - Coaptation Length?
        - < 4 mm
          - Recurrence Rate 17/36 (47%)
          - Redo Rate 10/36 (28%)
        - > 4 mm
          - Recurrence Rate 2/41 (5%)
          - Redo Rate 0/41 (0%)
    - No
      - Recurrence Rate 2/81 (2%)
      - Redo Rate 1/81 (1%)
What is a good result?

• A good coaptation
  – High
  – eH ≥ 9 mm
  – Long ≥ 5 mm
  – No residual or induced prolapse

• No residual AR

• A good valve opening
THANK YOU