AORTIC LIVE | 2016
October 17–18, 2016
Philharmonic Hall Essen, Germa

Universitätsklinikum Essen

Principles of root replacement

Ruggero De Paulis

Professor and Chief
Department of Cardiac Surgery, European Hospital, Rome, Italy

The valve sparing operation in the adults

1. When to do it
2. Why to do it
3. How to do it

When to do it

1. Root dilatation with normal functioning tricuspid or bicuspid valve
    1. Connective tissue disease
    2. Non connective tissue disease

2. Acute aortic dissection

1. All of above but in the presence of AR needing associated leaflet plasty

Why to do it

1. Reduced incidence of endocarditis and thromboembolism
2. Excellent hemodynamics
3. No need for anticoagulants or antiaggregants
4. Data on long-term demonstrate extremely low mortality and 90% freedom from redo at 10 years

How to do it

Indipendently from the type of technique, remodeling or reimplantation:

1. Anatomical reconstruction
2. Simple and reproducible
3. Safe
4. Stable long-term results

The need for sinuses

1. Historical data
2. Hystology
3. Geometry
4. Study on stress
5. In vivo cusp motion
6. Bench experiments
7. Specific surgical techniques

1. Leonardo intuition

"will be proportional to the different sizes of the pipe"

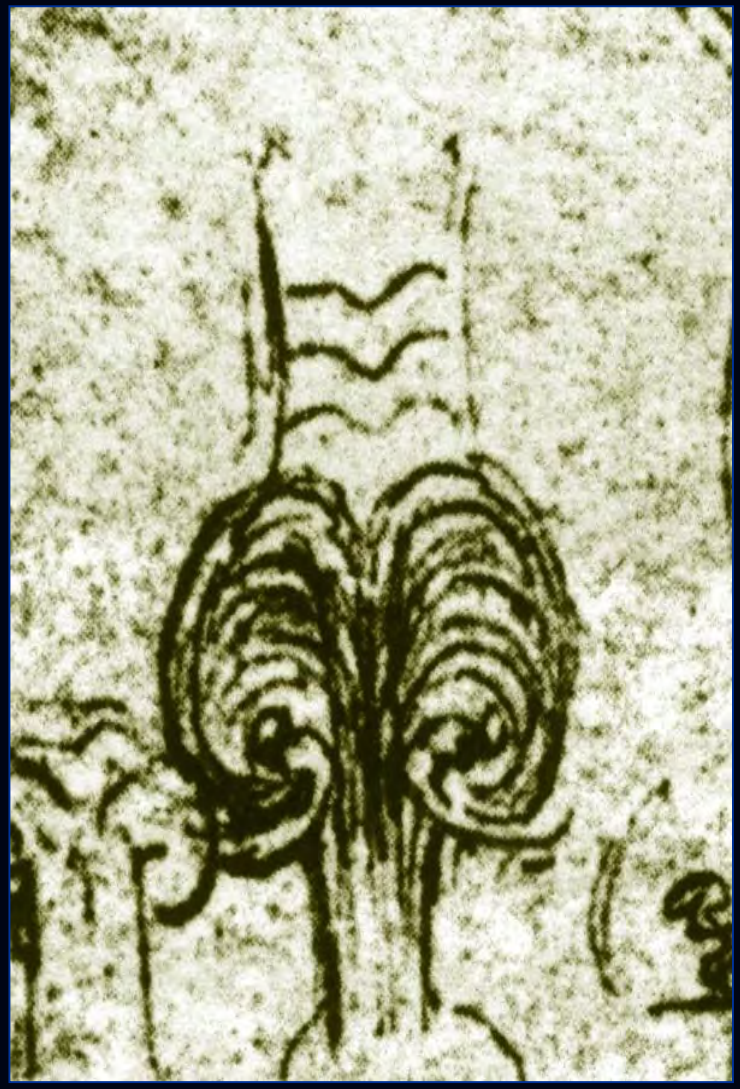
"…jnpari tempo qual sara la proporzione delle varie largezze dessa canna"

"…and then curls up and goes back to the entrance door"

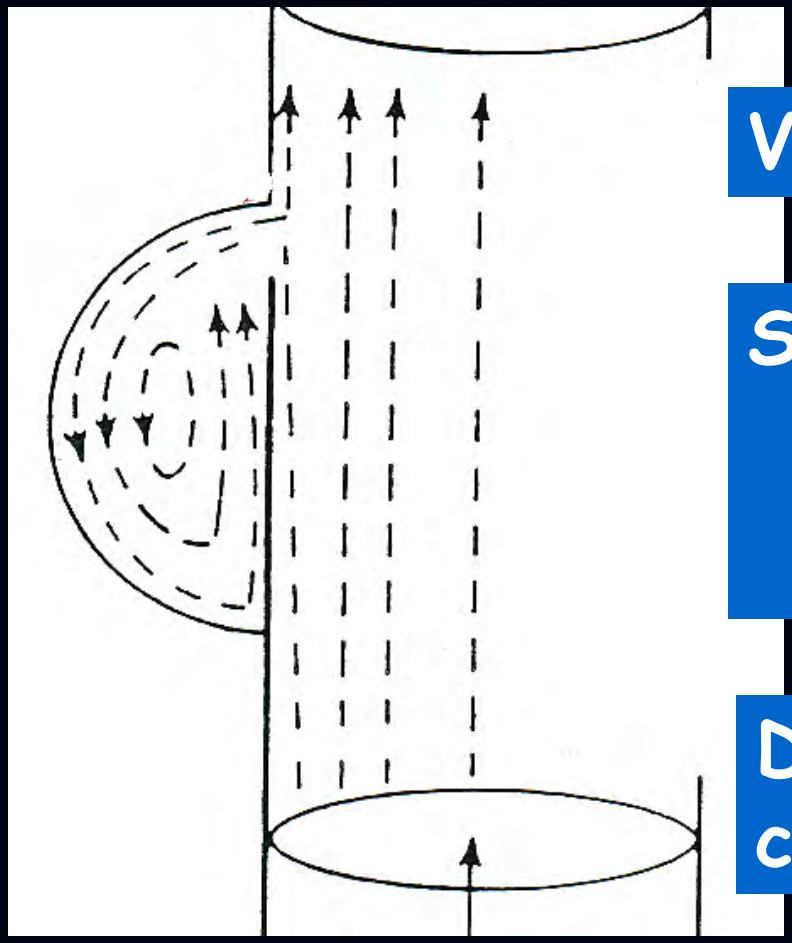
"…e poi si rivolta insu con moto refresso e ritorna alla porta del suo primo introito"

"the propulsion that remain in the blood closes the valve"

"limpeto che riman nel sangue serra lusciolo"



First experiment in the modern era



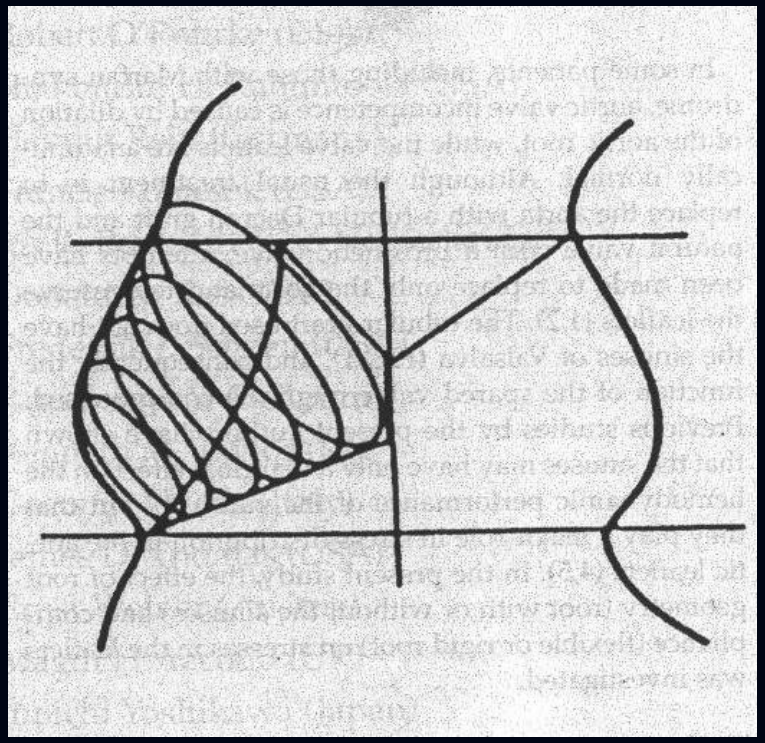
Vortex generation

Systole: to prevent the cusp from impacting the aortic wall

Diastole: smooth leaflet closure

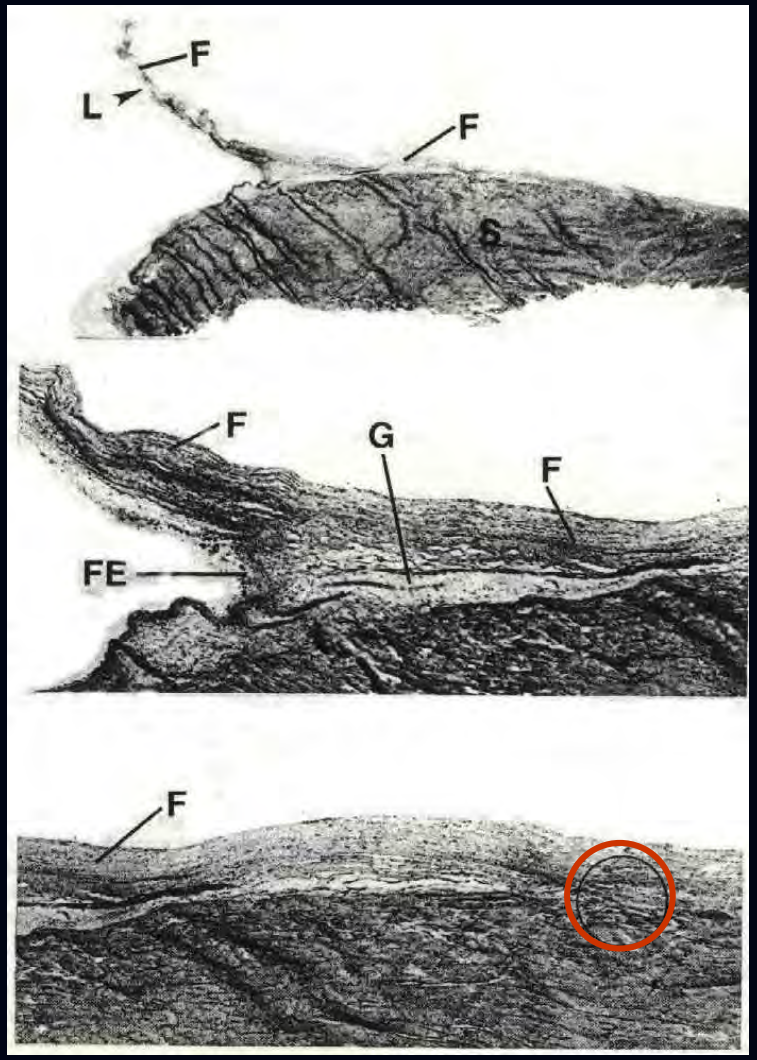
Bellhouse and Reid. Fluid mechanics of the aortc valve. 1969

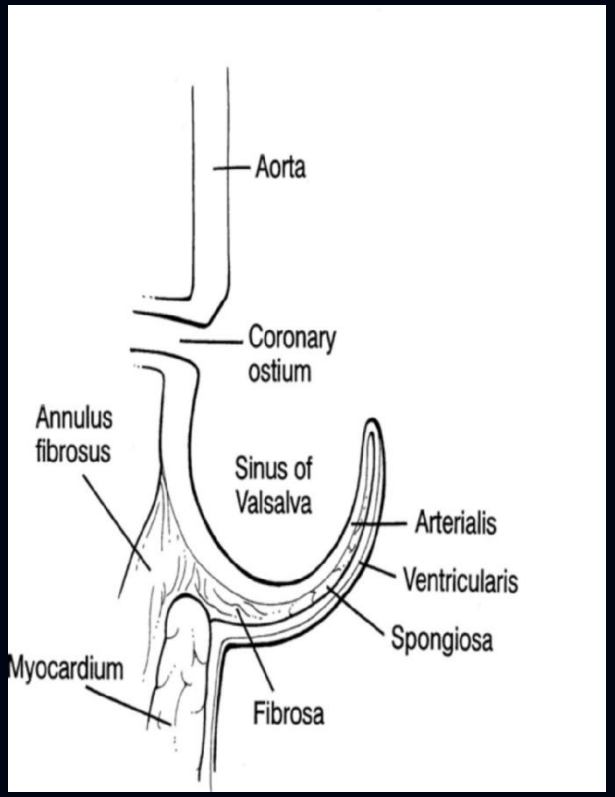
2. Geometry



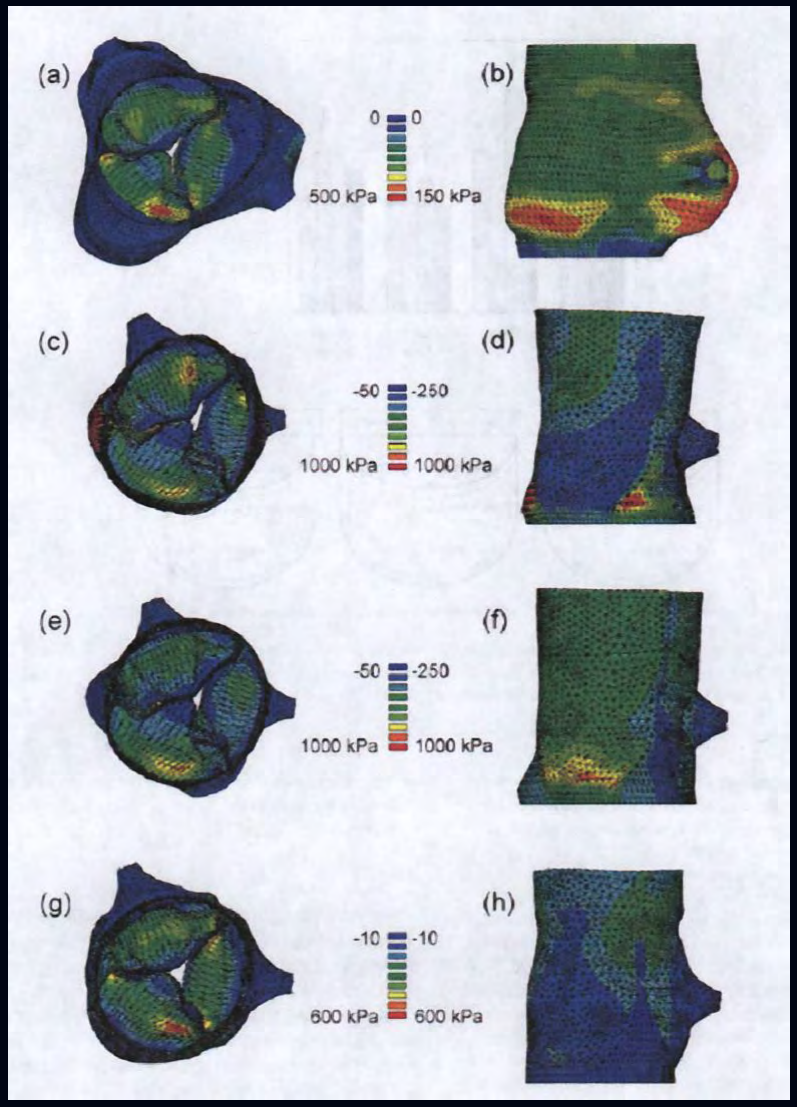
Thubrikar MJ, Nolan SP et al.
Ann Thorac Surg 1986

3. Hystology


F
L
F
S
F
G
F
FE
F


Aorta
Coronary ostium
Annulus fibrosus
Sinus of Valsalva
Arterialis
Ventricularis
Spongiosa
Myocardium
Fibrosa

4. Studies on stress



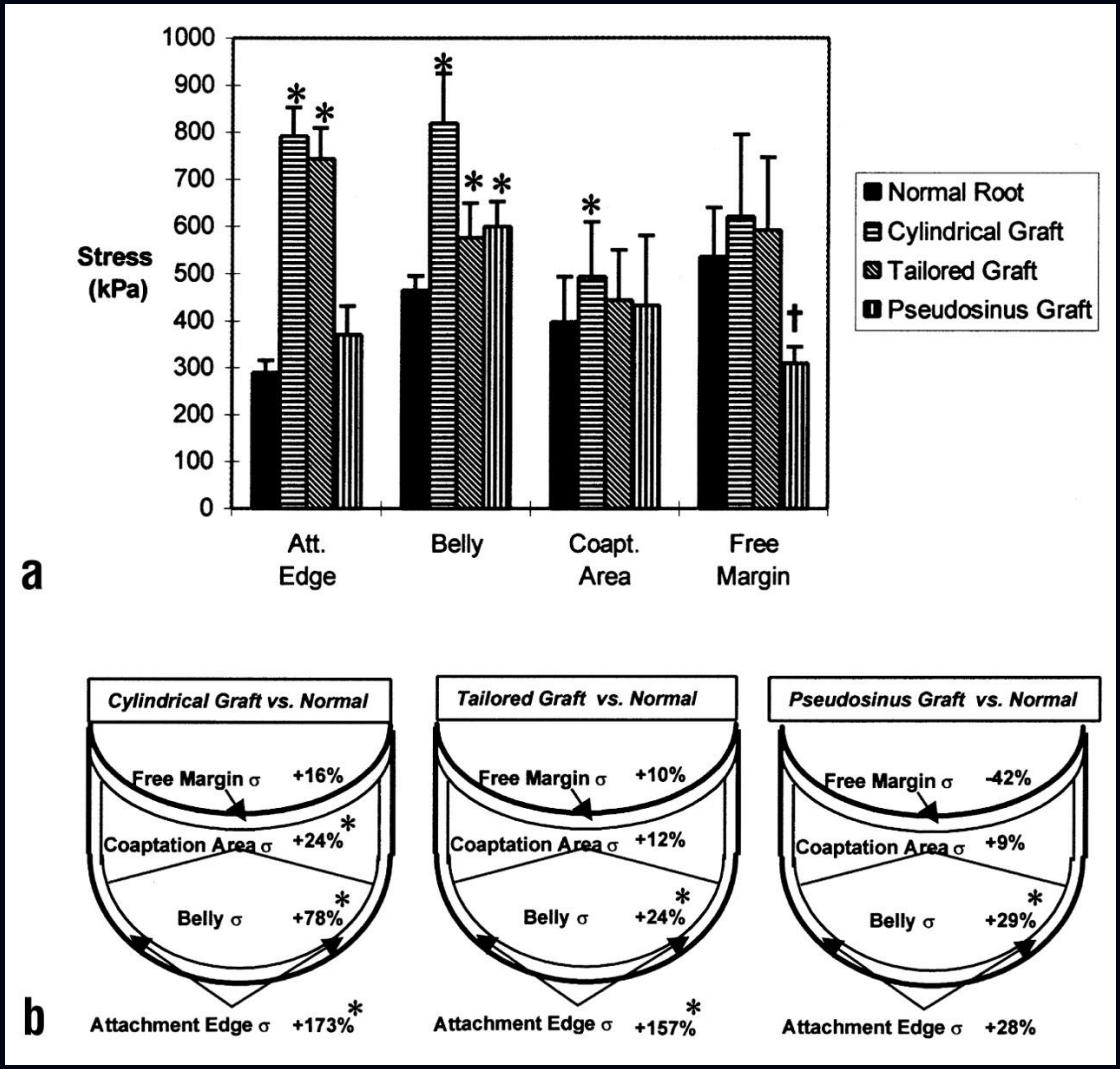
Normal root

David operation

Yacoub operation

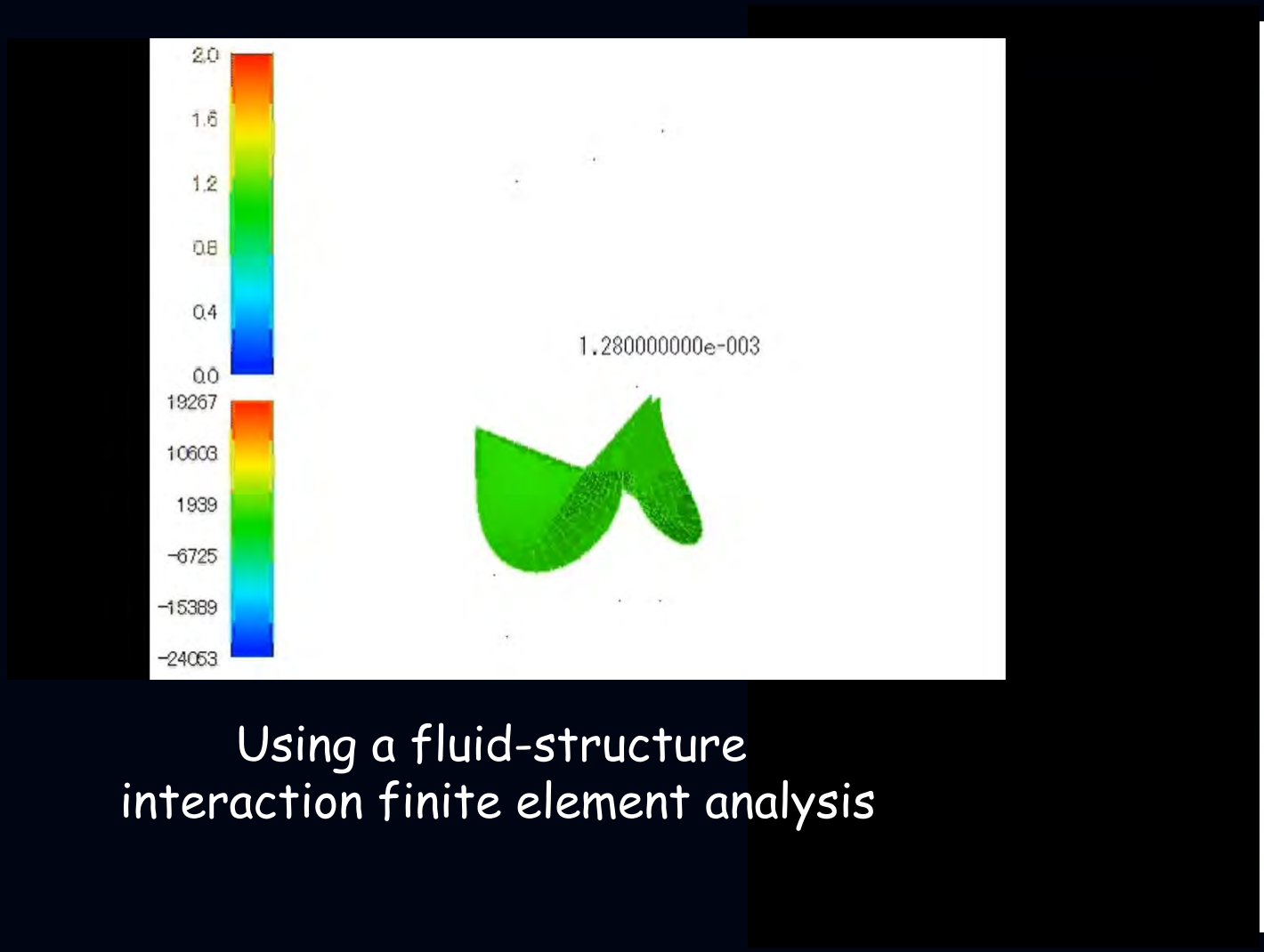
Pseudosinus modification

Studies on stress



Grande-Allen K. J. et al.; J Thorac Cardiovasc Surg 2000;119:753-762

The sinus of Valsalva relieves abnormal stress on leaflets by facilitating smooth closure

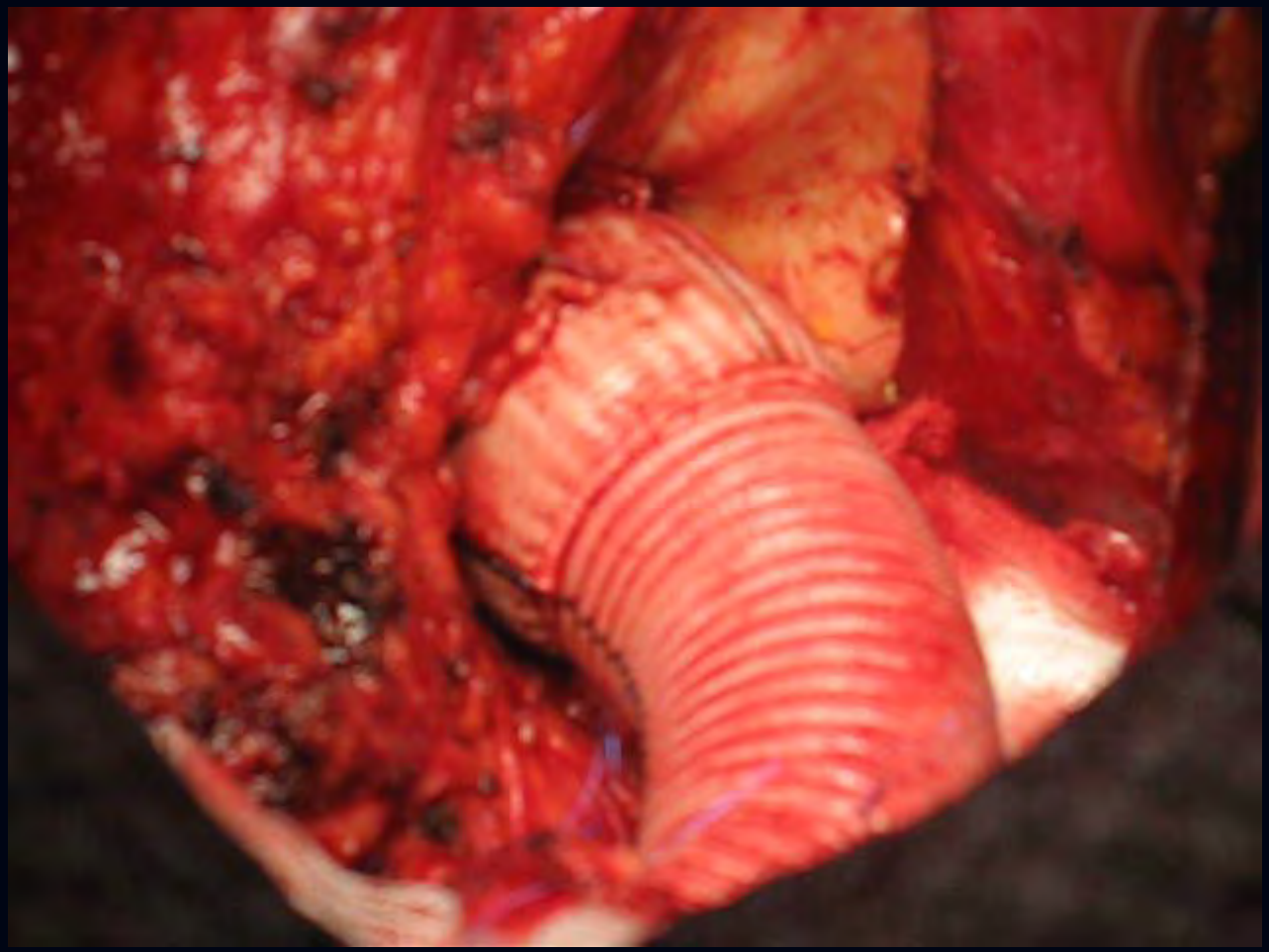


Using a fluid-structure interaction finite element analysis

Katayama S. et al.; J Thorac Cardiovasc Surg 2008;136:1528-1535

The Journal of THORACIC AND CARDIOVASCULAR SURGERY

The reduced stress on coronary anastomoses



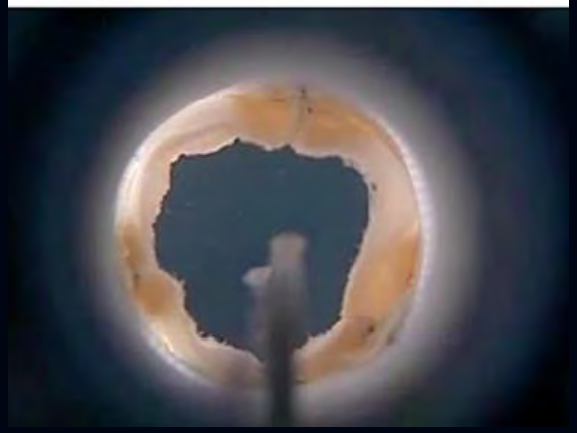
5. In vivo endoscopic view

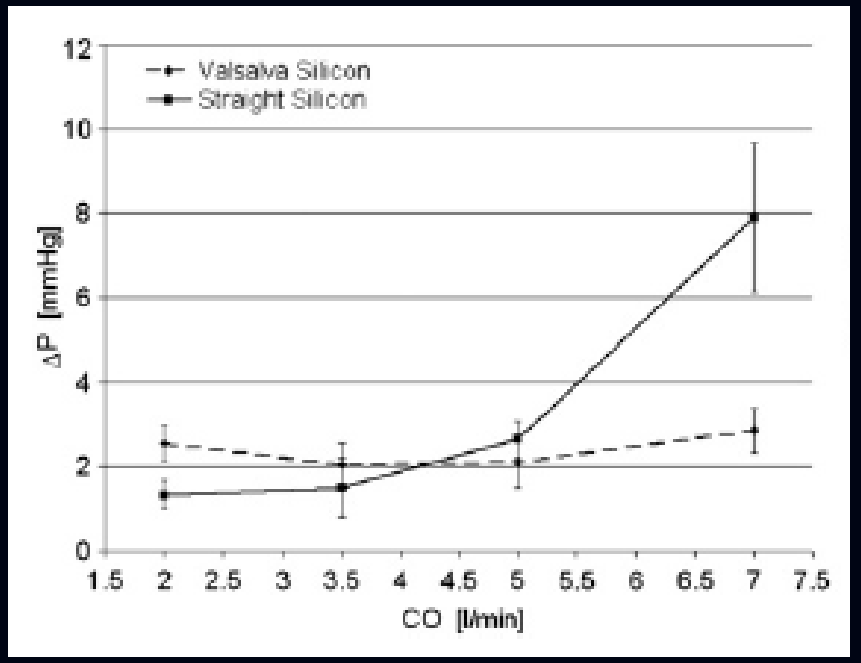
Without Valsalva sinuses

With Valsalva sinuses

De Paulis, Leiden 2002

6. Bench experiments





Role of the sinuses of Valsalva on the opening of the aortic valve

Giuseppe Pisani, MS,[a] Raffaele Scaffa, MD,[b] Ornella Ieropoli, PhD,[c] Edoardo M. Dell'Amico, MS,[c] Daniele Maselli, MD,[b] Umberto Morbiducci, PhD,[a] and Ruggero De Paulis, MD[b]

European Journal of Cardio-Thoracic Surgery 49 (2016) 1222-1227

The combined role of sinuses of Valsalva and flow pulsatility improves

Andrea Salica*, Giuseppe
Alberto Audenino*,

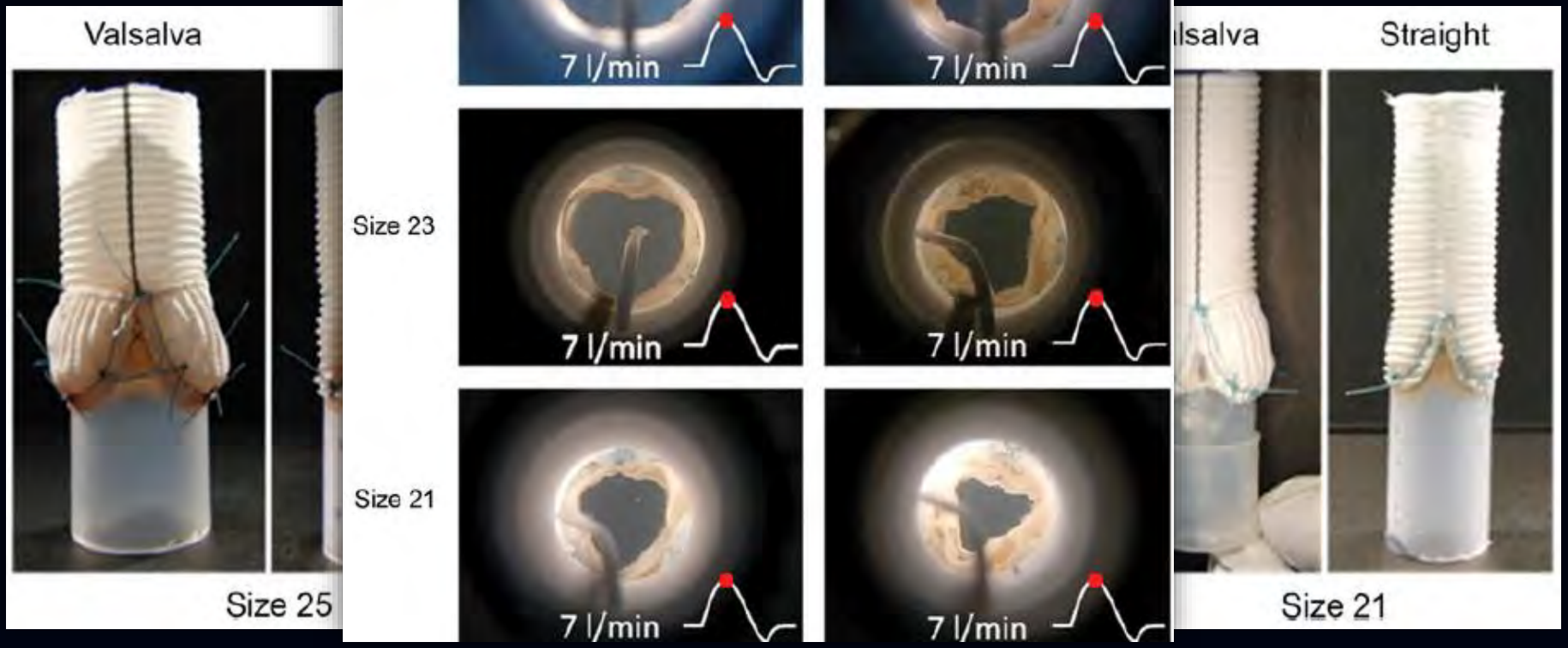


Figure 1: Experimental root configurations for valve size 25, 23 and 21 mm.

The combined role of sinuses of Valsalva and flow pulsatility improves energy loss of the aortic valve

Andrea Salica[a], Giuseppe Pisani[b], Umberto Morbiducci[b], Raffaele Scaffa[a], Diana Massai[b], Alberto Audenino[b], Luca Weltert[a], Lorenzo Guerrieri Wolf[a] and Ruggero De Paulis[a,*]

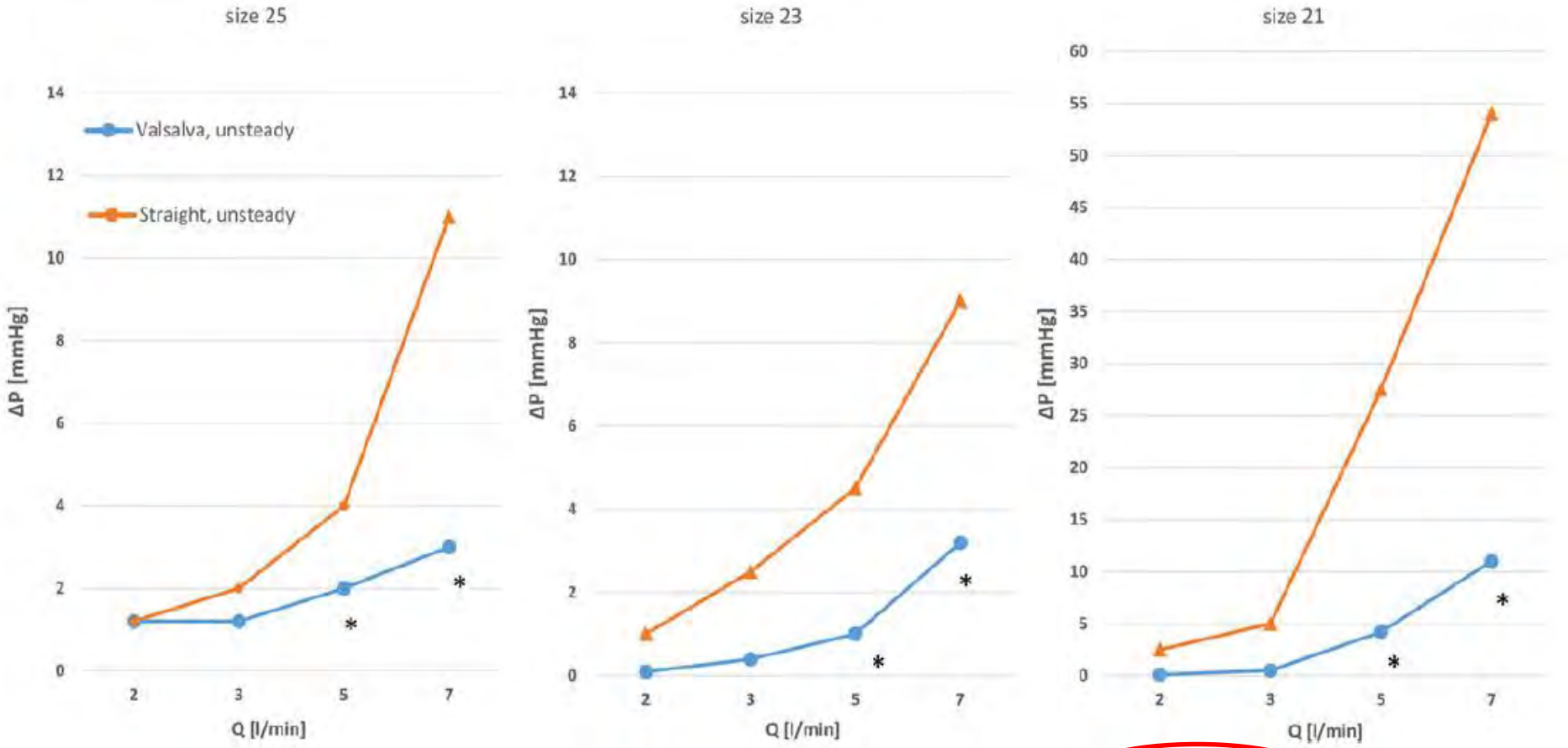
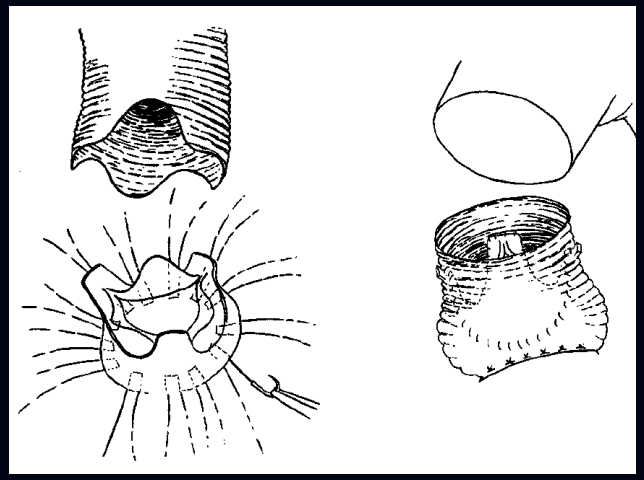


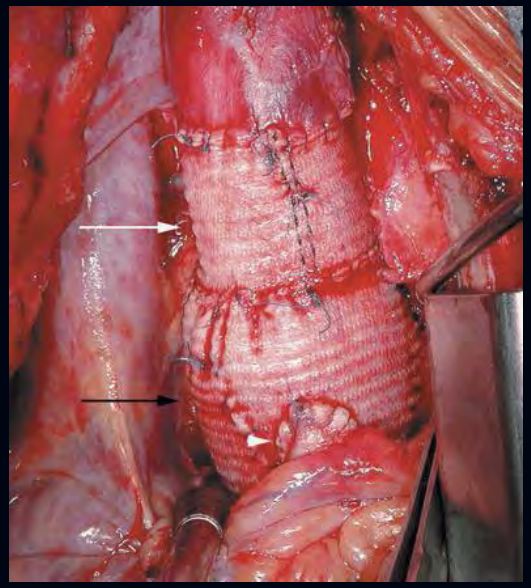
Figure 3: Pressure drops (Δp, mmHg) as measured in the two aortic root configurations for the three valve size in pulsatile flow regimes at different cardiac outputs. *$P < 0.001$.

European Journal of Cardio-Thoracic Surgery 49 (2016) 1222–1227

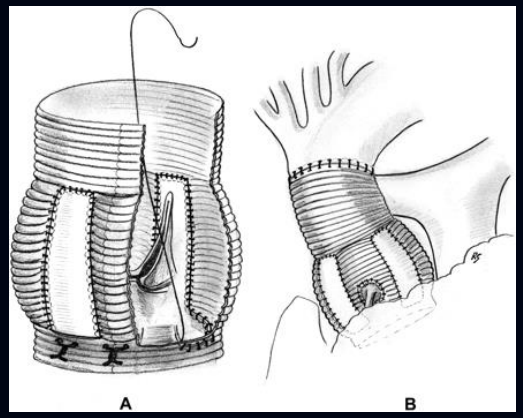
7. Various surgical modifications



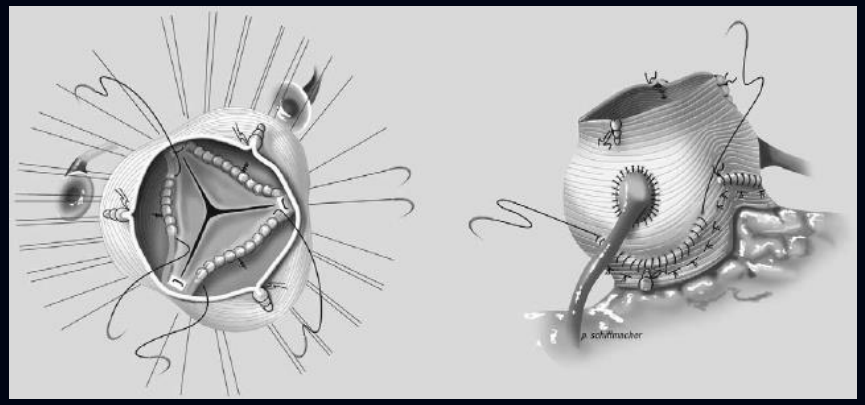
Cochran RP 1995



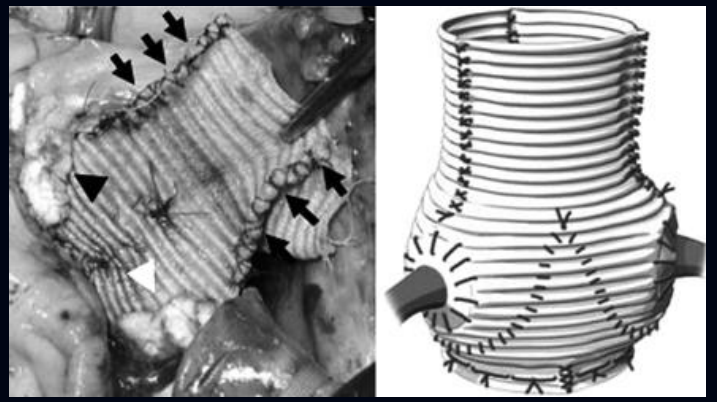
David V or Miller I 2005



Rama 2007



Gleason TJ 2005



Takamoto 2006

EDITORIAL COMMENTARY

Back to David I

Tirone E. David, MD[*,†]

In this issue of the *Seminars*, Mignosa and colleagues from the University of Catania, Italy, present an echocardiographic study on hemodynamics of the aortic valve at rest and exercise after reimplantation of the aortic valve into a cylindrical graft. Pertinent echocardiographic parameters of 13 patients who had reimplantation of the aortic valve more than 5 years ago were compared with those of 9 healthy individuals. Expectedly the mean and peak systolic gradients increased during exercise and were statistically higher than the values of healthy individuals but not clinically relevant. The mean systolic gradients were 6.1 ± 2.2 mm Hg and the maximum during the exercise increased to 13.2 ± 5.1 mm Hg. The aortic valve orifice area did not change during the exercise (3.1 ± 0.3 to 2.8 ± 0.8 cm^2, $P = 0.44$) whereas it did in normal individuals (3.0 ± 0.3 up to 4.0 ± 0.5 cm^2). As stated by the authors the sample size was small but the mean of the variables measured had small standard deviations of the means, suggesting fairly consistent results across the 13 patients, including 4 who had bicuspid aortic valves.

D'Ancona et al[1] from Palermo (not too far from Catania in

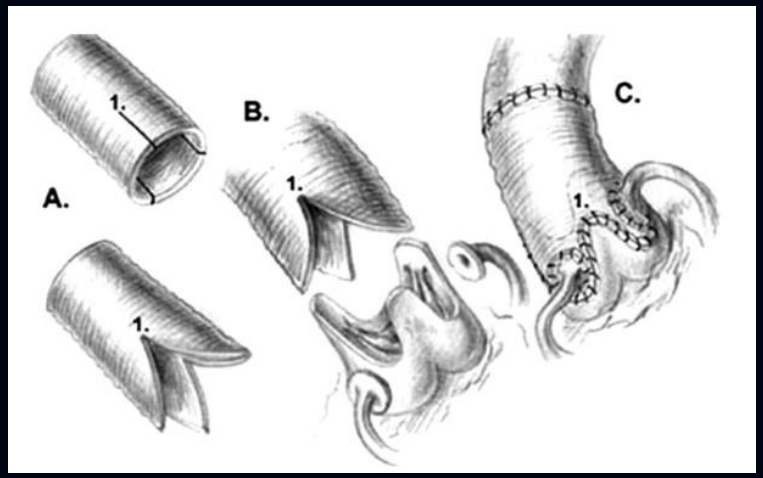
Tirone David, MD

See related article on pages 257–263.

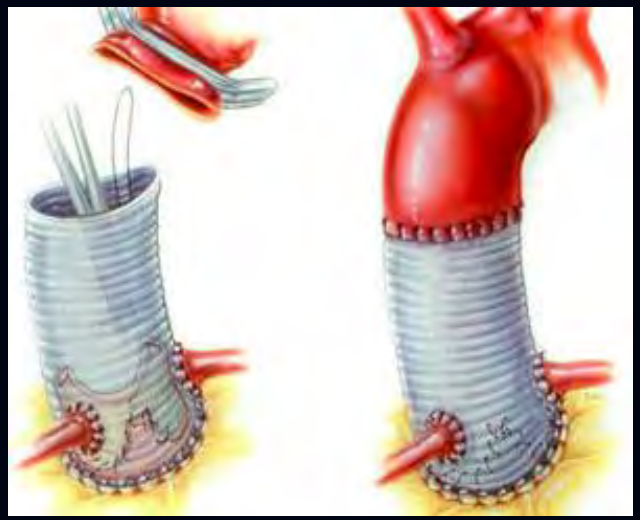
Christopher Feindel, one of my associates and coauthor of the original description of aortic valve reimplantation,[4] has always used a straight tubular Dacron graft because he does not believe that we should change what works well. After 27 years of performing aortic valve–sparing operations, I have gone "back to David I" because the results in our first 89 patients (mean follow-up of 15 years) showed that only 3 have required reoperation (1 due to endocarditis and 2 because of aortic insufficiency) and the remaining patients had competent aortic valves with mild, if any, aortic insufficiency and an aortic valve orifice that is

The available options

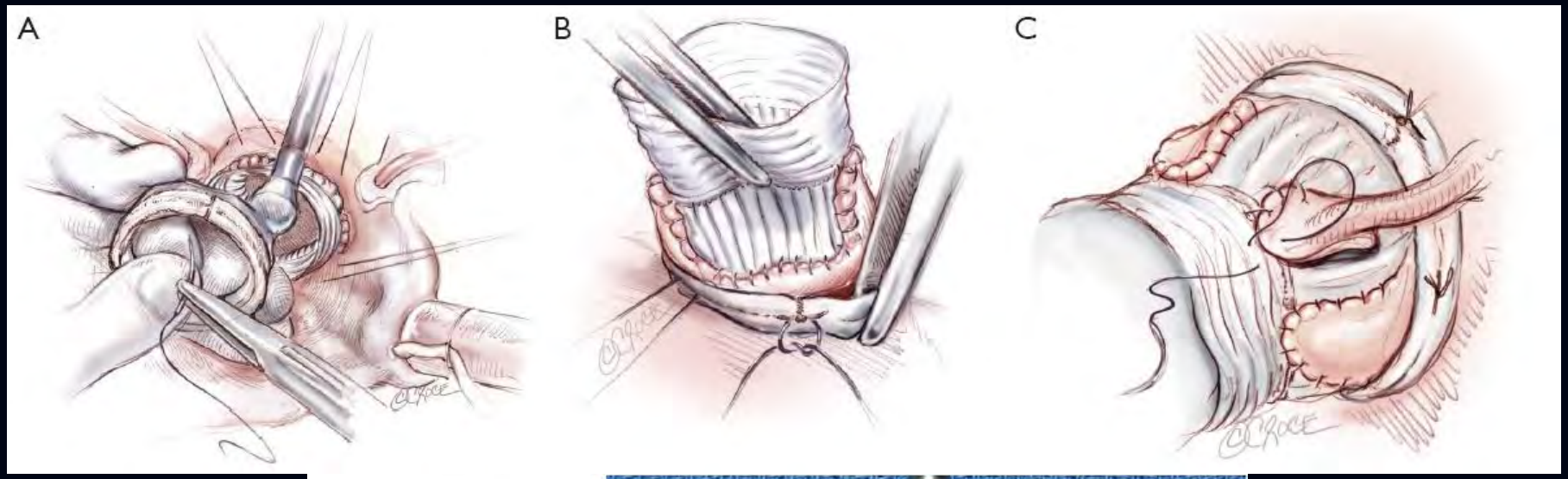
Remodeling

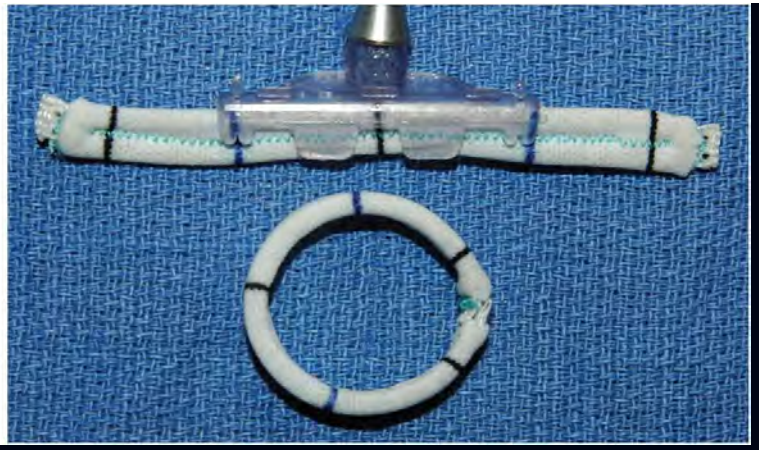


Reimplantation

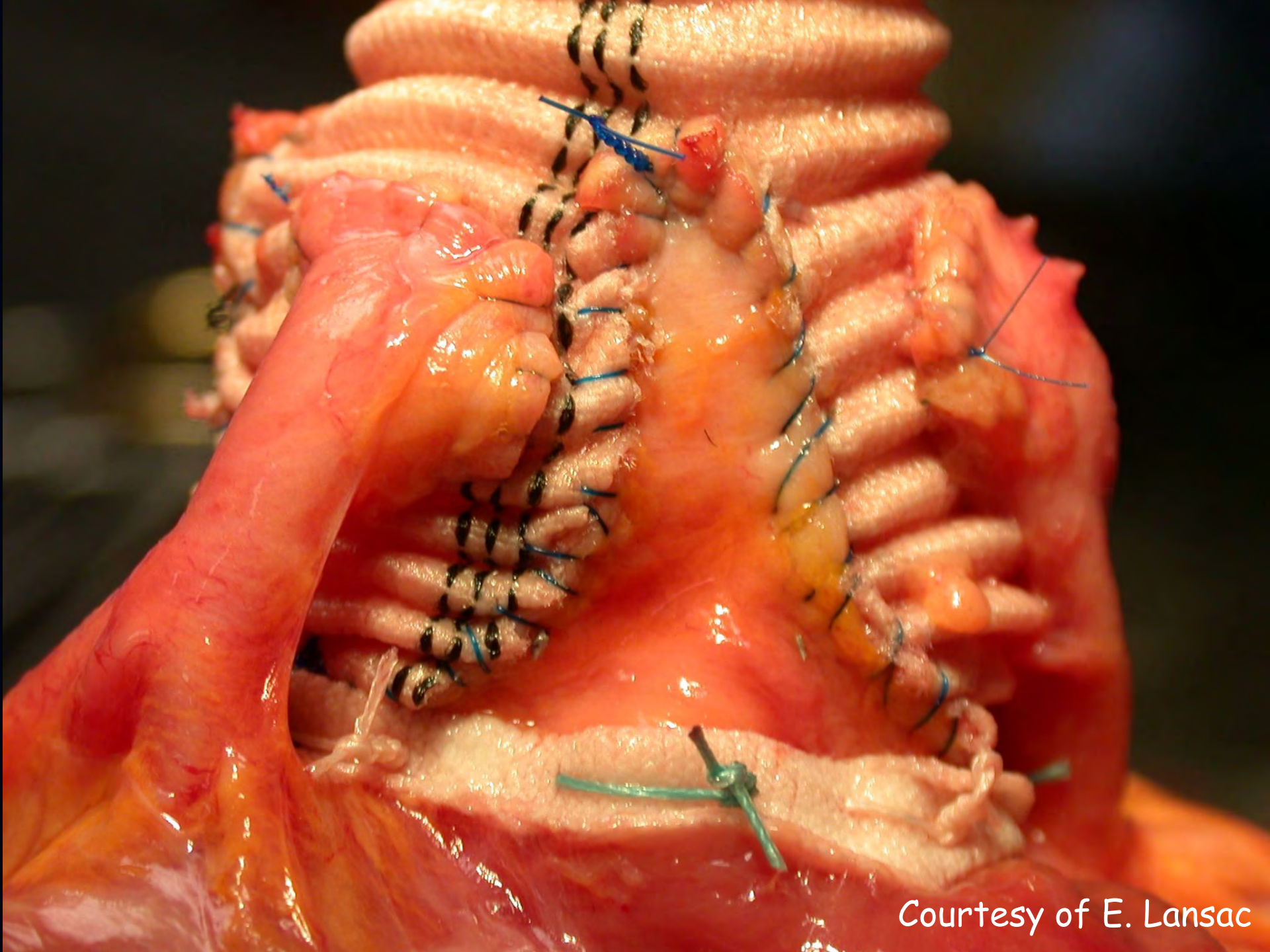


External ring annuloplasty





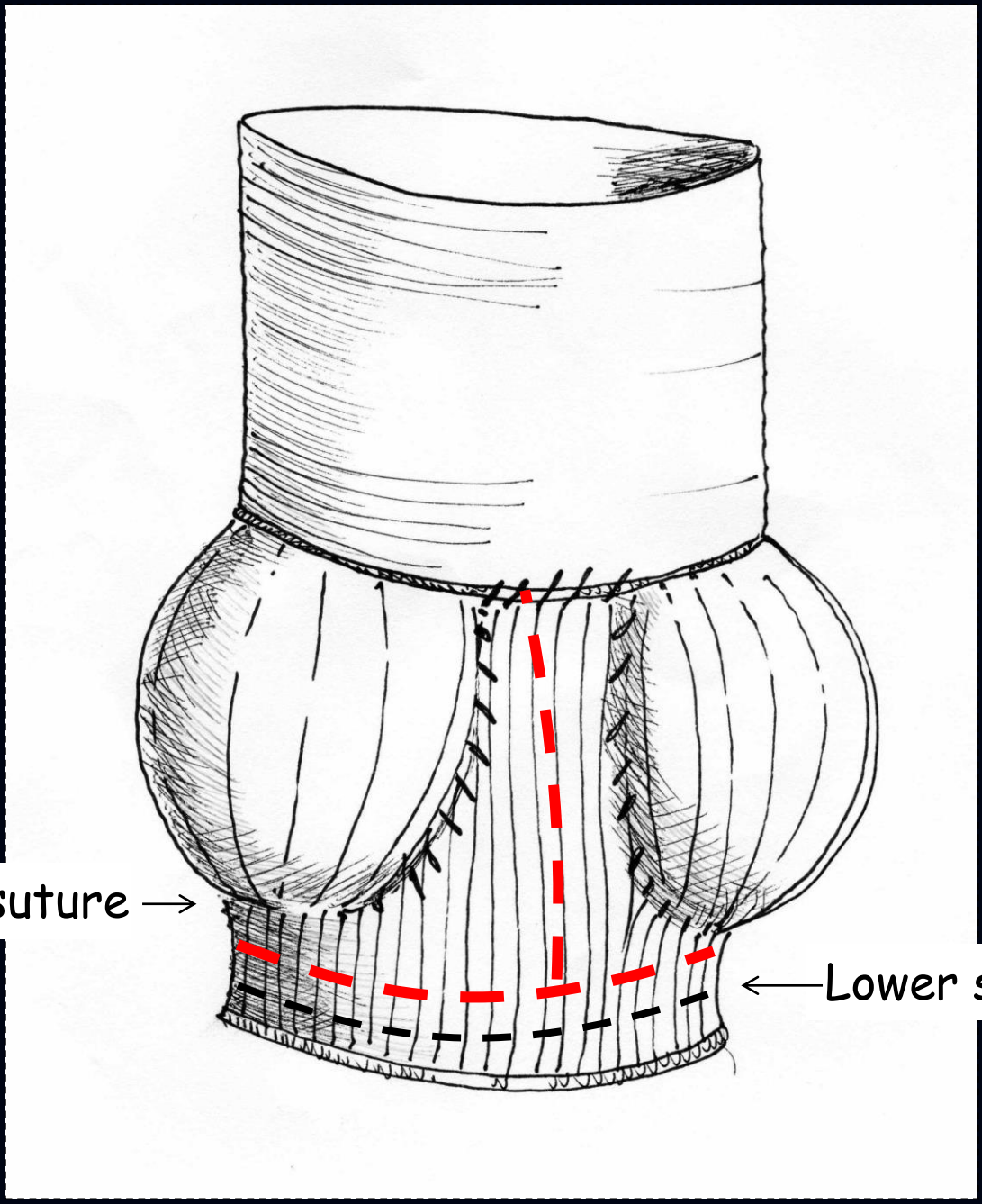
Lansac E et al. Eur J Cardiothorac Surg 2006;29:537-44

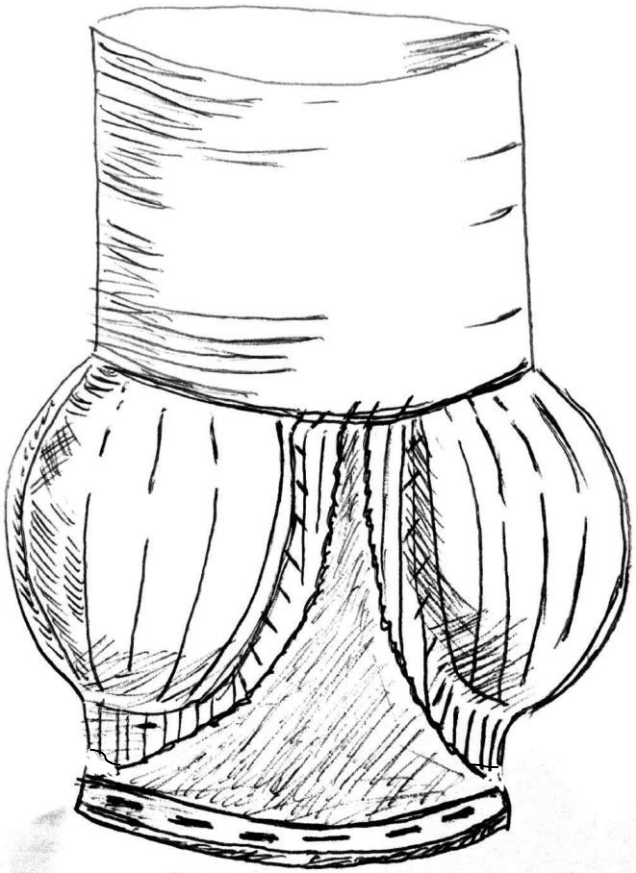

Courtesy of E. Lansac

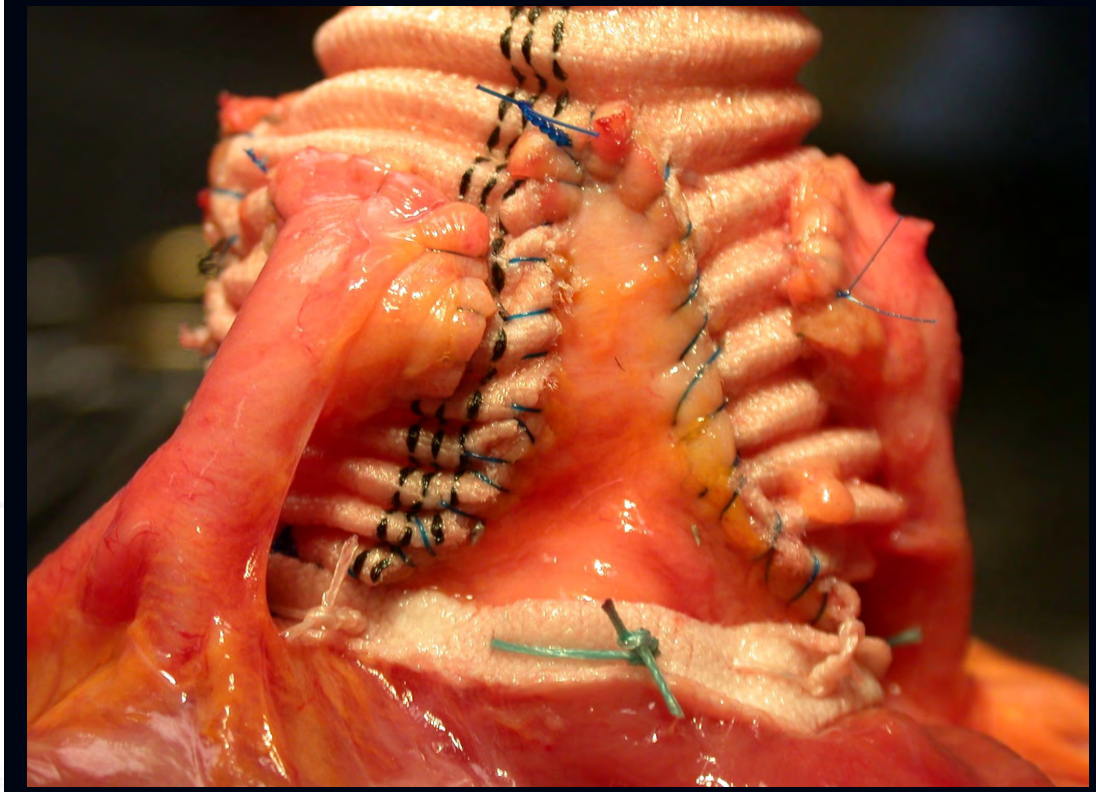
What is really a reimplantation?

A remodeling plus an annuloplasty…

….. without the intrinsic risk of bleeding


Upper suture
Lower suture





My choice for "REIMPLANTATION"

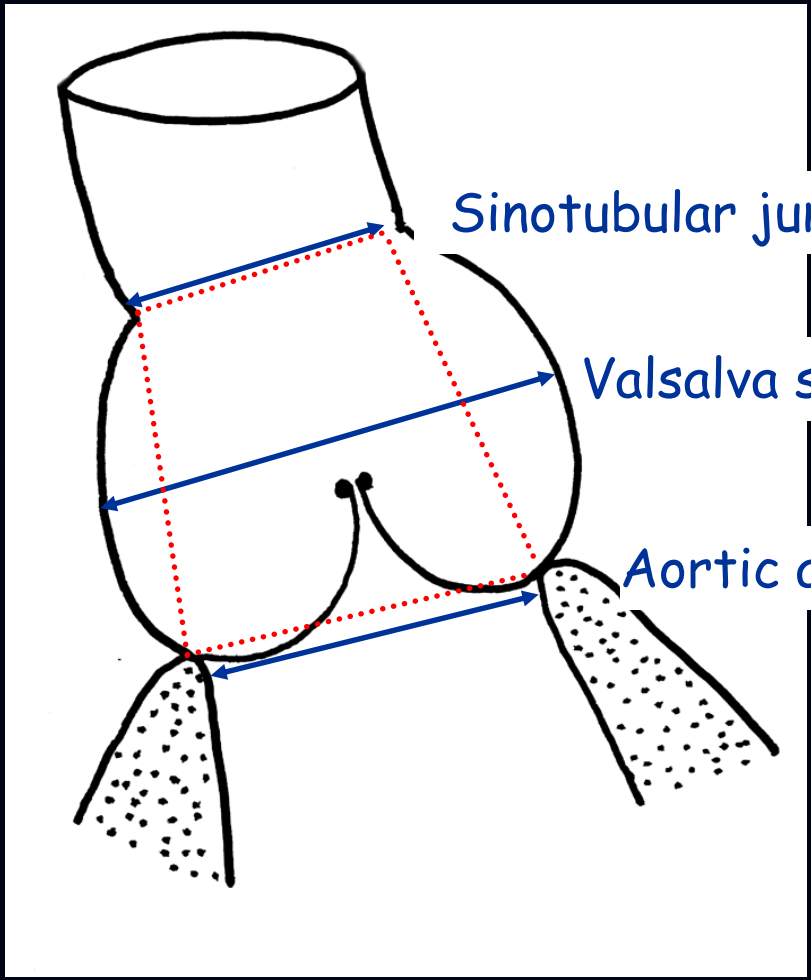
1. Safe and reproducible (no bleeding)
2. Annulus stabilization (long-term results)
3. Good anatomical reconstruction and good leaflet motion (remodeling-like)

Principles to be respected

1. Anatomical root reconstruction
2. Geometrical spatial relationship of the commissures
3. Proportion Root/Leaflets
4. Reduced tension on coronary buttons

Geometry
as
proportion of the various root components

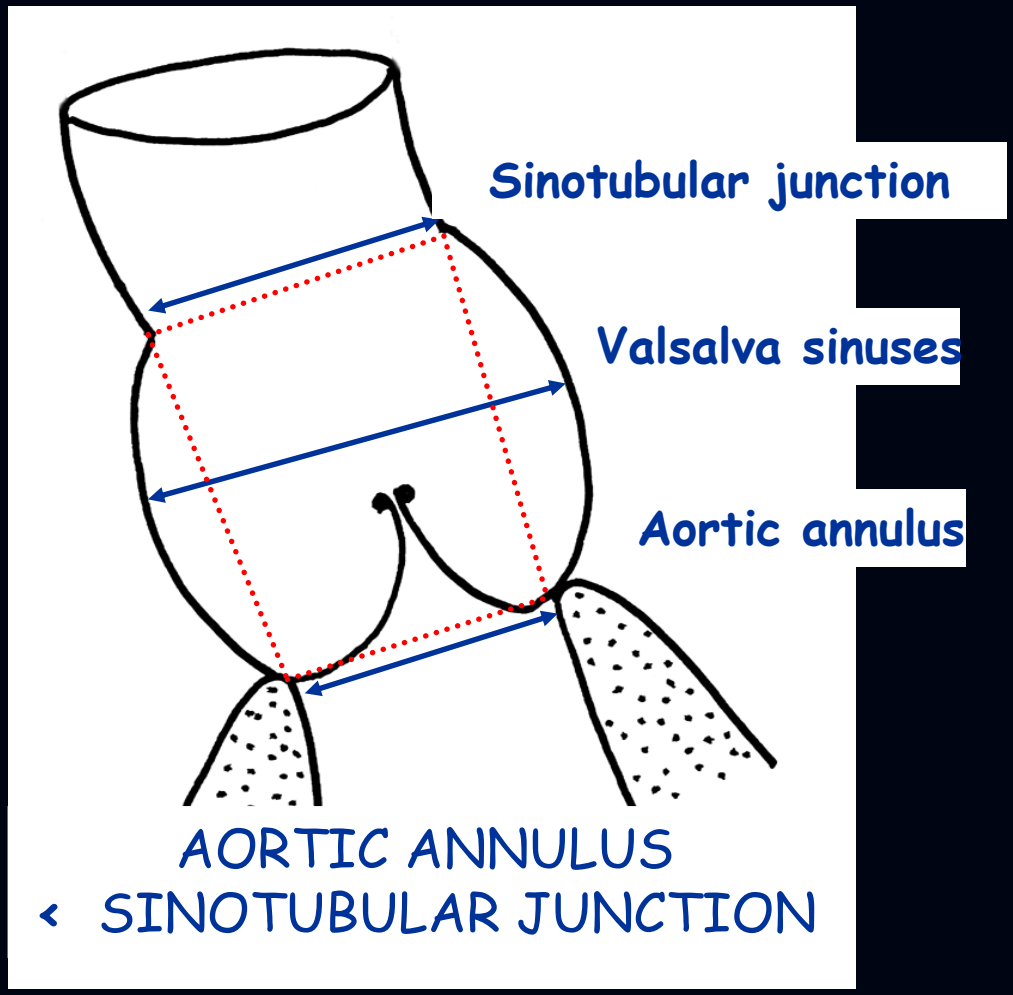
Normal anatomy (nonpressurized)



AORTIC ANNULUS
> SINOTUBULAR JUNCTION
with a 1 to 1.15 ratio

Acar C. 6th Symposium on aortic and mitral reconstructive surgery. Brussels 2006

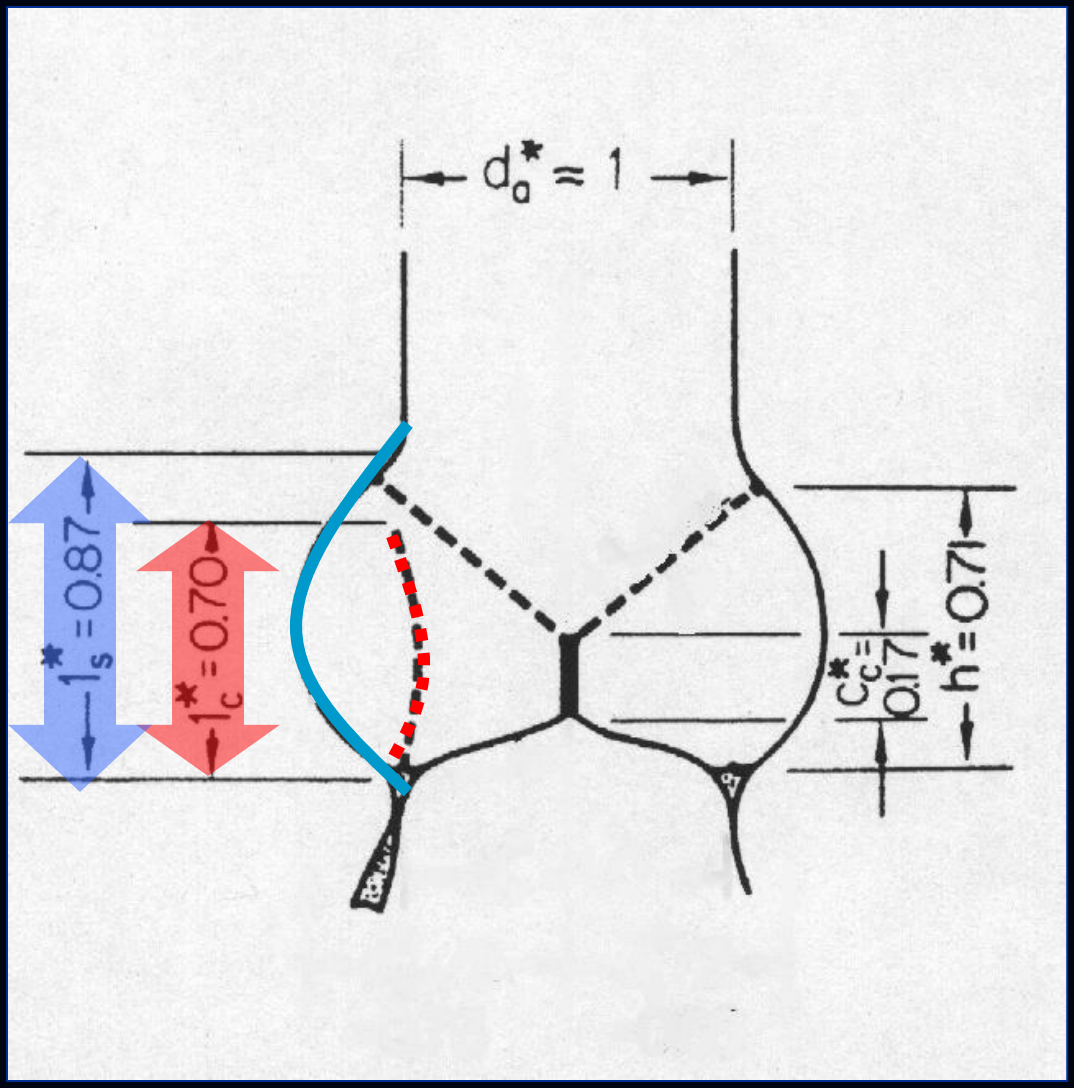
Echocardiographic anatomy

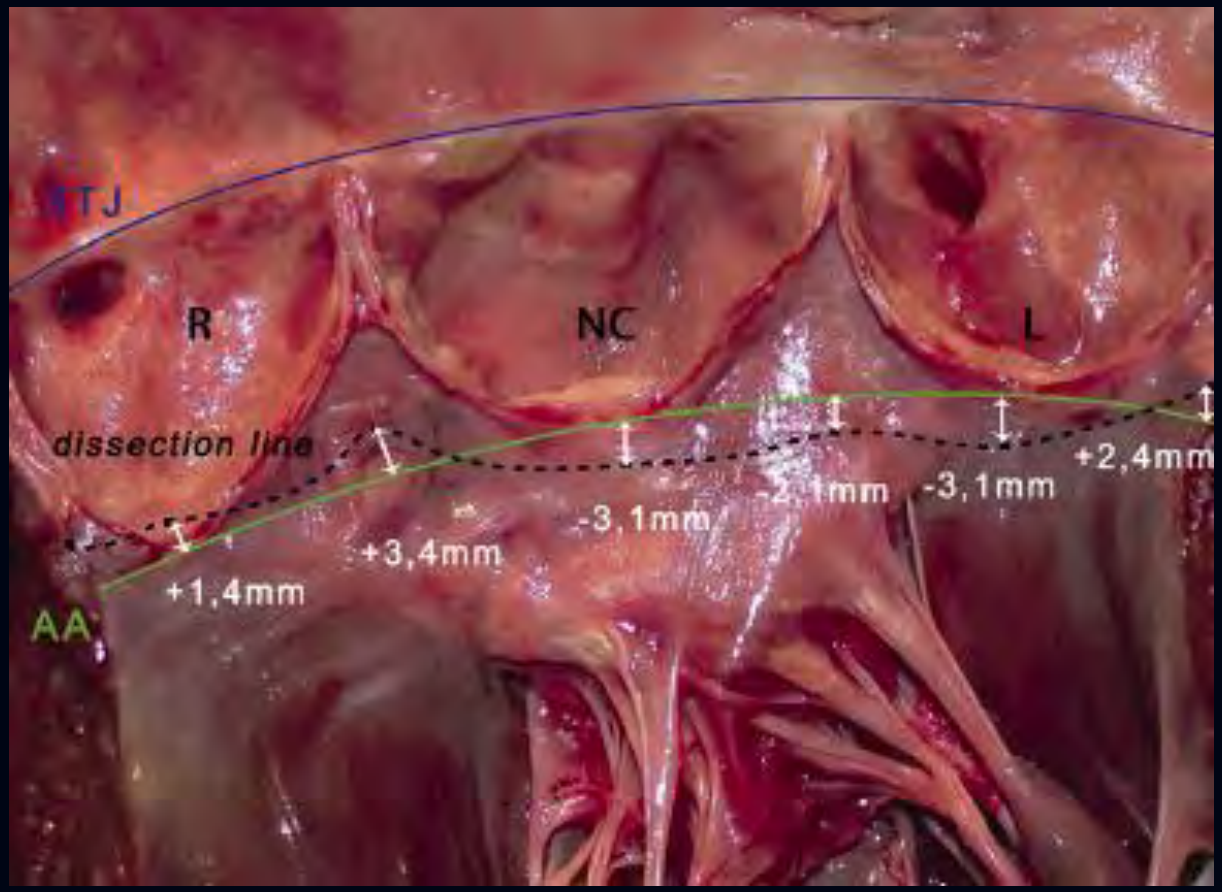


The sinotubular junction is larger than the annulus with a diameter ***ratio of 1.3*** *in a normal adult human heart*

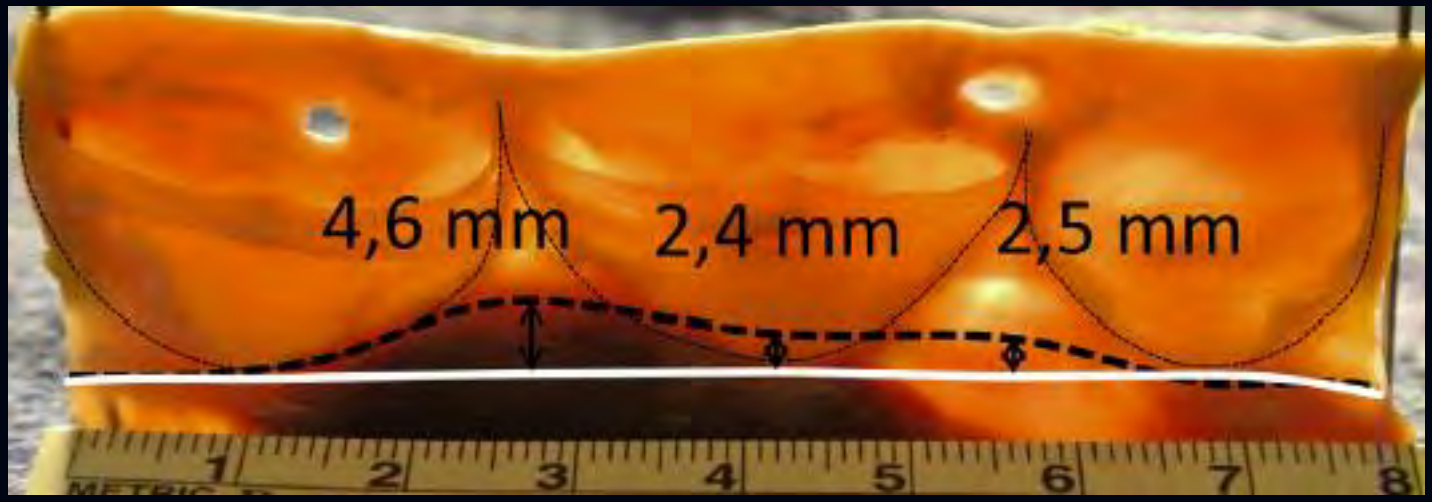
Acar C. 6th Symposium on aortic and mitral reconstructive surgery. Brussels 2006

Normal anatomy (nonpressurized)





Difficulty for a complete root dissection causes a difference in the measurements of the root externally or internally

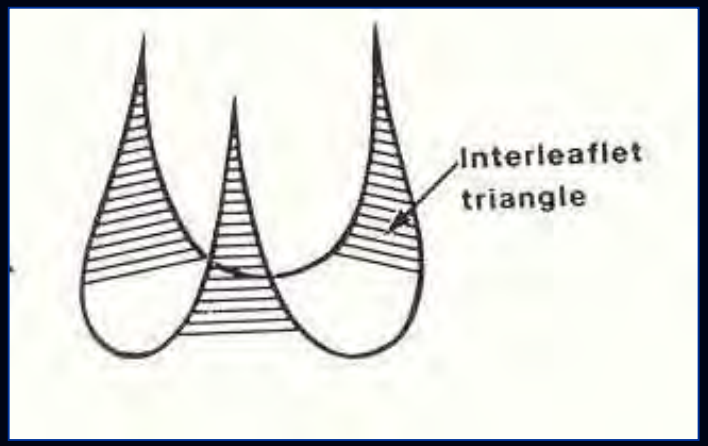


INTERNAL MEASUREMENTS

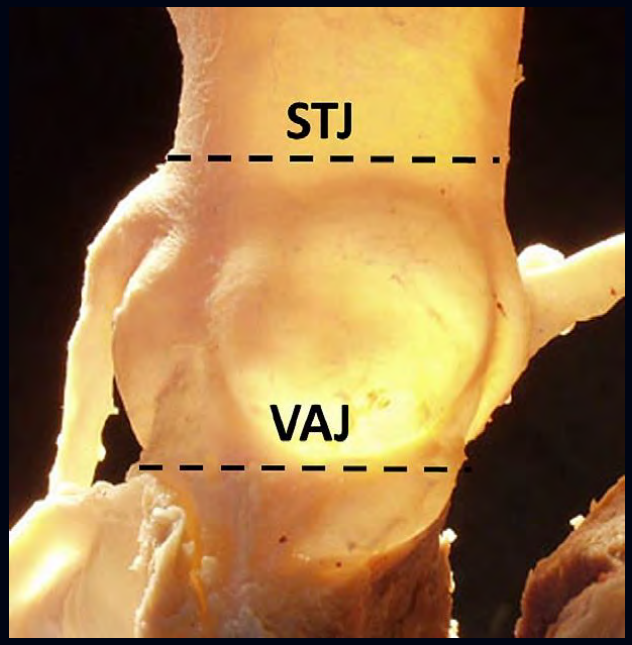
Mean Annulus Diameter 25 mm
Mean Cusps Height 20-21 mm
Mean Interleaflet Length 20-21 mm

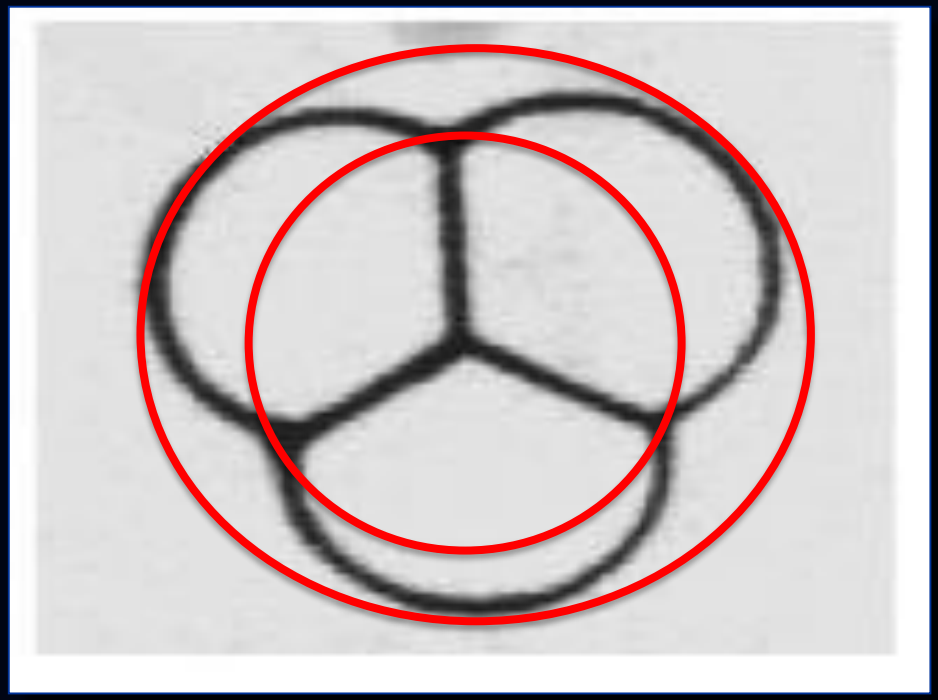
} 80%

NO SIGNIFICANT DIFFERENCES among
the three cusps or
the three interleaflet triangles



Spatial relationship of the commissural posts in respect to the sinuses





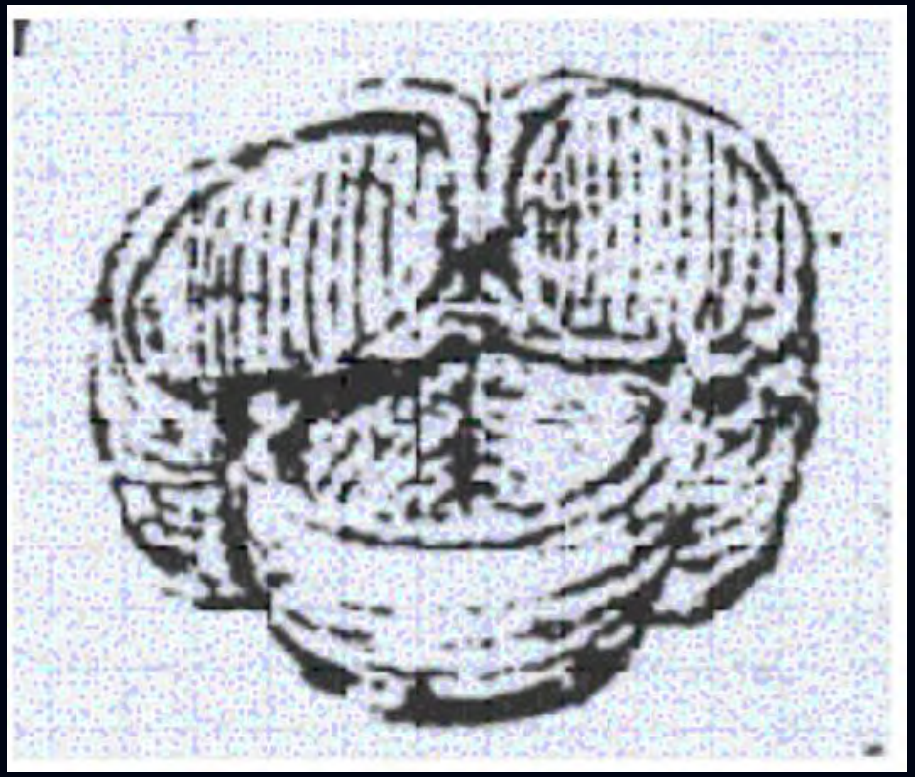
Radius of curvature passing along the commissures

Radius of curvature passing along the sinus edges

Geometry
as
relationship leaflets/root component

Coaptation

".. from the previously closed (aortic) valve-cusps which are not closed with their margin like the other doors but with <u>their sides with great and powerful contact</u>"

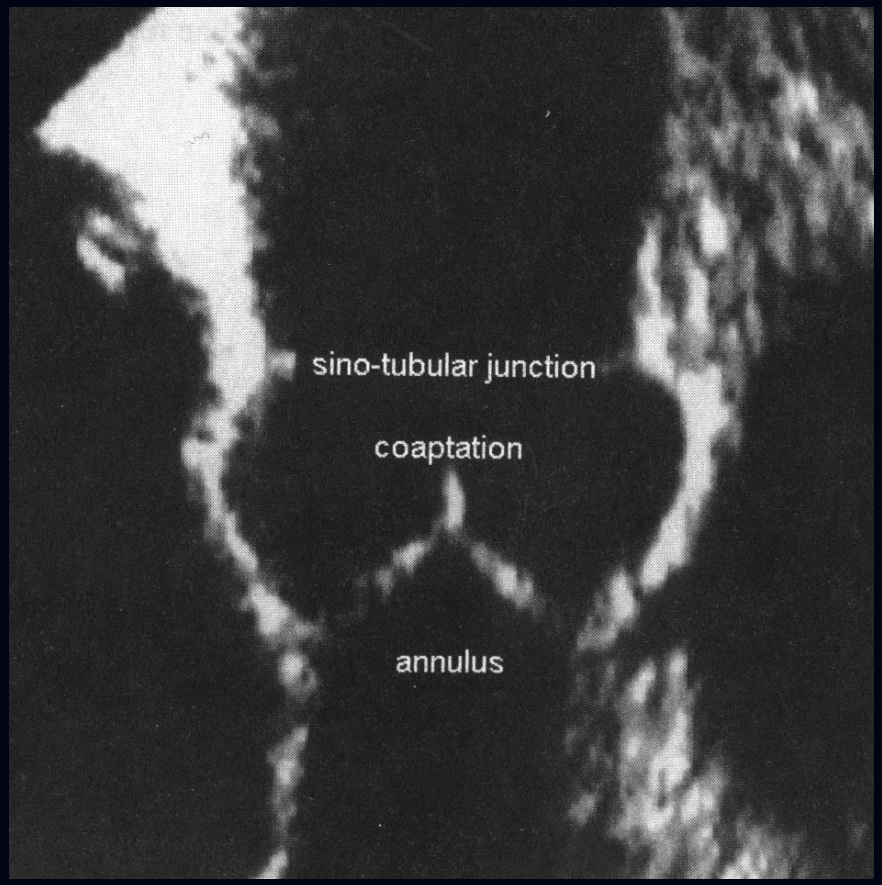


"…delle gia chiuse porte lequali si seran no colle fronte come le altre porte ma cosua lati con gran cotatto e potente"

Aortic cusps coaptation

Level of coaptation inside the root or "Effective height"

Amount of leaflet coaptation or "Coaptation height"

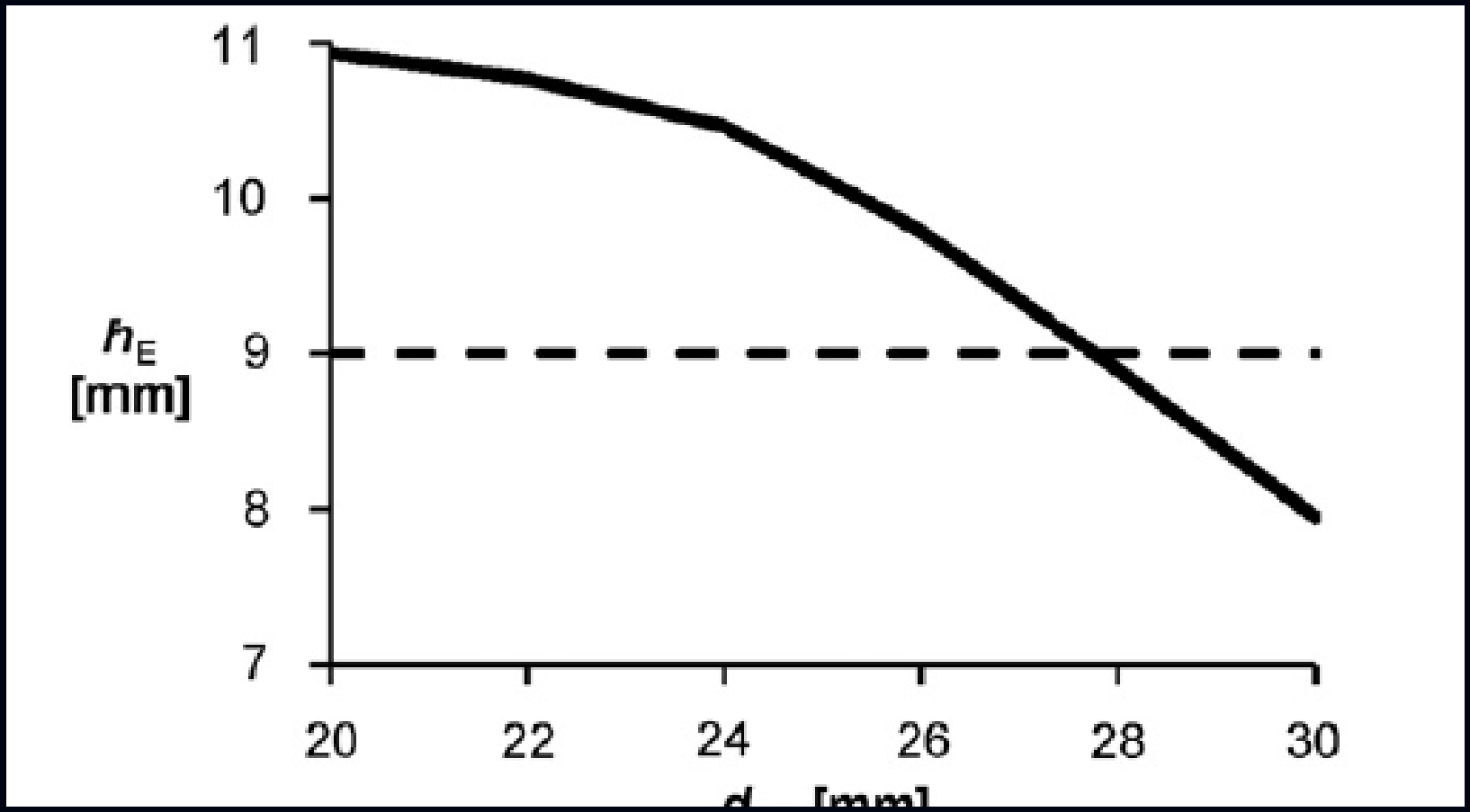


Aortic cusps coaptation

- Depends on the ratio between

- Annulus diameter
- Leaflet size
- Ratio STJ size/leaflet free margin

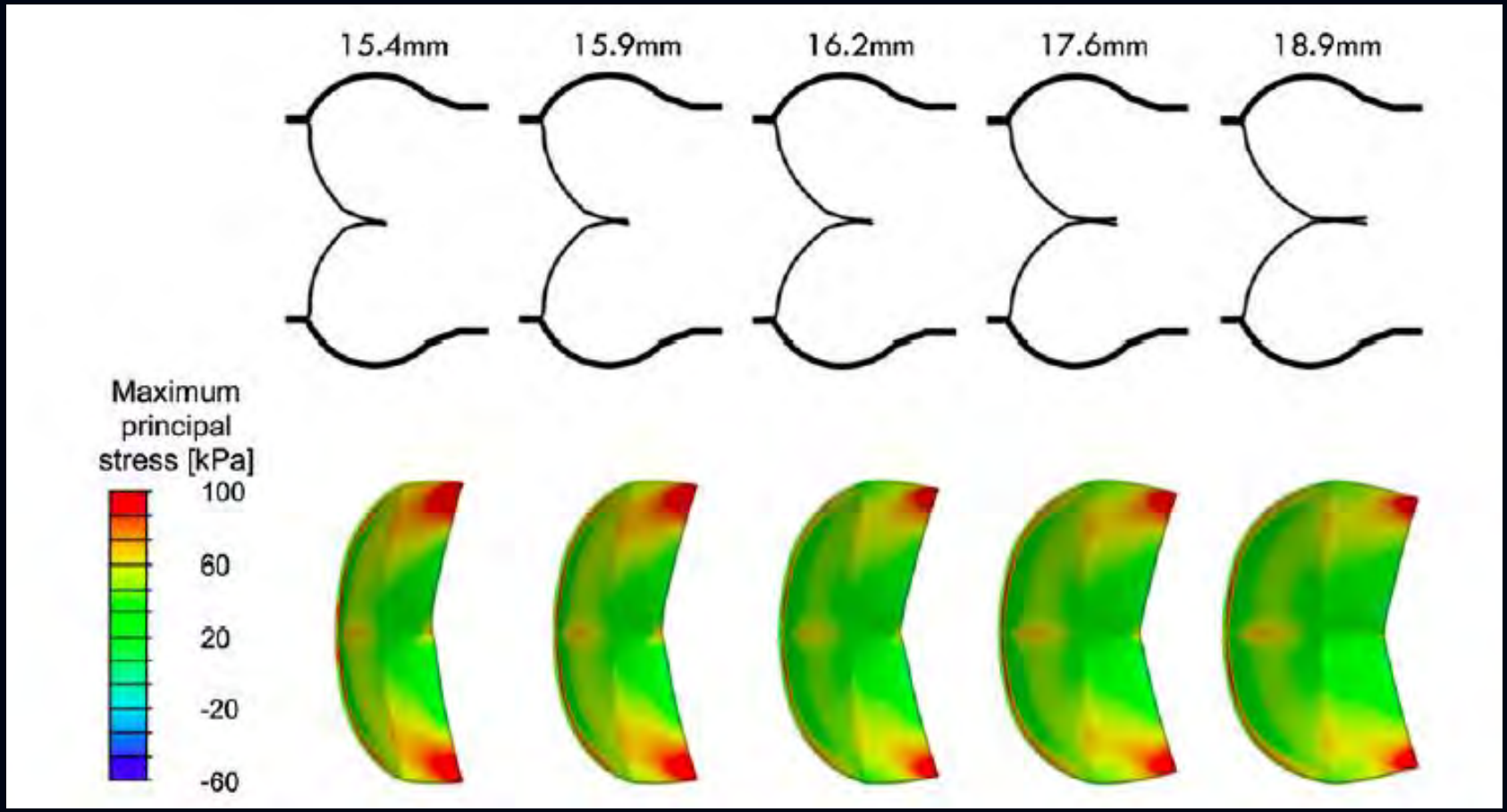
1. Annulus diameter and coaptation



Aortic root numeric model: Annulus diameter prediction of effective height and coaptation in post–aortic valve repair

Marom, Schaefers et al. JTCVS 2013

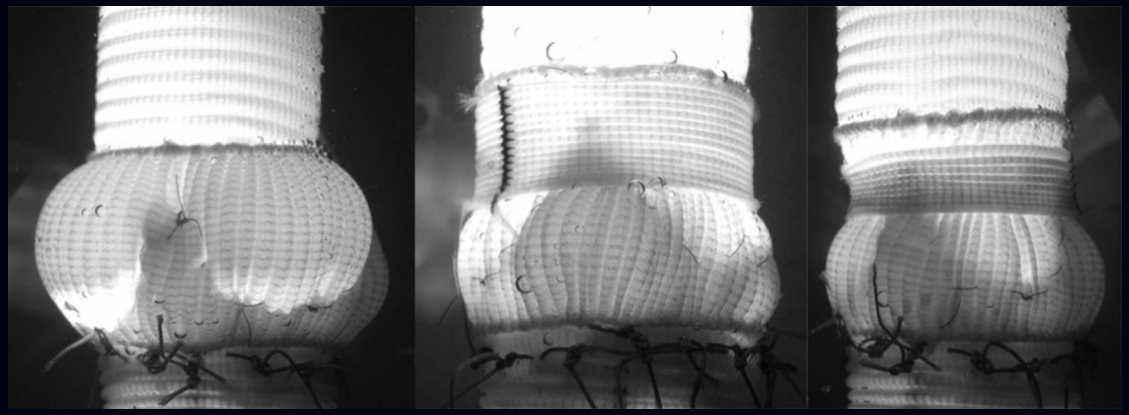
2. Leaflet size and coaptation



Aortic root numeric model: Correlation between intraoperative effective height and diastolic coaptation

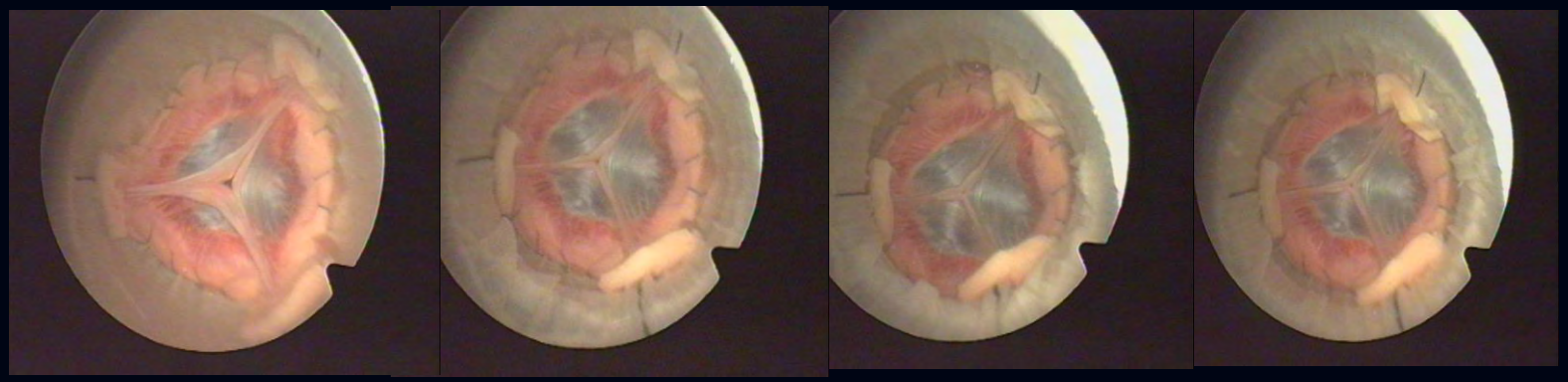
Marom, Schaefers et al. JTCVS 2013

STJ size and coaptation



Decrease both the effective height and height of coaptation

STJ > 32 mm | STJ 32 mm | STJ 30 mm | STJ 28 mm



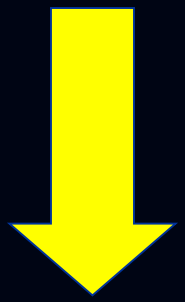
Sinotubular Junction Size Affects Aortic Root Geometry and Aortic Valve Function in the Aortic Valve Reimplantation Procedure: An In Vitro Study

Maselli, De Paulis et al. 2010

Functional geometry

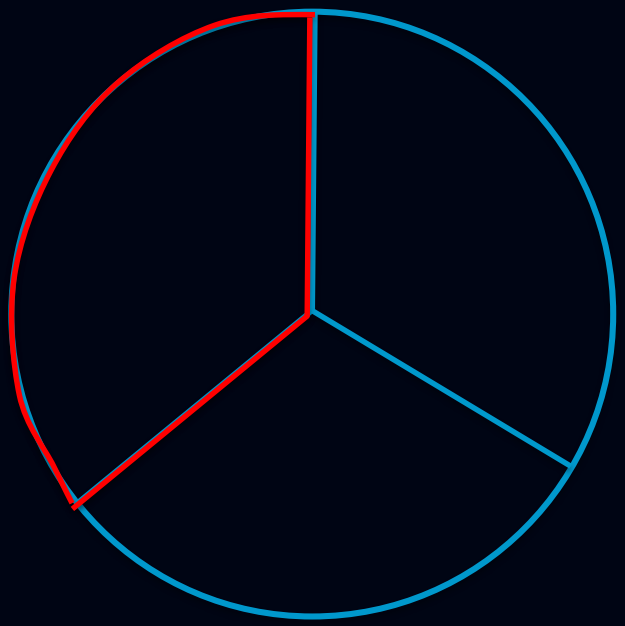
The total length of the free margin

- equal to the circumference
- > to the intercommissural distance



Complete opening in systole
Wrinkle-free leaflet closure

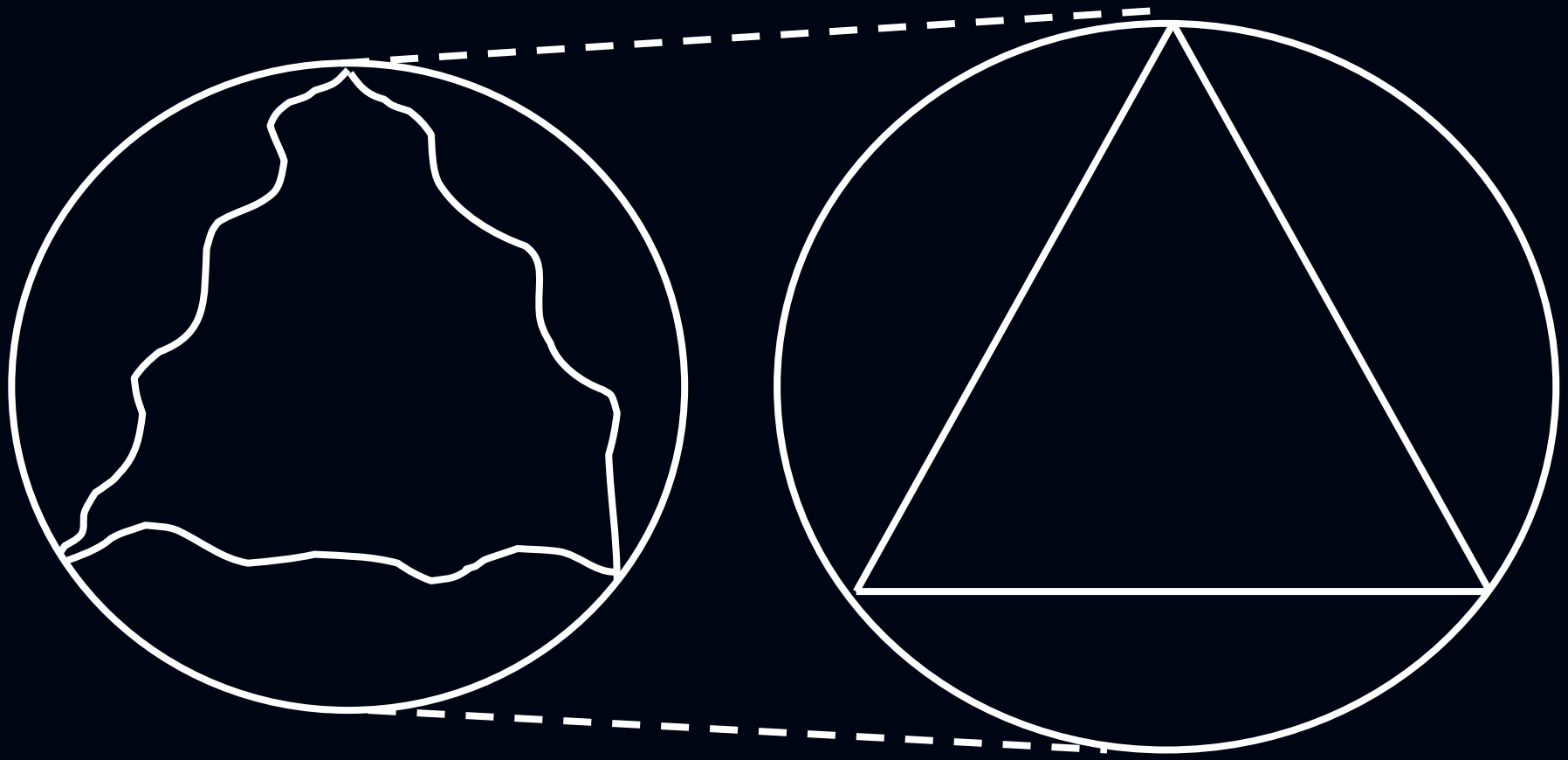
Cusp free margin and circumference between commissures ARE EQUAL



Symmetric cusp configuration

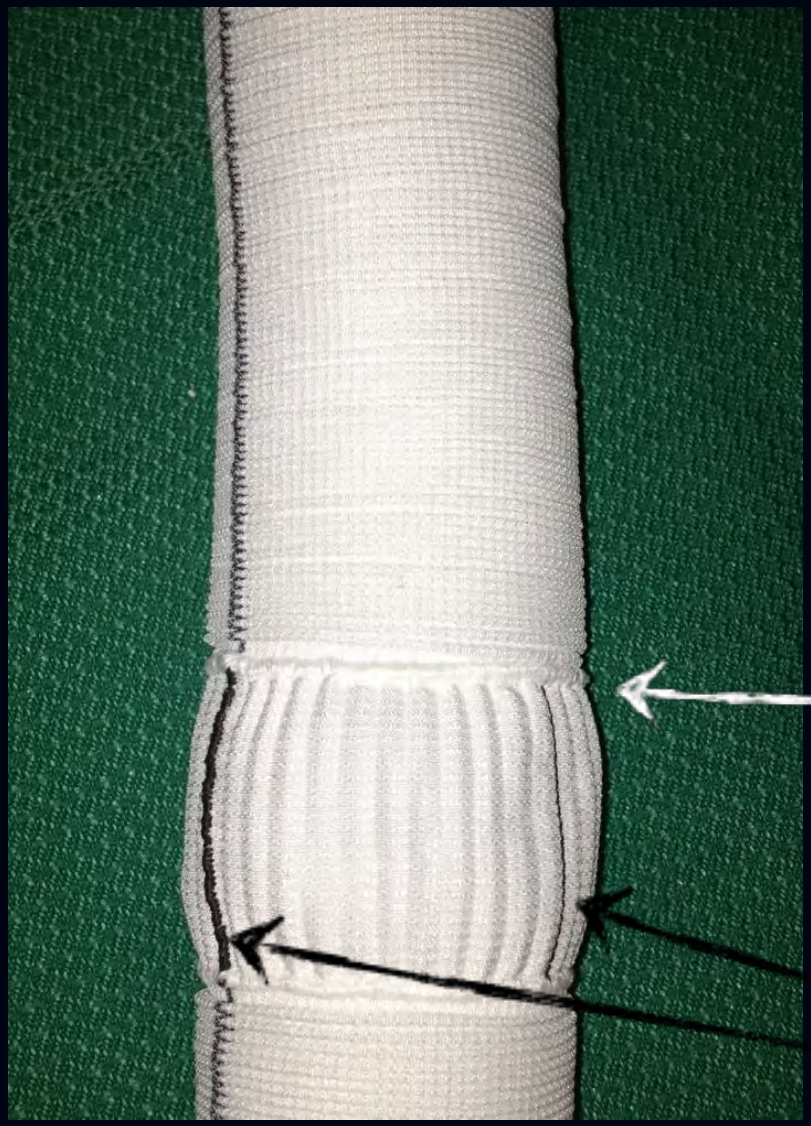
Asymmetric cusp configuration

Functional geometry



The progressive increase in aortic diameter maintain the leaflets flat through the whole sequence of leaflet opening

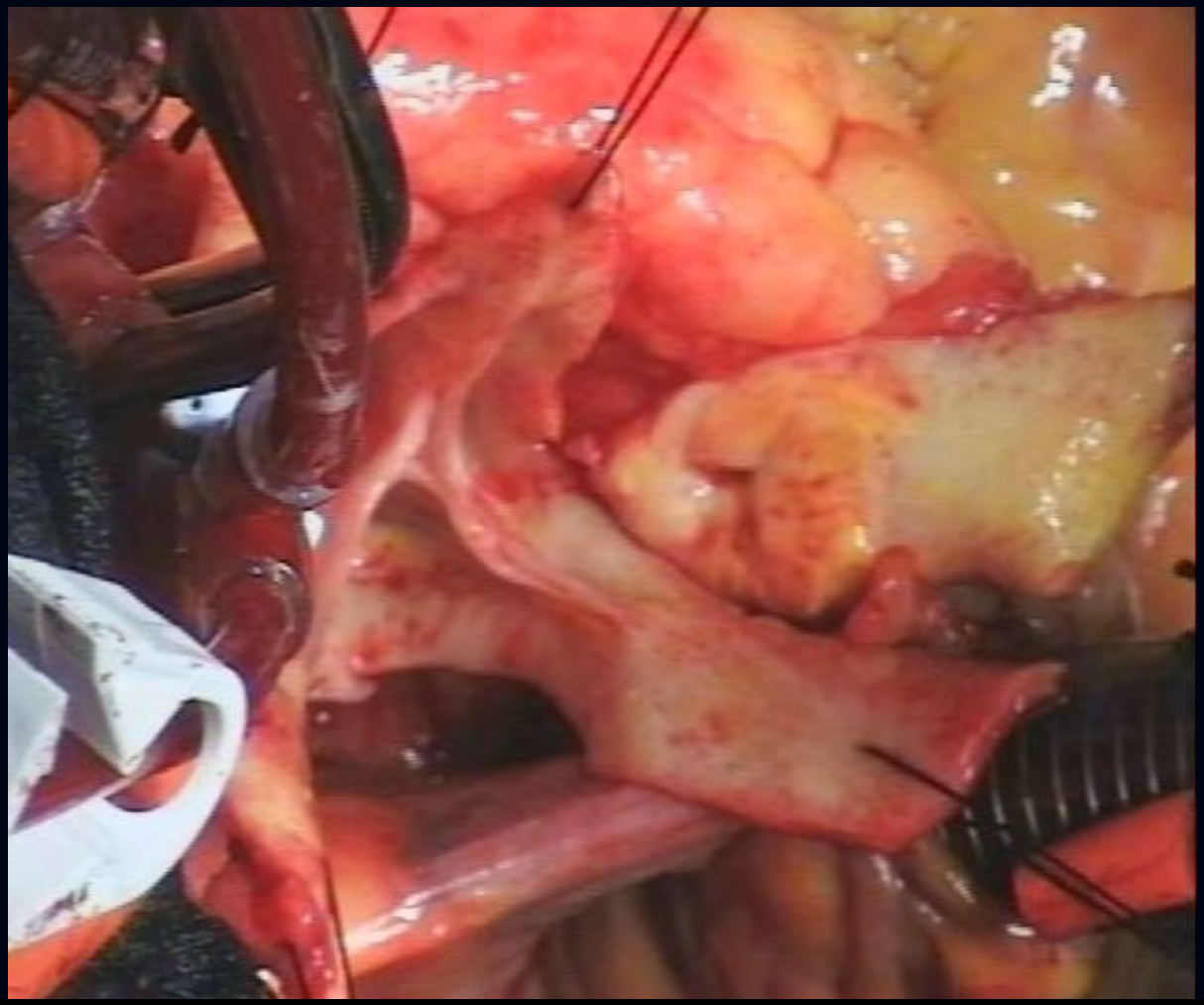
The Valsalva graft



Well defined ST junction

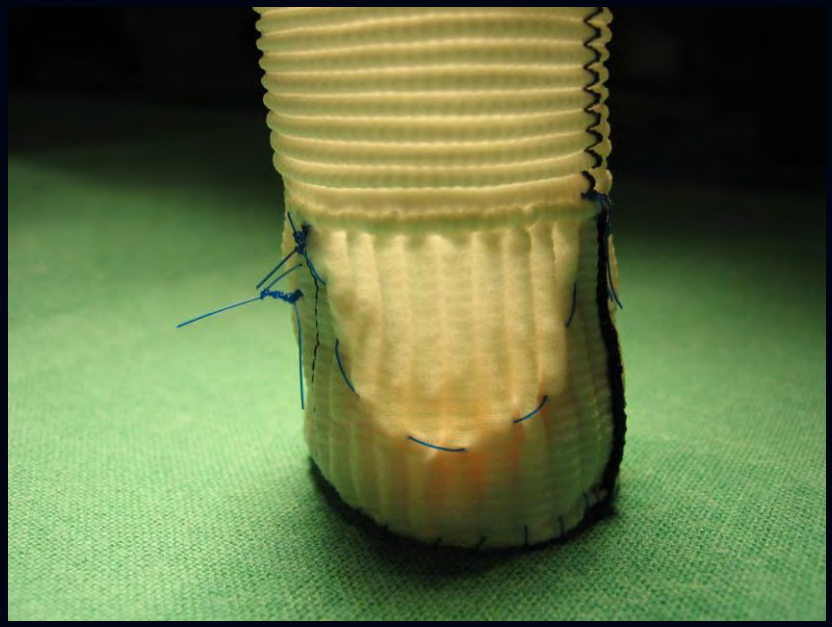
Three black line at 120° apart

Conduit sizing

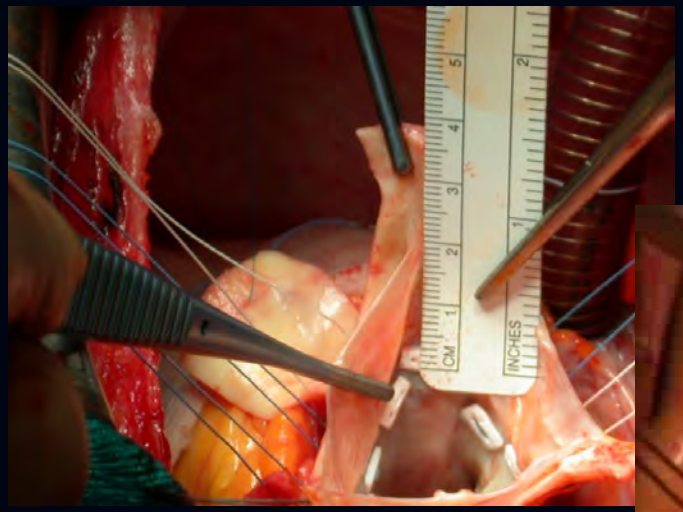


Size the annulus then add 5 mm to choose the conduit optimal size
(e.g. for a 25 mm choose a 30 mm Valsalva graft)

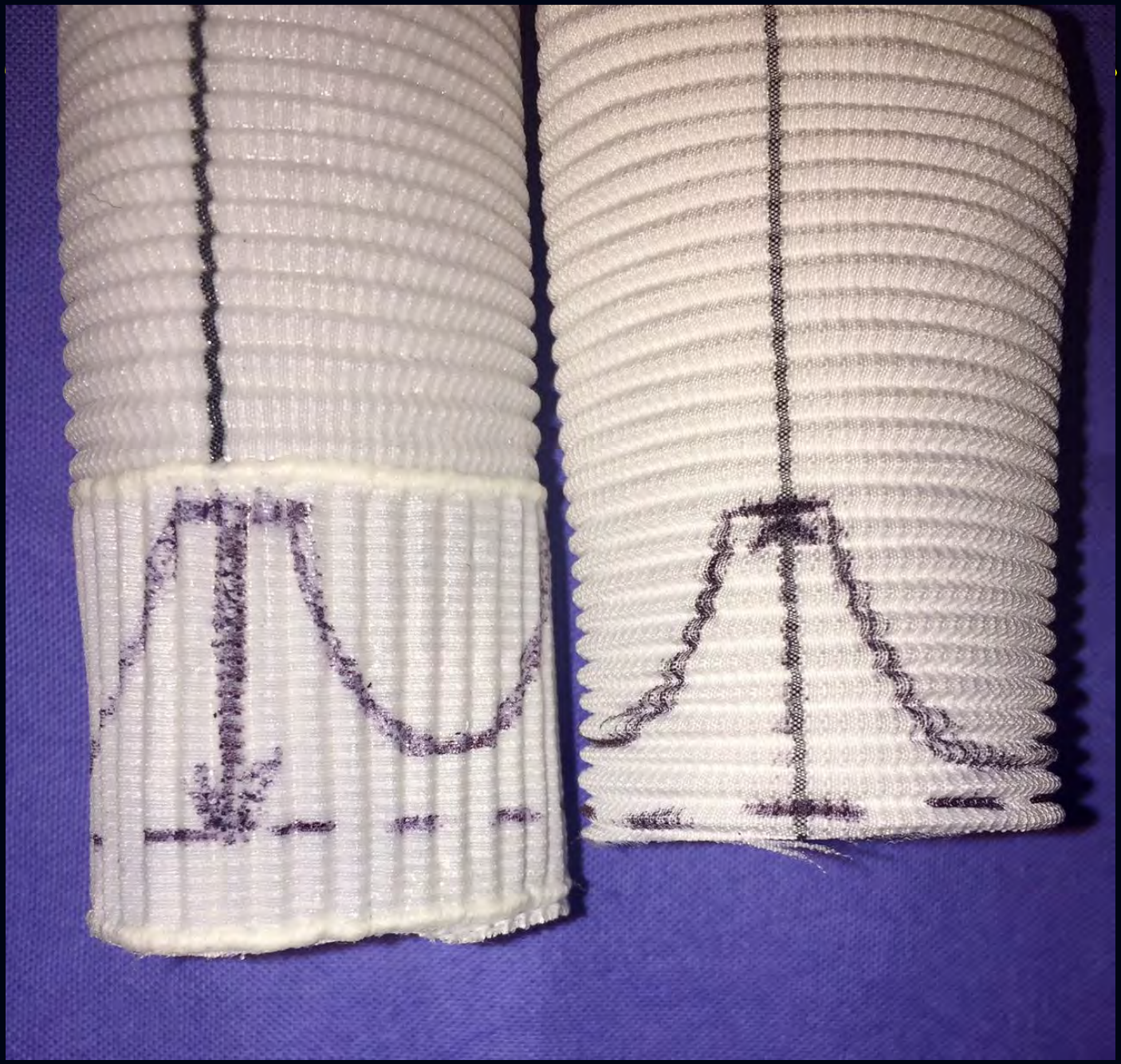
After choosing the proper conduit size, (annulus diameter + 5mm) just adapt the patient's valve to the skirt of the graft



Measuring the commissures



Lenght of commissures = 25 mm



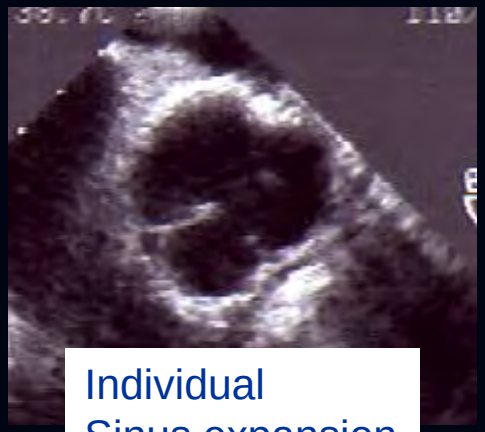
Attaching the commissures at the level of the new ST juntion

Unequal tension
or stretching of the
three commissural posts
might alter leaflet
coaptation causing
eccentric jets

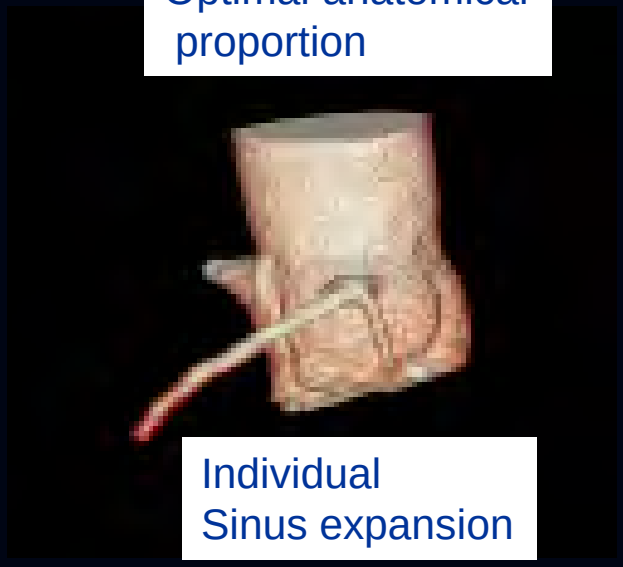
Anatomical root reconstruction

Optimal anatomical proportion

Optimal anatomical proportion



Individual Sinus expansion



Individual Sinus expansion

Optimized sinus shape and dimension

Perfect sinus shape and optimal sinus-leaflet assembly

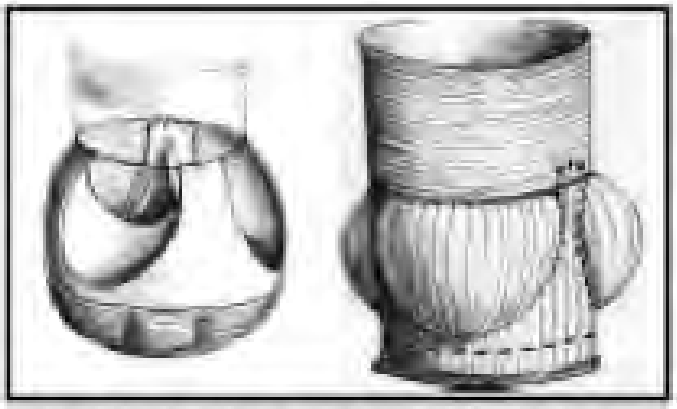
ST junction re-established

Long-term results of the valve reimplantation technique using a graft with sinuses

Ruggero De Paulis, MD,[a] Ilaria Chirichilli, MD,[a] Raffaele Scaffa, MD,[a] Luca Weltert, MD,[a] Daniele Maselli, MD,[a] Andrea Salica, MD,[a] Lorenzo Guerrieri Wolf, MD,[a] Alessandro Bellisario, MD,[b] and Luigi Chiariello, MD[a]

- 124 patients
- Age 53 ± 13
- 87% Men
- 21% Marfans
- 12% bicuspid

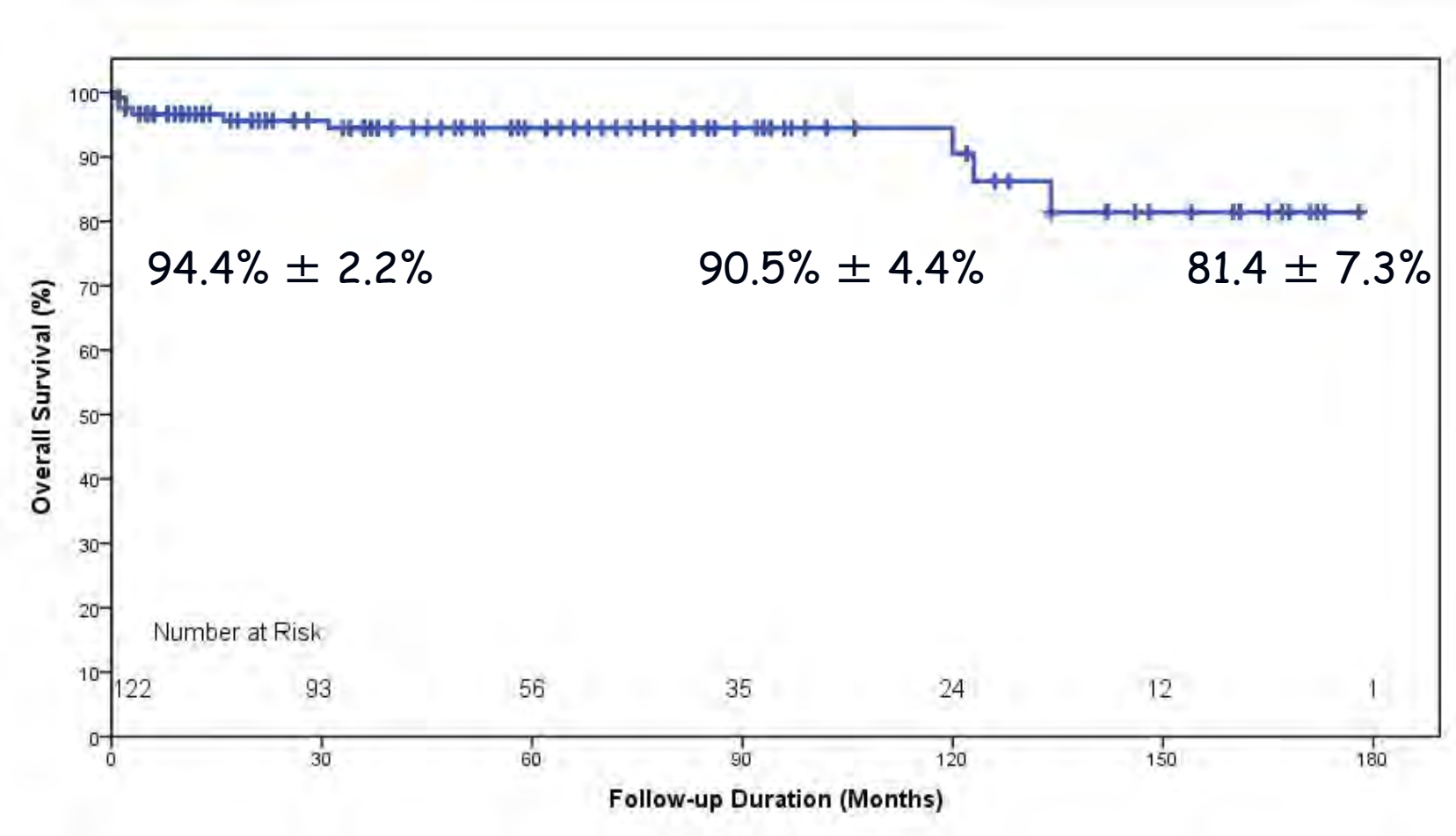
15 Years



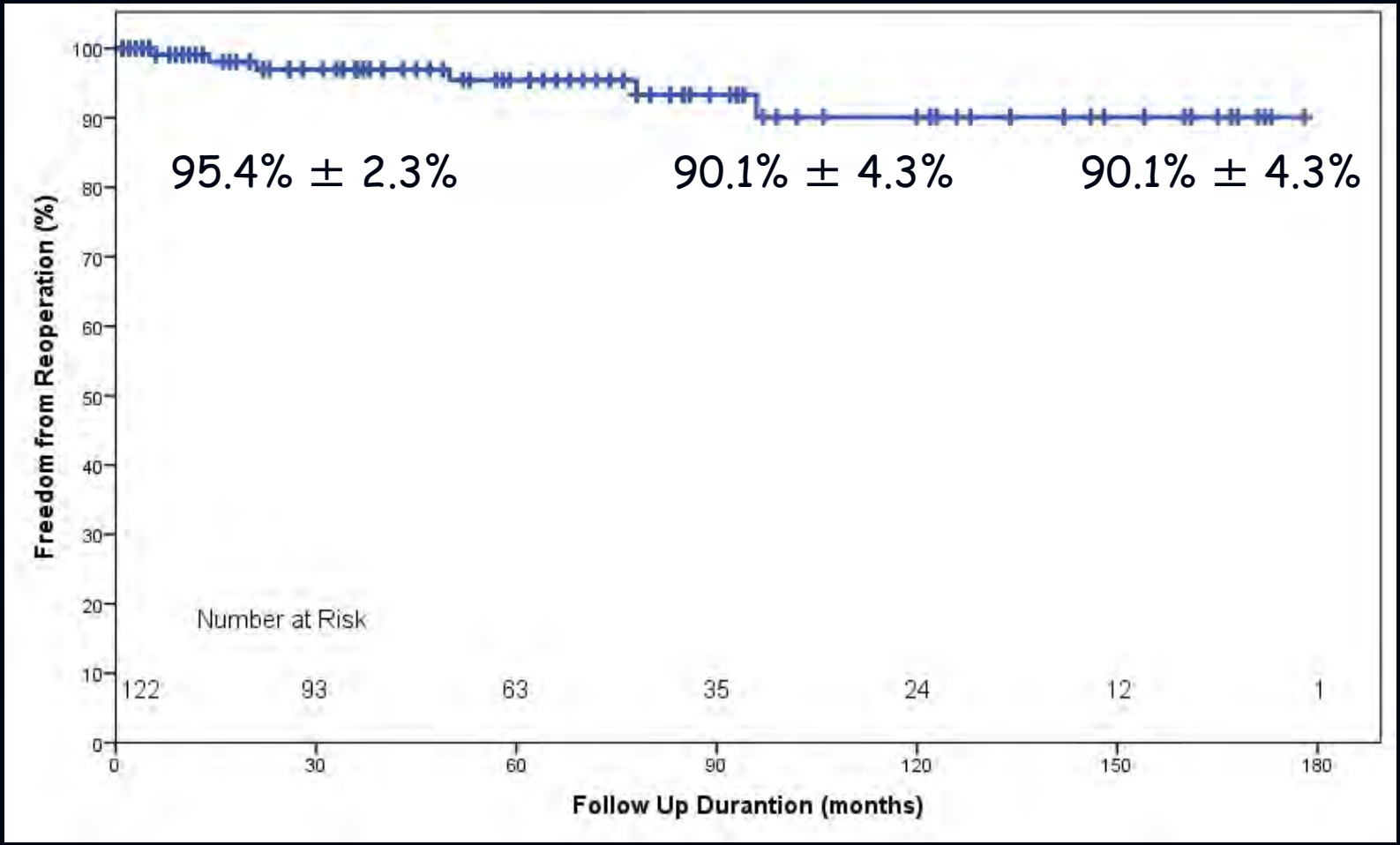
An aortic valve reimplanted into a graft with sinuses and into a large straight graft.

JTCVS, January 2016; 151: 112-9

Overall survival

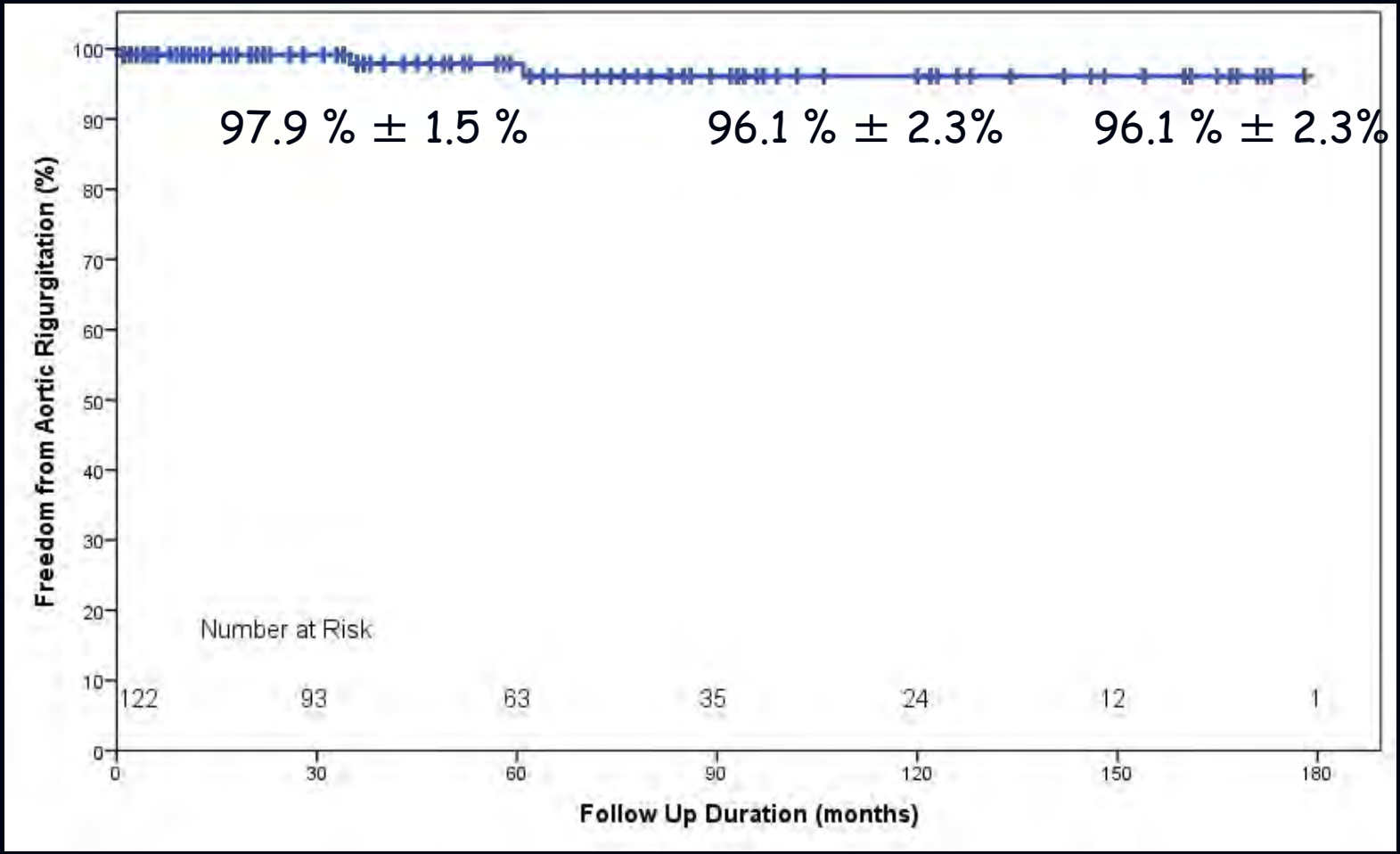


Freedom from reoperation

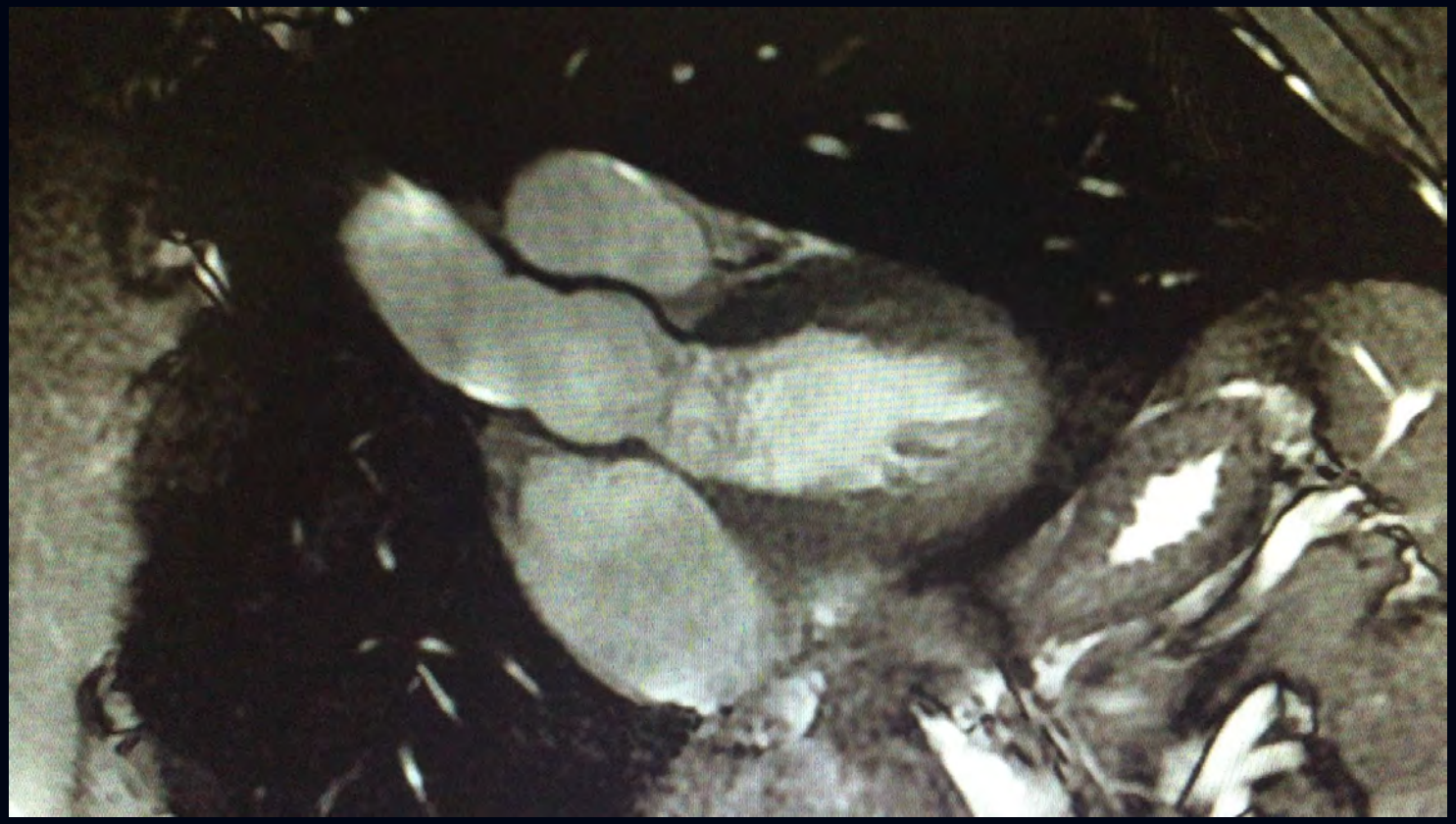


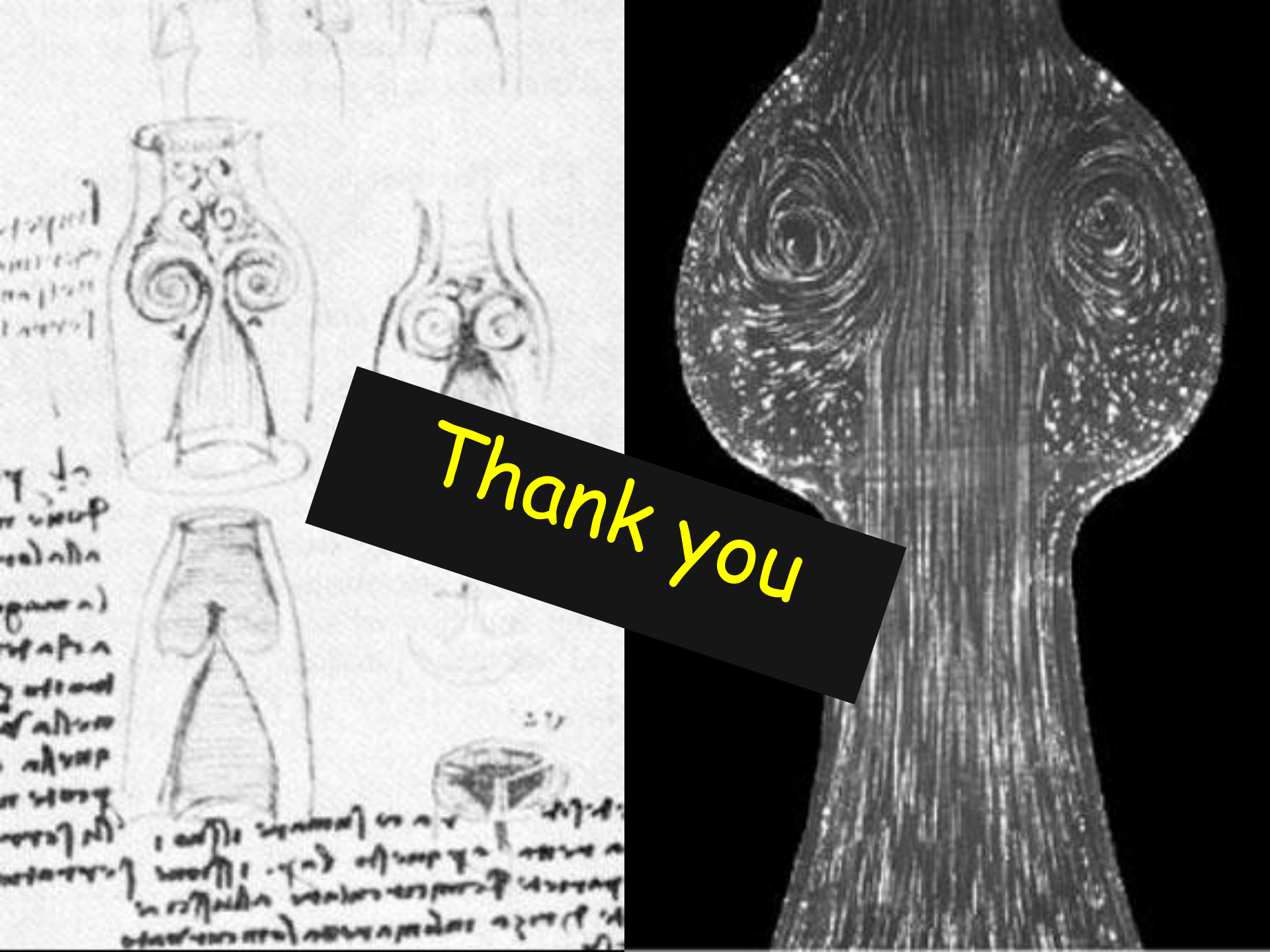
Freedom from residual AR

(not including reoperation)



The first world Valsalva graft 16 years after an acute dissection




Thank you