HEART VALVES AND GREAT ARTERIES IN PEDIATRIC AND ADULT CARDIAC SURGERY

AORTIC ROOT REMODELING
Dr. P. Kalandadze
Aortic Root
Aortic root
Sinutubular junction

Mid-sinusal level

Anatomic ventriculo-arterial junction

Virtual basal ring
Aortic root and valve relationships: Impact on surgical repair
Karyn S. Kunzelman, PhD, K. Jane Grande, BA, Tirone E. David, MD*, R. P. Cochran, MD, Edward D. Verrier, MD

The critical finding of the paper was that if the diameter of the aortic root was defined at the mid-sinus as 100%, then the sinus ridge should be 81% of that diameter and the aortic root base 97% of that diameter in the normal aortic root. In other words, the sino-tubular ‘ridge’ is approximately 85% of the diameter of the ‘annulus’ at the base of the root.
“eddy-currents of Leonardo”
Geometric Relationships

Immediately below level of STJ

AA = 15 - 20% > STJ

Aortic Valve Closure and Currents

At Systole

At Diastole

Leaflets longer in diastole
Computational Fluid Dynamics Simulation

GRID MOVEMENT
1) The cusps begin to open even before flow occurs across the valve (initiated by rise in intraventricular pressure, acting on the ventricular aspect of the valve).

2) Flow through the aortic valve continues in late systole even when the aortic pressure exceeds that in the left ventricle.

3) Due to the “eddy-currents of Leonardo”, aortic valve closure begins even while the blood is still streaming through the aortic orifice.
Marker placement in the aortic valve. (I) Three markers (A, B, and C) are at the center of the aortic Sinuses. (II) Top view of the valve. Markers D and E are at the center of the free edge of two leaflets. (III, IV) Markers R, M, and S indicate longitudinal curvature of the sinus. Markers L, M, and N show circumferential curvature of the sinus. The distances RMS and RS represent arc length and height, respectively, for the longitudinal curvature. The distances LMN, and LN represent arc length and height (or width), respectively, for the circumferential curvature. Marker T is in the opposite commissure, and marker P is on the free edge of a leaflet.
A four-dimensional study of the aortic root dynamics
E. Lansac\textsuperscript{a}, H.S. Lim\textsuperscript{b}, Y. Shomura\textsuperscript{c}, K.H. Lim\textsuperscript{b}, N.T. Rice\textsuperscript{c}, W. Goetz\textsuperscript{c}, C. Acar\textsuperscript{a}, C.M.G. Duran\textsuperscript{c}\textsuperscript{*}

Location of the sonomicrometry crystals in the aortic root. B, base; SoV, sinus of Valsalva; C, commissures; STJ, sinotubular junction; AA, ascending aorta.
Relative cross-sectional area diagram of the aortic root at end-diastole (a) and at maximum expansion (b) during ejection. B, base; SoV, sinus of Valsalva; STJ, sinotubular junction; C, commissures.
**Schematic 2** The cartoon shows an idealised aortic root. The attachments of the valvar leaflets, shown in red, extend through the entire length of the root, from the sinutubular junction, in blue, to the virtual basal ring, shown in green, and produced by joining together the basal attachments of the leaflets. The crown-like attachments of the leaflets cross the anatomic ventriculo-aortic junction, shown in yellow.
Stress of flexion
Stress of contact
Stress of pressure
Operations

- Bental and Debono 1968
- Wolfe 1980
- David and Feindel 1992
- Yacoub and colleagues 1993
Bentall

- Anticoagulants
- Bio valve degeneration
Reimplantation
Modern techniques

Reimplantation

- TD I
- Seattle technique
- TD IV

Remodeling

- Yacoub
- TD II
- TD III
- Hopkins
Valve sparing operations

► Root remodeling

More physiological

Annulus remains untreated:
Annulus dilatation
AI

► Additional annulus support
Valve sparing operations

- Reimplantation technique
  - annulus stabilization
- abnormal leaflet motion
Valsalva graft vs Tube graft

better root physiology
Comparison of distensibility of the aortic root and cusp motion after aortic root replacement with two reimplantation techniques: Valsalva graft versus tube graft

Masamichi Matsumori, Hiroshi Tanaka, Yujiro Kawanishi, Tetsuari Onishi, Keitaro Nakagiri, Teruo Yamashita, Kenji Okada, Yutaka Okita*

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Aortic root distensibility
Percent changes in radius

(a) PCR annulus

- Group T (n = 5) Tube graft
- Group V (n = 15) Valsalva graft
- Group C (n = 5) Normal control

(ns)

(b) PCR sinus

- Group T (n = 5) Tube graft
- Group V (n = 15) Valsalva graft
- Group C (n = 5) Normal control

(P = 0.003)

(c) PCR ST junction

- Group T (n = 5) Tube graft
- Group V (n = 15) Valsalva graft
- Group C (n = 5) Normal control

(P = 0.03)

(P = 0.003)
## Aortic valve motion

**RVOV**-rapid valve opening velocity  
**RVCV**-rapid valve closing velocity

<table>
<thead>
<tr>
<th></th>
<th>Tube graft (T) (n=5)</th>
<th>Valsalva graft (V) (n=15)</th>
<th>Control (C) (n=5)</th>
<th>P-value</th>
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<tbody>
<tr>
<td>RVOV/HR</td>
<td>48.2±6.2</td>
<td>36.2±11.9</td>
<td>33.7±9.6</td>
<td>C vs. T=0.03</td>
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<td>(cm/s/min)</td>
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<td>C vs. V=ns</td>
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<tr>
<td>RVCV/HR</td>
<td>26.1±6.7</td>
<td>40.7±16.6</td>
<td>28.4±16.3</td>
<td>T vs. V=ns</td>
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<td>(cm/s/min)</td>
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<td>C vs. V=ns</td>
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<td>T vs. V=ns</td>
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</table>
Tube graft
Flexible root
Aortic valve opening and closing
Using finite element modeling we found the stress at the leaflet-belly to be 0.26 N/mm. In the model without sinuses, stress along the leaflet attachment rose to 0.65 N/mm. Furthermore, we also found that the stress along the attachment line to be lower (0.3 versus 0.4 N/mm) if the sinus root was modeled flexible.
Valsalva versus tube graft

- Reconstructing sinus reduces stress and strain of the cusps
- Sinus distensibility is important to prevent premature degeneration of the cusps
AORTIC LEAFLETS

► ANTATOMICALLY NORMAL

BUT NOT

► GEOMETRICALLY
normal valve function was only achieved after both the annulus and the leaflet free-edge length were reduced: (a) valve after conventional valve sparing; (b) after annuloplasty only; (c) after leaflet free edge reduction only; (d) after both annuloplasty and leaflet reduction.
Aortic root remodeling operation: how do we tailor a tube graft?

Kiyofumi Morishita, MD*a, Gen Murakami, MDa, Tokuo Koshino, MDa,

- Diameter values predicted by equations versus measured diameter from Japanese cadavers at sinus level: (A) Yacoub’s method; (B) our method; (C) David’s method.

- Diameter values obtained from equations versus measured diameter at sinus level in white casts: (A) Yacoub’s method; (B) our method; (C) David’s method.
Aortic root remodeling operation: how do we tailor a tube graft?
Kiyofumi Morishita, MD* a, Gen Murakami, MD a, Tokuo Koshino, MD a, Johji Fukada, MD a, Yasuaki Fujisawa, MD a, Tohru Mawatari, MD a, Tomio Abe, MD a

► graft sizing should be performed using Yacoub’s way
► the tube graft should be cut into three parts in proportion to the size of each cusp; and
► the position of the commissures in the tube graft should be secured with sutures first, and the depth of the sinuses should be determined later.
The mean diameter of the sinotubular junction was 21.1 ± 1.0 mm and the mean length of the free margins of the aortic cusps was 32.4 ± 1.3 mm. Thus, in the normal, fresh aortic root, the diameter of the sinotubular junction was approximately 30% less than the average length of the free margins of the aortic cusps and not 10%.

Although anatomic studies of the normal aortic root show that the diameter of the aortic annulus is 15% to 20% larger than the diameter of the sinotubular junction, after successful aortic valve sparing operations, those two diameters are either equal or the sinotubular junction is larger than the aortic annulus.

Similarly, the lengths of the bases of normal aortic cusps are approximately one and one-half times longer than the lengths of their free margins.
Sizing the graft

- Reimplantation technique in general requires a somewhat larger graft (30–34 mm), in effect matching the ideal ‘annulus size’ for the aortic valve prior to dilatation.

- The reimplantation method is based on the aortic root external diameter (internal diameter + wall thickness).

- David describes reconstruction of the aortic root based on the size of the aortic cusps and avoids using grafts smaller than 30 mm in diameter to avoid constraining the aortic sinuses and causing damage to the leaflets.

- Yacoub’s group has suggested measuring the distance between the commissures, which produces maximal coaptation of the cusps and equating that to the diameter.

- Remodeling is based on internal diameters.
A normogram to anticipate dimension of neo-sinuses of valsalva in valve-sparing aortic operations

Daniele Masellia,*, Andrea Montaltoa, Gianluca Santisea, Giovanni Minardib, Carla Manzarab, Francesco Musumecia

a Department of Cardiac Surgery, S. Camillo Hospital, Rome, Italy
b Department of Cardiology, S. Camillo Hospital, Rome, Italy
Table 2: Predicted dimensions (mm) for functional aortic valves

<table>
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<th>AD</th>
<th>LH</th>
<th>FE</th>
<th>STJ</th>
<th>AD</th>
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AD: annulus diameter; LH: leaflet height; FE: leaflet free edge length; STJ: sinotubular junction diameter.
Is aortic valve-sparing operation or replacement with a composite graft the best option for aortic root and ascending aortic aneurysm?

Christos Tourmousoglou*, Chris Rokkas

*Department of Cardiothoracic Surgery, Attikon University Hospital, Athens, Greece

Received 20 June 2008; received in revised form 14 September 2008; accepted 2 October 2008
Sixteen papers reported a 10-year reoperative-free survival from 54% to 98% for valve-sparing operations and 67% to 81% for replacement operations in two further studies. Six papers reported their 10-year freedom from re-operation as 75–97% for valve-sparing operations.

Our findings suggest that the results of both techniques are excellent and comparable and the operating surgeon may safely make his decision as to which technique to select based on patient factors and his own experience without compromising the long-term outcomes of the patient.
Restitution of the Aortic Valve: What is New, What is Proven, and What is Obsolete?

Johannes M. Albes, MD, PhD, Ulrich A. Stock, MD, PhD, and Martin Hartrumpf, MD

Department of Cardiovascular Surgery, Heart Center Brandenburg, Bernau, Germany
Fig 1. Freedom from reoperation. Cumulative actuarial freedom from reoperation and cumulative patients at risk of all three investigated methods of reimplantation (diamonds), remodeling (boxes) and resuspension (triangles).

Data are extrapolated from 31 studies.
Restitution strategies of the insufficient aortic valve belong to the clinical armamentarium. To date, the accumulated body of evidence comprises 126 articles dealing with restitution strategies on the insufficient aortic valve with concomitant aortic surgery. In a cumulative analysis an almost identical number of reimplantation (506) and remodeling (489) procedures were found in the literature, whereas 357 patients underwent aortic valve resuspension. The cumulative results tend to favor the reimplantation technique in terms of longevity of the reconstruction, particularly in congenital degenerative disorders of the aortic wall, whereas remodeling appears to exhibit a more physiologic behavior of the reconstructed valve and re-suspension serves as a simplified approach particularly in acute type A dissection. Although restitution of the native aortic valve has its place in current treatment options, the accumulated worldwide numbers indicate that it is not yet routinely implemented in the vast majority of cardiac institutions.
Valve sparing surgery

► Good medium term results
► Ideal method remains to be demonstrated
► All components of the aortic root must be considered
► New prosthetics improve sinus reconstruction
► Correct tailoring of the graft

MORE ART THEN SCIENCE
FLORIDA SLEEVE REPAIR

- Dimension stability of the sleeved root
- No need for radical sinus resection
- No need for coronary artery transfer

- Extent of expansion of periaortic Dacron tube grafts in extravascular locations remains unknown
- Short follow up
Aortic root remodeling with tree patch technique

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Aortic valve reconstruction associated to ascending aorta tubular graft replacement in aortic incompetence by annuloaortic ectasia

Marco Giambuzzia, Salvatore Spagnoloa, Vincenzo Dottoria, Enrico Parodib, Giuseppe De Gaetanoa

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b Cardiac Surgery Institute, University Of Genoa, Genoa, Italy
accepted 5 May 1998.
Aortic root patch remodeling

- Alternative of valve sparing procedures
- Not used prosthetic material
- No need for coronary reimplantation
- No need for graft sizing
Operative steps
Operative steps

Jiena technique
Operative steps
Operative steps
Operative steps
Operative steps
Operative steps
Operative steps
Operative steps
angiography
Reoperation
## Patients characteristics

<table>
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<tr>
<th>Characteristics</th>
<th>Value</th>
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<tbody>
<tr>
<td>Number of patients</td>
<td>89</td>
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<tr>
<td>Mean age</td>
<td>65.5 (29-84)</td>
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<td>Male/female</td>
<td>50/39</td>
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<td>Aortic ectasia</td>
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<td>Marfan</td>
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<td>Aortic dissection</td>
<td>2</td>
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<td>Bicuspid valve</td>
<td>0</td>
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<tr>
<td>LVEF (%)</td>
<td>54 (26-72)</td>
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<tr>
<td>Diameter of annulus (mm)</td>
<td>43 (35-55)</td>
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<tr>
<td>Diameter of aneurysm</td>
<td>52 (45-66)</td>
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</table>

### Aortic insufficiency:
- Severe: 7
- Moderate: 26
- Mild: 56
## Postoperative complications

<table>
<thead>
<tr>
<th>Variable</th>
<th>n</th>
<th>%</th>
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<td>Hospital death</td>
<td>2</td>
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<td>Low cardiac output</td>
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<td>Aortic insufficiency in O.R.</td>
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<tr>
<td>Bleeding</td>
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<td>TIA</td>
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<td>Sternal infection</td>
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<td>Pneumonia</td>
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<td>Renal complications</td>
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</table>
conclusions

► Aortic root patch remodeling is an alternative of valve sparing procedures

► Simplified reconstruction completely avoids transection of the aortic root and mobilization of the coronary ostia

► This technique allows the fixation of the aortic annulus, reconstruction of the sinuses of valsalva by plication and exclusion of parts of the sinus wall and creation of a new sinotubular junction in a most physiological way, without prosthetic material and need for coronary reimplantation

► No need for graft sizing

► The learning curve for this operation is not significant

► Long term results should be verified

► Ideal method should be personalized
Aortic root surgery is an Art but why we don’t do it easier

Leonardo DaVinci

Pablo Picasso