Conceptual Development of the Expansible Ring and Update on the CAVIAAR Registry

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Disclosure information

Consultant for Coroneo, Inc
« I don’t believe a word of what you told me »
The aortic valve: a passive or dynamic structure?

Leonardo da Vinci 1508
Quadr Anat IV

Belhouse Cir Res 1969
In vitro Vortex formation

Brewer JTCVS 1976
Interdependence of valve opening and root expansion

Thubrikar JTCVS 1979: In vivo 9% commissural expansion prior ejection
Circular orifice

Dagum Circulation 1999
Deformational dynamics of the aortic root (60Hz)
The aortic annulus: a 3D structure

Inter leaflets triangle

Membranous septum

Sino-tubular junction

Aortic annulus

3D

2D

Sutton et al. ATS 1995

Anderson et al. ATS 1991
Aortic Root = 2 functional compartments

SUPRAVALVULAR COMPARTMENT:
- STJ + ascending aorta

SUBVALVULAR COMPARTMENT:
- Aortic annulus + Commissures (inter-leaflet triangles)

Sutton et al. ATS 1995  Lansac et al. EJTCS 2002
Sonometrics crystals 200-800Hz
Aortic root expansion starts prior to ejection

36.7 ± 3.3% of root volume expansion

Lansac et al. EJTCS 2002; 22:497-503
Aortic valve opening starts prior to ejection

(2.1±0.5%)

Related to annular base and commissural (subvalvular compartment) pre-ejectional expansion

Correlated to LV pressure increase (r=0.95)

Due to a redistribution of LV volume below the leaflets (inter-leaflet triangle)

Optimize ejection

Stressless opening

Lansac et al. EJTCS 2002; 22:497-503
Aortic valve opening is maximum during the $1/3$ of ejection.

Leaflet area overshot Commissural area by $28.8\pm3.4\%$ = Clover-shaped orifice

Maximizes hemodynamic performance unimpeded blood flow through the sino-tubular junction to the systemic circulation
Aortic root expansion is asymmetric
Tilt angle of the aortic valve during cardiac cycle

End diastole: 16.3±1.5° postero-left

During systole: 6.6±1.5°
Alignement of LVOT and ascending aorta

Maximize ejection

During diastole: +6.6±1.5°

Shock absorber

Lansac et al. JHVD 2005; 14:400-407
Importance of Sinuses of Valsalva

Recirculating flows (vortices) accommodated by the sinuses contribute to efficient and smooth valve closure at end systole.

Leonardo da Vinci 1508
Quadr Anat IV

Belhouse Cir Res 1969
In vitro Vortex formation

Kilner Circulation 1993
3D MRI

Katawama 2008
Aorto mitral junction dynamics: two to tango

DIASTOLE

T1 -11.5±2.3%  
T2

SYSTOLE

Aortic Ø + 10.6±0.3%

T1 +11.5±2.3%  
T2

Transverse Ø: -12.1±1.5%
Antero Posterior Ø: -23.6±2.5%

MAXIMIZE LV FILLING

MAXIMIZE EJECTION

Lansac et al. JTCVS 2002; 123:911-918
Annulus excursion during cardiac cycle 13 ± 2.3 mm

The angle between the mitral and aortic annulus reduces 11° in systole.

Annulus excursion contributes to an efficient cardiac output

Alignement of LVOT and ascending aorta Maximize ejection

Sughimoto JHVD 2010

What are the normal diameters of the aortic root?

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<td>Annular Ø</td>
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<td>STJ/annulus</td>
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What are the normal diameters of the aortic root?
## Expansibility of the aortic root

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<td><strong>N</strong></td>
<td>599</td>
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<tr>
<td><strong>Annular base</strong></td>
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<td></td>
<td>5.7% (2.5-9.6)</td>
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<td>4.3% (0.5-10.3)</td>
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<tr>
<td><strong>STJ</strong></td>
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<td>5.4% (1.7-9.8)</td>
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**Aortic annulus and STJ expansion**

![Image of aortic annulus and STJ expansion with measurements](image)
Parameters for valve coaptation

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

Bierbach EJTCVS 2010
Tamas JHVD 2007
Dynamic anatomy

Aortic Root expansion

= Stress less opening and closure of the valve

Clover shape orifice

Cusp effective height

Annulus < STJ Ratio 1.2

Dilated STJ >30 mm

Dilated annulus >25 mm

Valve repair

Treatment of dilated diameters

Aortic annular base Ø STJ Ø

Preserves root dynamics

Neosinuses of valsalva

Systolic expansion (interleaflet triangles)

Restores cusp effective height

Restores ratio

Durability of a native valve

Durability of repair

Restores ratio

Dilated annulus >25 mm

Dilated STJ >30 mm

Dilated annulus >25 mm

Annulus < STJ Ratio 1.2
The surgical correction of aortic insufficiency by circumclusion


First subvalvular aortic annuloplasty

Beating Heart Right thoracotomy

11 patients, rheumatic disease (8/11)
Treatment of aortic insufficiency by means of aortic annuloplasty


Plicating U stitches at the base of the interleaved triangles

Plicating U stitches at the commissures

= partial subvalvular annuloplasty

= partial supravalvular annuloplasty

Plication of the interleaved triangles impairing valve dynamics
Annuloplasty for root aneurysms

Remodeling of the aortic root
Yacoub 1983

- Treatment of STJ dilation
- Sinuses of Valsalva
- Aortic Root expansibility (interleaflet triangles)
- Treatment of aortic annular base dilation

Supravalvular annuloplasty

Reimplantation of the aortic valve
David 1992

- Sub and supravalvular annuloplasty
**First series of Remodeling**

**Burkhart JHVD 2003**
- Risk factor: Cusp repair, aortic annulus >25 mm

**Lansac EJTCVS 2006**
- Sub valvular external aortic ring

**Hancke JTCVS 2009**
- Risk factor: Marfan, cusp repair, aortic annulus >26 mm

**David JTCVS 2010**
- Anulus dilation if Ø >27 mm men, Ø >25 mm women

**Kunihara JTCVS 2011**

**Asano EJCTS 2012**

**Table 4: Analysis of risk factors for reoperation**

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Univariate</th>
<th>Multivariate</th>
<th>HR</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVJ &gt; 28 mm</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>11.647</td>
<td>2.506-54.134</td>
</tr>
<tr>
<td>Pericardial patch</td>
<td>0.05</td>
<td>0.42</td>
<td></td>
<td></td>
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<tr>
<td>Non-TAV</td>
<td>0.09</td>
<td>0.21</td>
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<tr>
<td>Cusp plackation</td>
<td>0.10</td>
<td>0.14</td>
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<tr>
<td>STJ &gt; 30 mm</td>
<td>0.20</td>
<td>0.28</td>
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<tr>
<td>Sinus valsalva</td>
<td>&gt;40 mm</td>
<td>0.53</td>
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</table>

**Post STJ remodeling**
Physiological and standardized approach to Valve Sparing Root Replacement

Remodeling + Aortic annuloplasty

RF Annulus > 25 mm

Remodeling 1983 Yacoub
Reimplantation 1992 David

2003 Lansac
Aortic valve repair, using the re-implantation technique or remodelling with aortic annuloplasty, is recommended in young patients with aortic root dilation and tricuspid aortic valves.
Techniques for aortic annuloplasty

Isolated A1

Duran 1983
Carpentier 1983
Frater 1986
Haydar 1997
Izumoto 2002
Lansac 2003

Hahm 2006
Schäfers 2009
Fattouch 2011
Scharfschwerdt 2011
Rankin 2011

Need for standardization
External Dissection of the Subvalvular Plane

Kheli et al ATS 2015
Aortic annuloplasty can be performed in the subvalvular plan, except at the level of the infundibulum where the dissection stops 1.4±1.8 mm above the nadir of the right coronary sinus.
External aortic annuloplasty (ring or proximal suture of reimplantation) induces a minimum of 5 mm reduction of aortic annulus diameter, corresponding to tissue thickness.
Expansible Extra Aortic Ring

Silicone expansible

Polyester extensible
10 % systolic expansion
Ovin experimental study

6 sheep
Double annuloplasty

intracardiac Echocardiography
(AcuNav®)

Lansac et al JTCVS 2009
Double sub and supravalvular annuloplasty

**Pre implantation**

- Sino tubular junction: 21.2 ± 2.5
- annulus: 19.6 ± 1.2
- Coaptation: 2.6 ± 0.1

**6 mois**

- Sino tubular junction: 14.5 ± 2.8
- annulus: 16.1 ± 3.9
- Coaptation: 6.0 ± 0.1

-30%  -15%  +130%
## Dynamic parameter of the aortic root after double expansible annuloplasty

<table>
<thead>
<tr>
<th>Parametres</th>
<th>Expansibility (%)</th>
<th>Distensibility (10^{-5}/Pa)</th>
<th>Compliance (10^{-1}µm/Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Annulus</strong></td>
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<tr>
<td>Pre-op</td>
<td>9.1 ± 4.9</td>
<td>1.10 ± 0.12</td>
<td>2.17 ± 0.25</td>
</tr>
<tr>
<td>6 M</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td><strong>STJ</strong></td>
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</tr>
<tr>
<td>Pre-op</td>
<td>9.6 ± 6.1</td>
<td>0.97 ± 0.07</td>
<td>1.76 ± 0.37</td>
</tr>
<tr>
<td>6 M</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

*pre-op versus post op p NS*
Explantation at 6 months
Pre implantation

6 months post op

Silicone properties remained stable at 6 months
Moving from Valve Sparing to a standardized approach of Aortic valve REPAIR

- Physiological root Remodeling
- Resuspension of cusp effective height
- Expansible aortic annuloplasty
Standardized approach according to each aorta phenotype
482 patients Aortic valve repair with annuloplasty ring (2003 -2018)
Operative mortality : 1.2%

92% Freedom from reoperation at 7 years similar among each phenotype with no difference between bicuspid and tricuspid valve

Since 2007, calibrated expansible annuloplasty and systematic cusp effective height assessment improve freedom from reoperation up to 98.9% at 7 years

• 99.1 % for remodeling root repair + ring
• 97% for double annuloplasty

Multicentric Comparative trial (CAVIAAR) to Mechanical Bentall
Same operative mortality and trend toward more MAVRE in Bentall compare to valve repair

Lansac et al JTCVS 2015; EJTCVS 2016; JTCVS 2017, data in press or in process of submission
Midterm results of CAVIAAR trial at 4 years

4 years Freedom from Valve related death
99.1 % (1 patient) for REPAIR Versus 94.3 % (7 patients) for REPLACE (p = 0.031)
Midterm results of CAVIAAR trial at 4 years

(In process of submission)

<table>
<thead>
<tr>
<th>Criterion</th>
<th>RR</th>
<th>CI95%(RR)</th>
<th>P Value</th>
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<tbody>
<tr>
<td>Composite criterion</td>
<td>1.58</td>
<td>[0.97;2.59]*</td>
<td>0.068*</td>
</tr>
<tr>
<td>MAVRE criterion</td>
<td>1.94</td>
<td>[1.16;3.24]*</td>
<td>0.011*</td>
</tr>
<tr>
<td>Valve related reoperation</td>
<td>0.54</td>
<td>[0.23;1.30]*</td>
<td>0.172*</td>
</tr>
<tr>
<td>Bleeding</td>
<td>2.91</td>
<td>[1.37;6.17]*</td>
<td>0.005*</td>
</tr>
<tr>
<td>Embolism</td>
<td>1.91</td>
<td>[0.51;7.13]*</td>
<td>0.338*</td>
</tr>
</tbody>
</table>

REPAIR significantly reduce MAVRE compare to REPLACE at 4 years with no difference in valve related reoperation.
Overall survival of isolated AV repair is similar to general population
Open Prospective International Multicenter Registry

Open to all centers, Join us!

AVIATOR@HeartValveSociety.org

Surgical Registry
Aortic valve Repair / sparing and Replacement

Medical Registry
(In progress)

Isolated AI and/or ascending aorta aneurysm
Candidates for Aortic valve repair / sparing

Surgical indication
Yes
No

Evaluation of the Guidelines
Evaluation of the results

Aortic Annuloplasty: a practical approach (EACTS)
Paris March 9-11th 2020
(live surgery-video session)

www.eacts.org