BAV Repair and Aortopathy

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May 21th , 2015
Homburg

Topics

I:

- **Congenital variations**
- **Dysfunction mechanisms**
- **Repair techniques**

II:

- **BAV Aortopathy**

BAV

- Prevalence 1 – 2 %

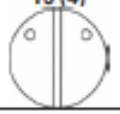
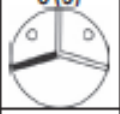
- Fusion left-right 86 %
  right-non 12 %
  left-non 3 %

- Associated with:
  male gender 3:1
  Other congenital malformations

A classification system for the bicuspid aortic valve from 304 surgical specimens

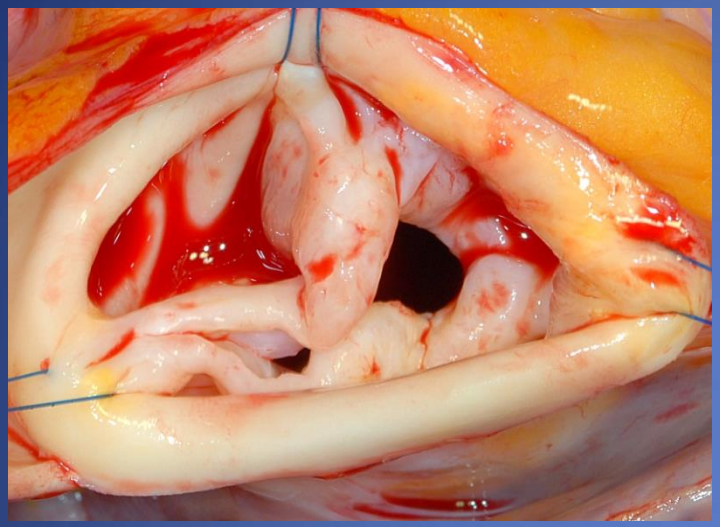
Hans-H. Sievers, MD, and Claudia Schmidtke, MD, MBA

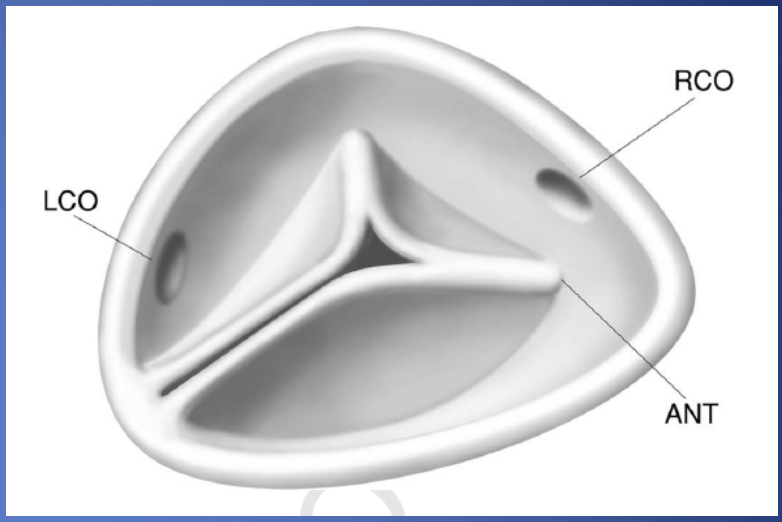
TABLE 1. Schematic presentation (as viewed from the surgeon's position with the left coronary sinus on the left side) of the classification system of BAVs with one main and two subcategories, including the number of specimens (percent in parenthesis)

main category: number of raphes		0 raphe - Type 0		1 raphe - Type 1			2 raphes - Type 2
		 21 (7)		 269 (88)			 14 (5)
1. subcategory: spatial position of cusps in Type 0 and raphes in Types 1 and 2		lat 13 (4) 	ap 7 (2) 	L – R 216 (71) 	R – N 45 (15) 	N – L 8 (3) 	L – R / R – N 14 (5) 
2. subcategory:							
VALVULAR FUNCTION	I	6 (2)	1 (0.3)	79 (26)	22 (7)	3 (1)	6 (2)
	S	7 (2)	5 (2)	119 (39)	15 (5)	3 (1)	6 (2)
	B (I + S)		1 (0.3)	15 (5)	7 (2)	2 (1)	2 (1)
	No			3 (1)	1 (0.3)		

Sievers H, JTCVS , May 2007

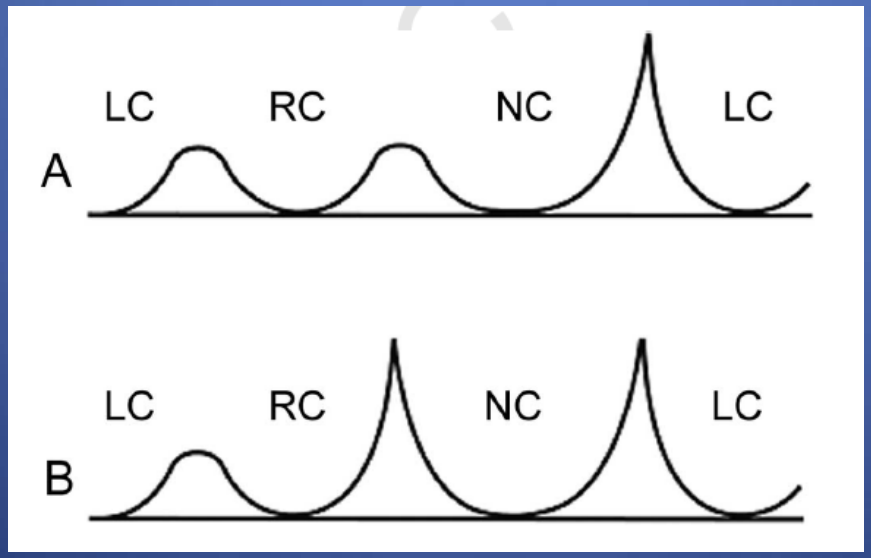
Unicuspid Aortic Valve





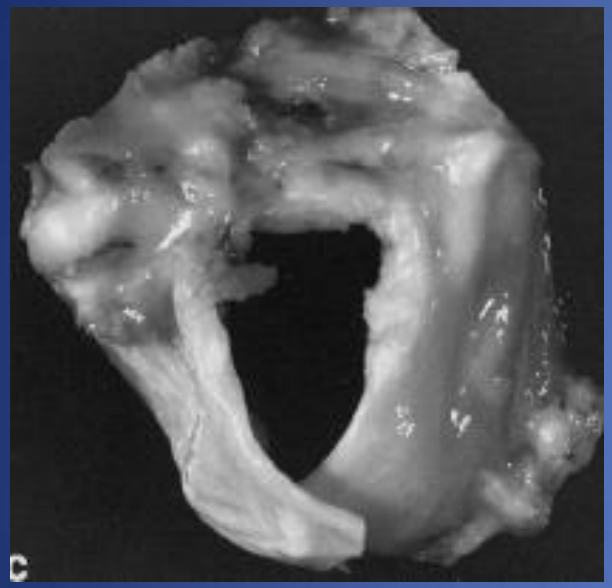
unicuspid

bicuspid

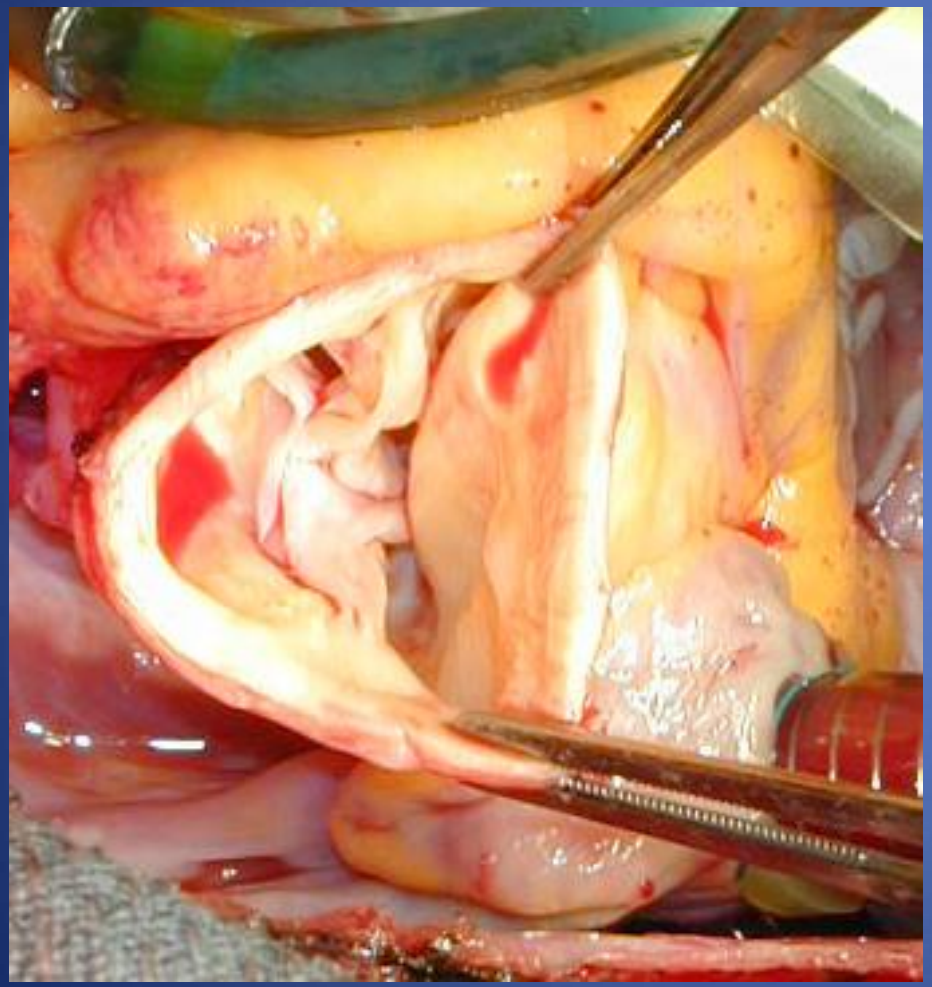


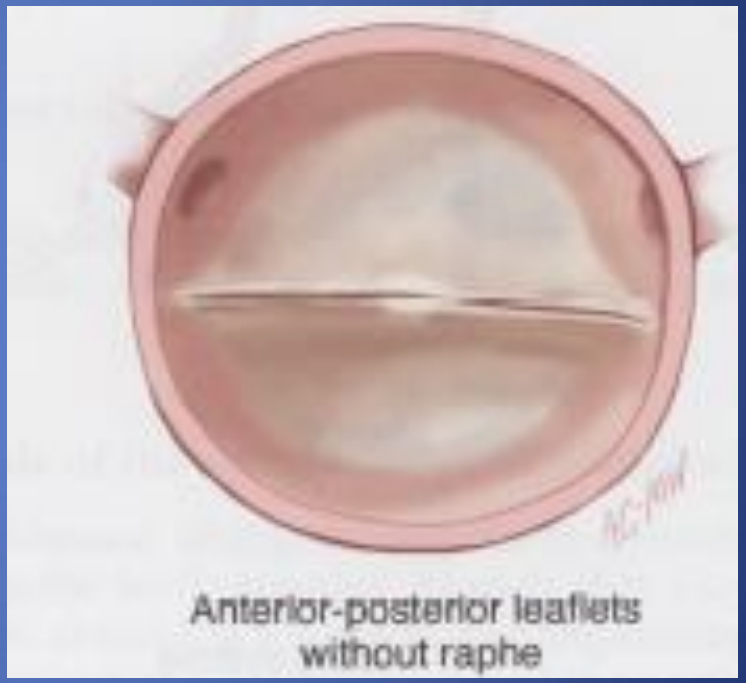
R. Anderson

Unicuspid AV Eccentric Opening

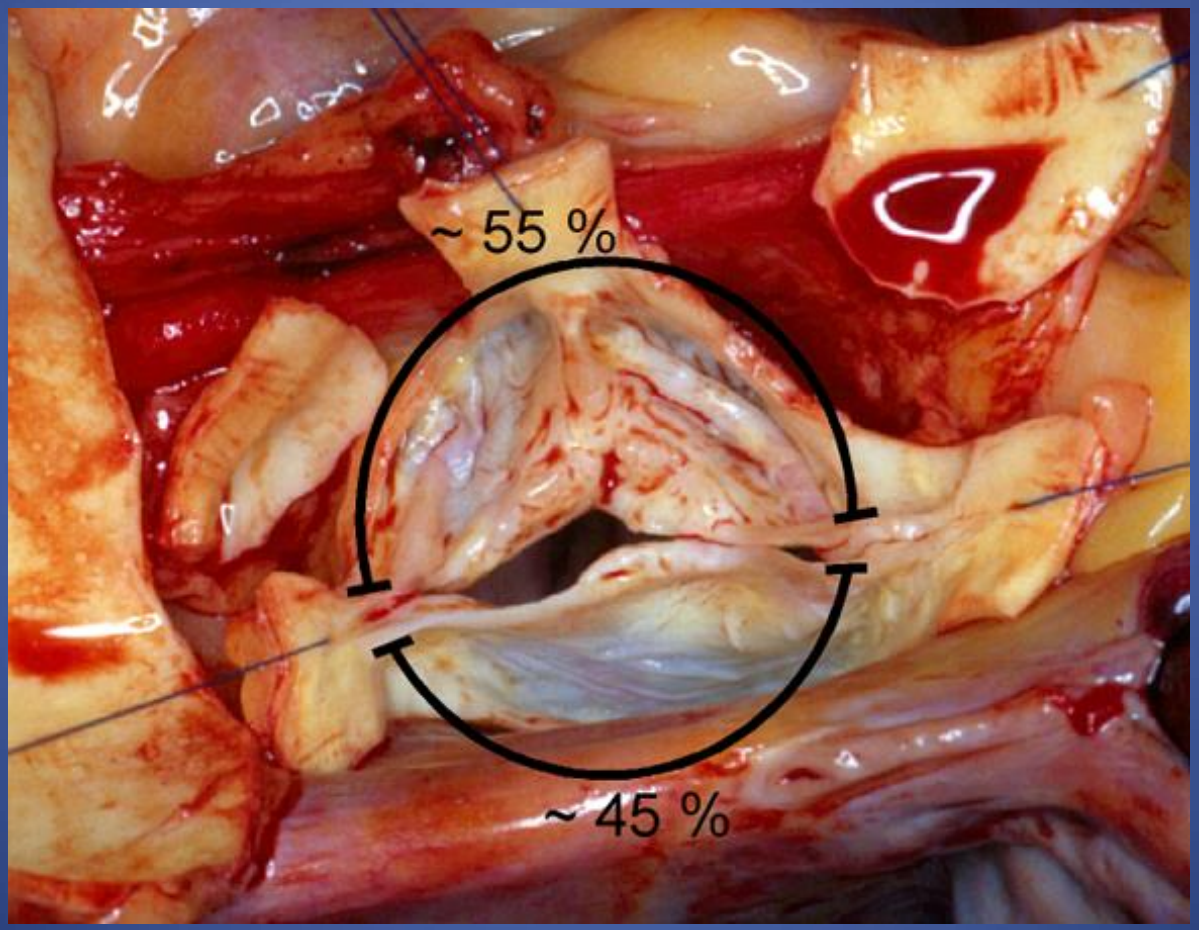


„Perfect“ BAV <1% (no raphe, 180 degrees angle)

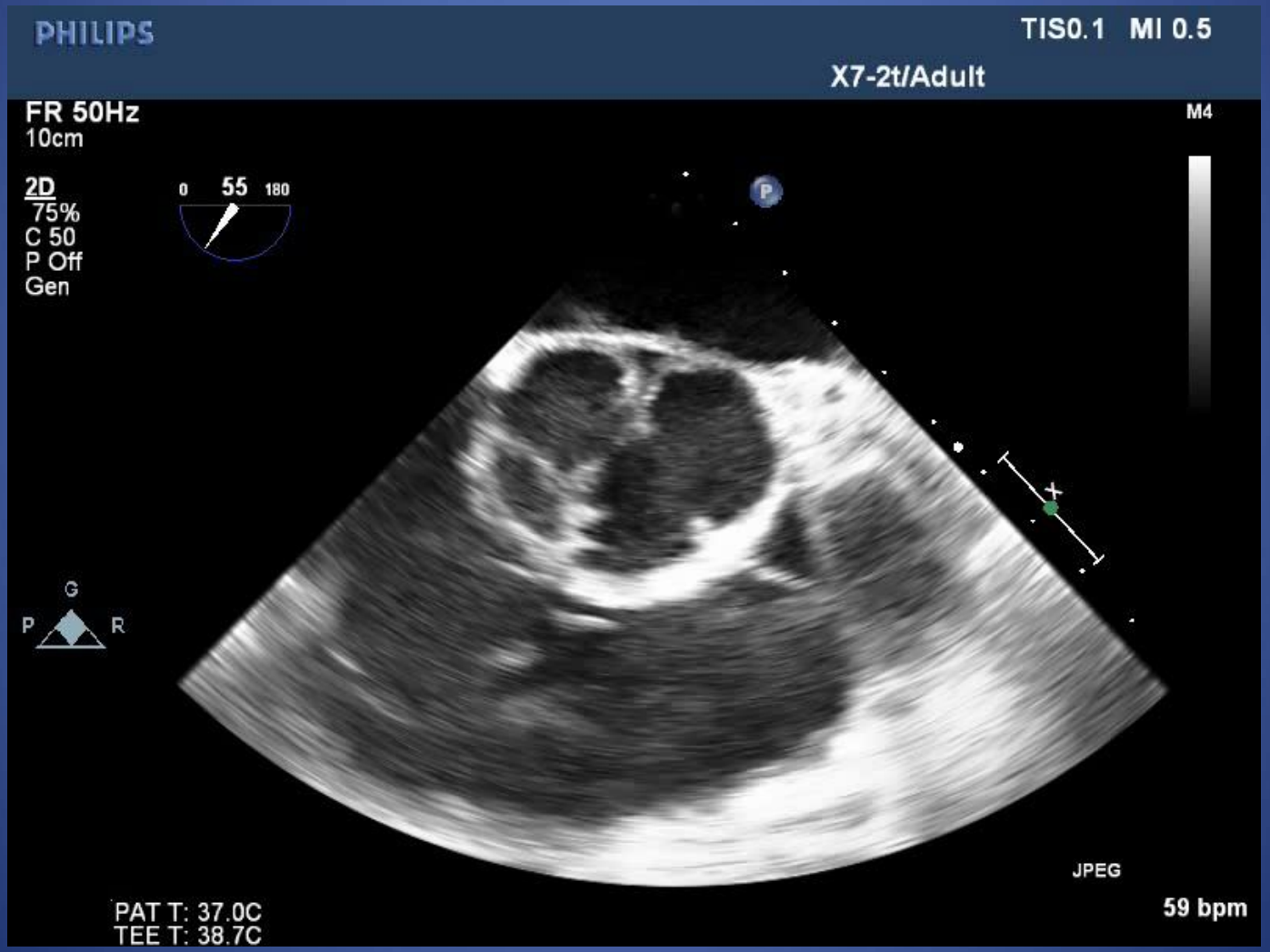




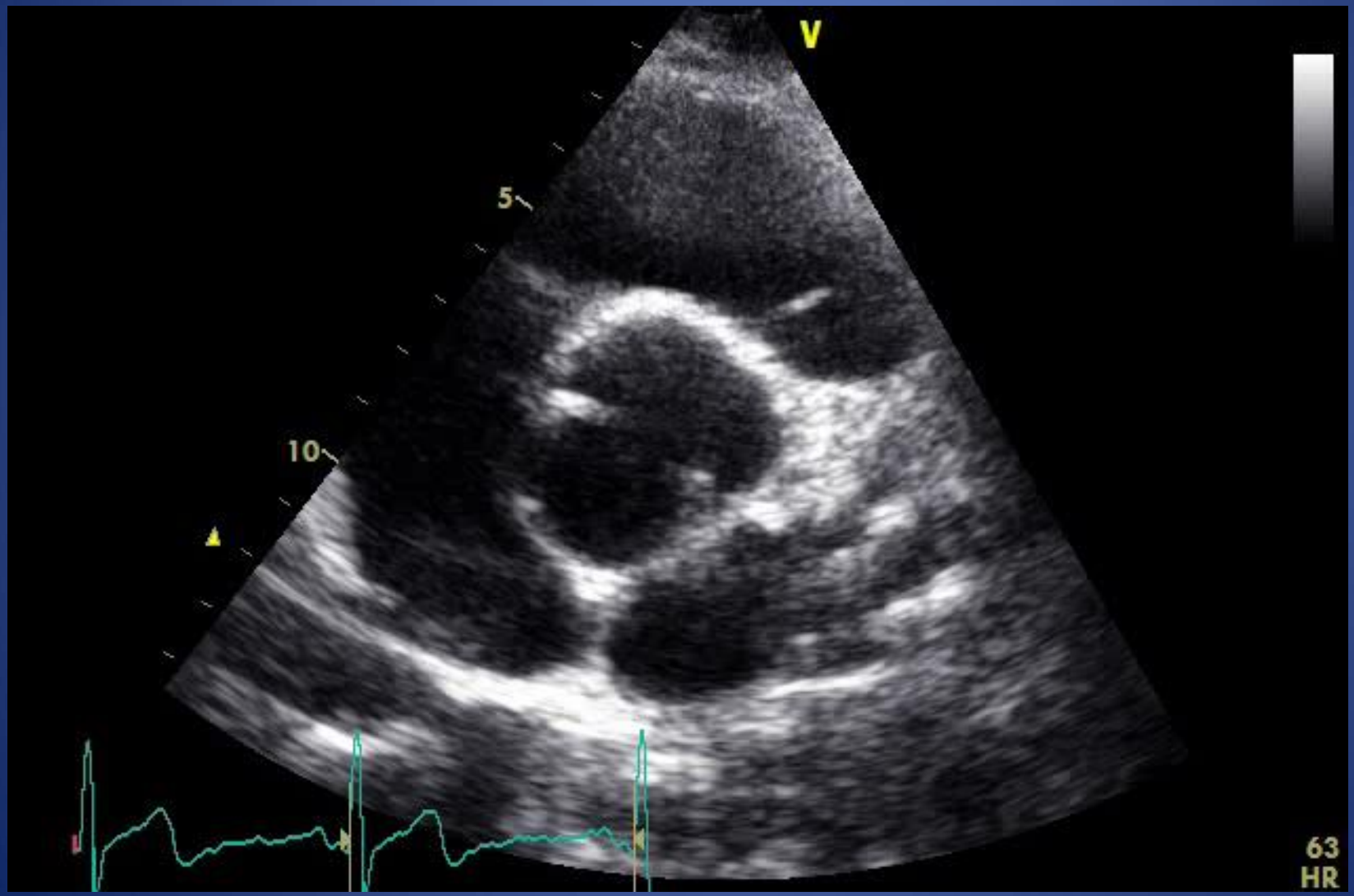
Different angles (120-180 degrees)



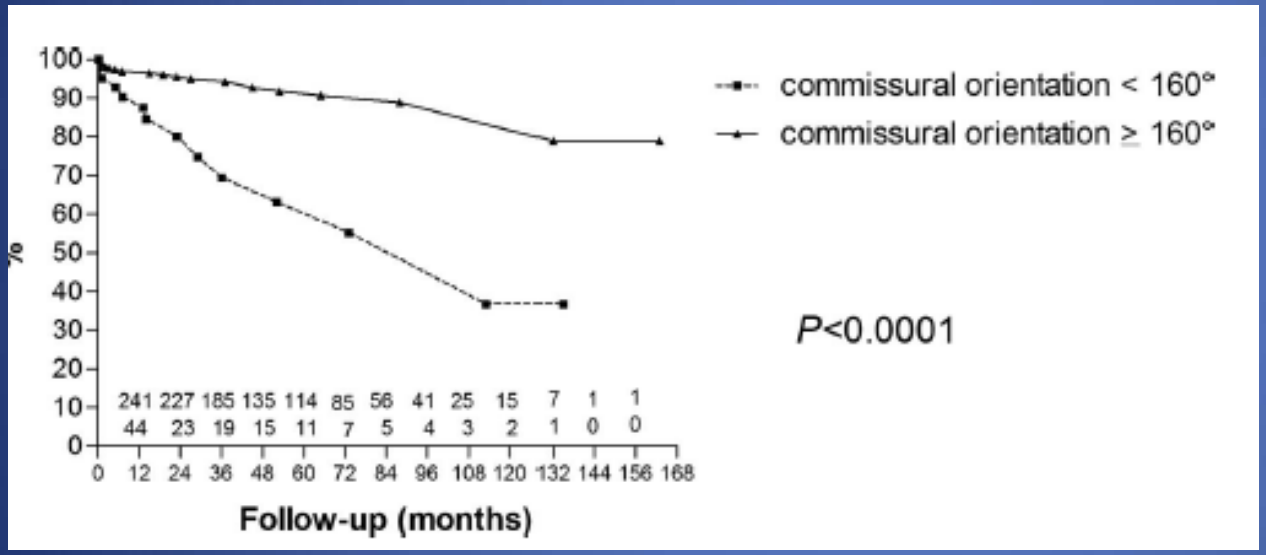
160º

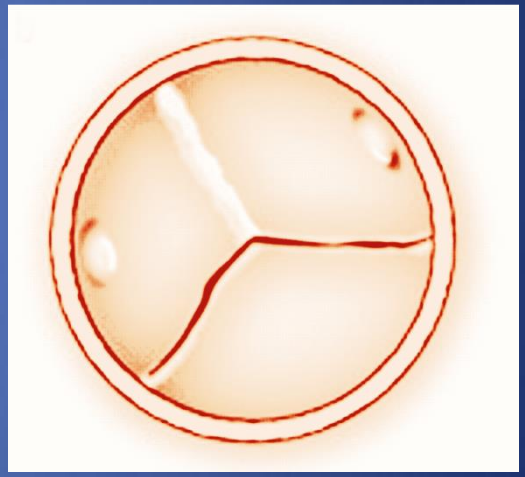

PHILIPS
TIS0.1 MI 0.5
X7-2t/Adult
FR 50Hz
10cm
M4
2D
75%
C 50
P Off
Gen
0 55 180
G
P R
JPEG
PAT T: 37.0C
TEE T: 38.7C
59 bpm

180º



Freedom from reoperation BAV repair depending on the orientation of the 2 normal commissures

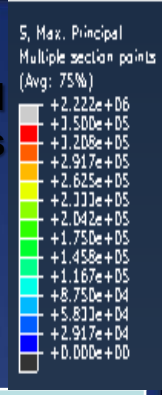


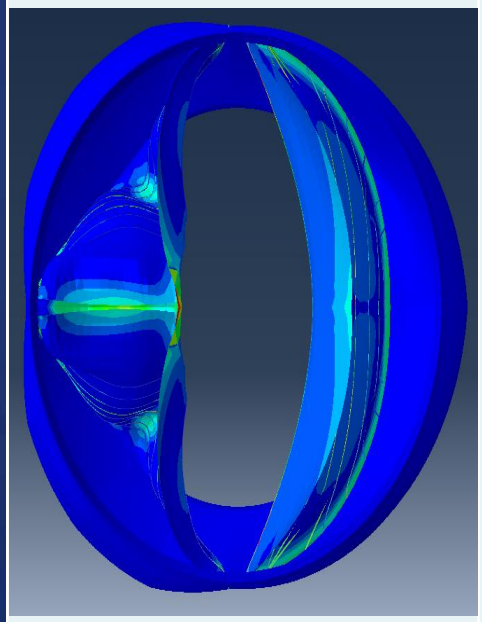
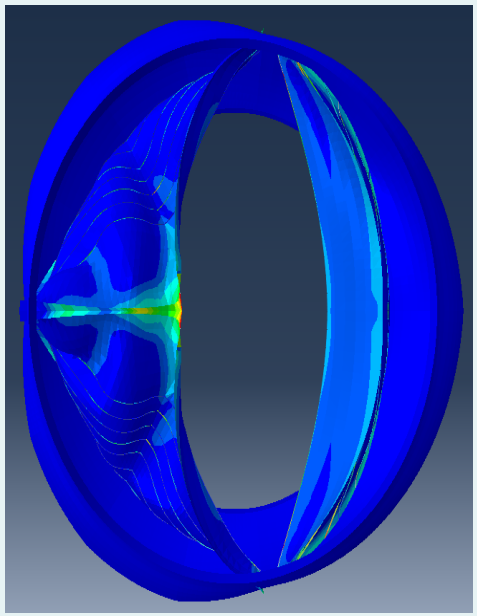
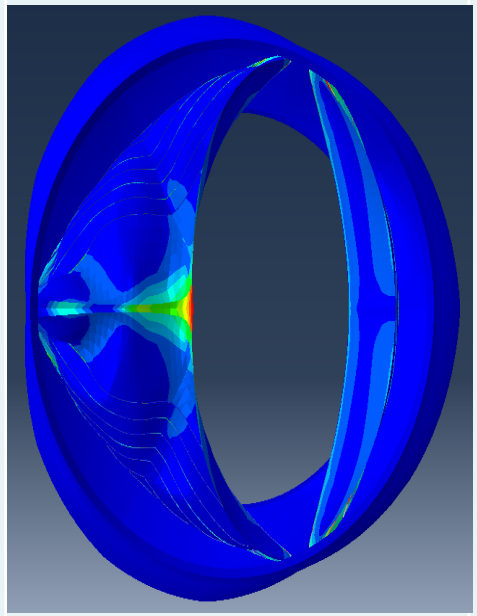
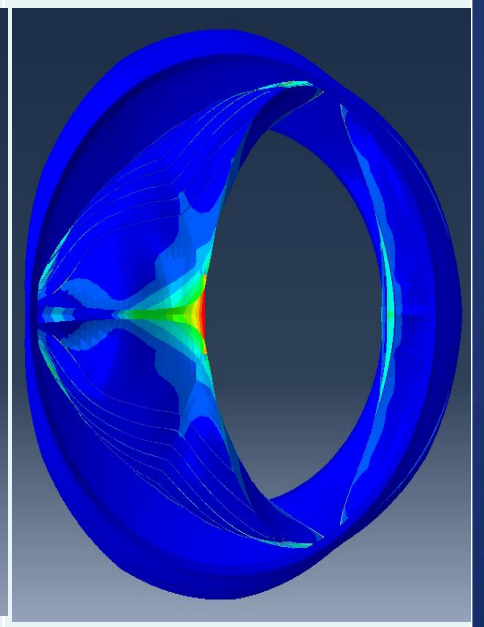


Aicher D et al. Circulation 2011;123:178-185

Orifice Area in Peak Systole

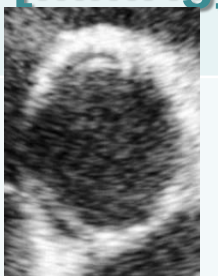
Results



180°	160°	140°	120°
			
2.11 [cm²]	2.38 [cm²]	2.44 [cm²]	2.84 [cm²]

Echo Results

Resul
ts

180°	150°	120°	NFC Angle
			Echo Video
3	2	7	Number of Patients
2.5 [cm²]	3.35 [cm²]	3.65 [cm²]	EOA
1.83 [m/s]	1.55 [m/s]	1.41 [m/s]	Velocity
14 [mmHg]	10 [mmHg]	8.4 [mmHg]	Pressure Grad.
			Max Opening

Results of Valve Preservation and Repair for Bicuspid Aortic Valve Insufficiency

Bahaaldin Alsoufi, Michael A. Borger, Sue Armstrong, Manjula Maganti, Tirone E. David

Division of Cardiovascular Surgery of Toronto General Hospital and University of Toronto, Toronto, Ontario, Canada

Conclusion: **BAV repair is a safe procedure with good early functional results. However, recurrent AI remains a problem at five to eight years of follow up. Since dilation of the aortic root is a common cause of AI and a common feature of patients with BAV, aortic valve-sparing reimplantation operations should provide better long-term outcomes.**

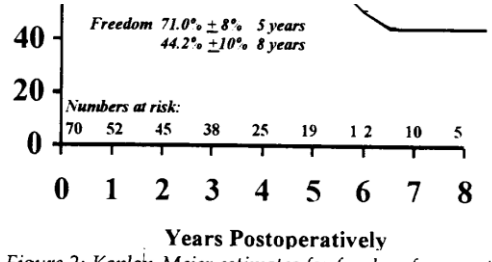


Figure 2: Kaplan-Meier estimates for freedom from aortic insufficiency (AI) grade ≥3+ (moderate) in all patients.

J Heart Valve Dis
Vol. 14. No. 6
November 2005

Is repair of aortic valve regurgitation a safe alternative to valve replacement?

Kenji Minakata, MD
Hartzell V. Schaff , MD
Kenton J. Zehr, MD
Joseph A. Dearani, MD
Richard C. Daly, MD
Thomas A. Orszulak, M
Francisco J. Puga, M
Gordon K. Danielson,

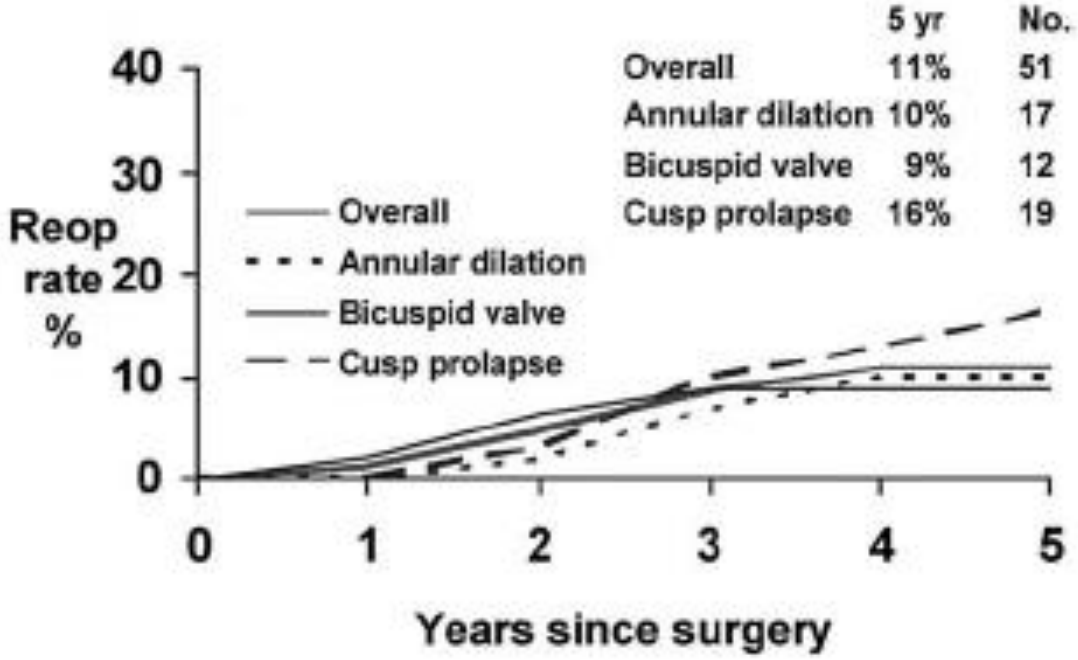


Figure 4. Cumulative risk of reoperation stratified according to the main etiology.

he Journal of Thoracic and Cardiovascular Surgery • Volume 127, Number 3

Mechanisms of AR in BAV is in many cases a combination of:

Root pathology:

Asc. Aortic aneurysm (STJ)

Root aneurysm:

STJ

Annular dilataion

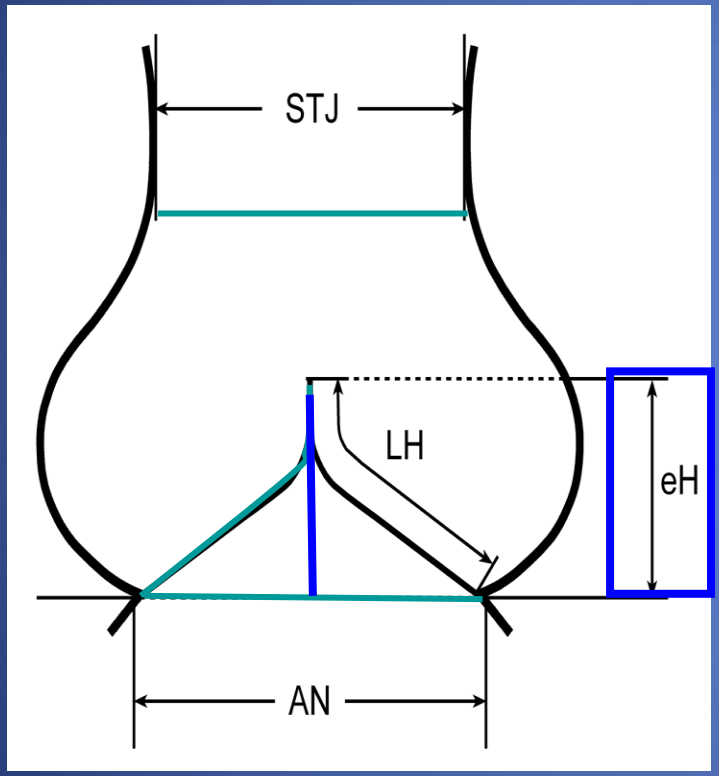
Cusp pathology:

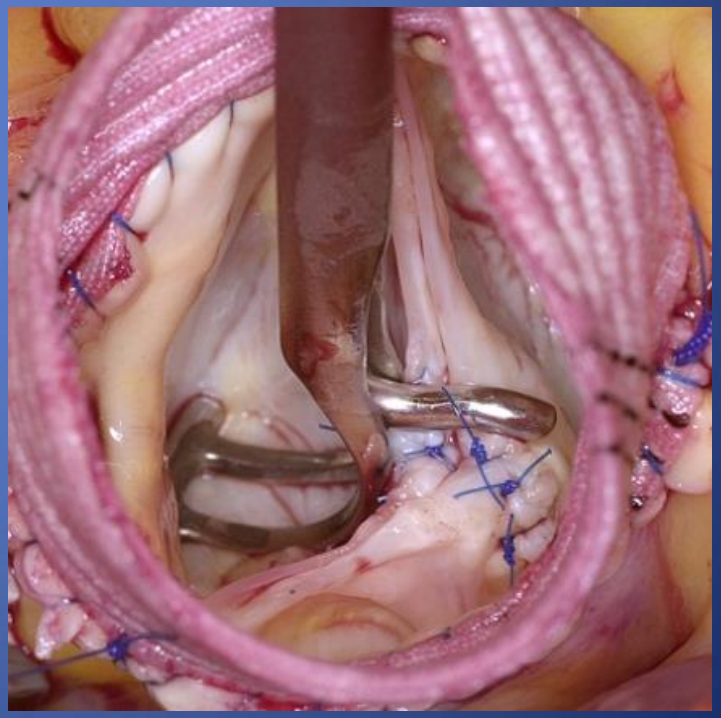
Cusp Prolapse

Calcific degeneration

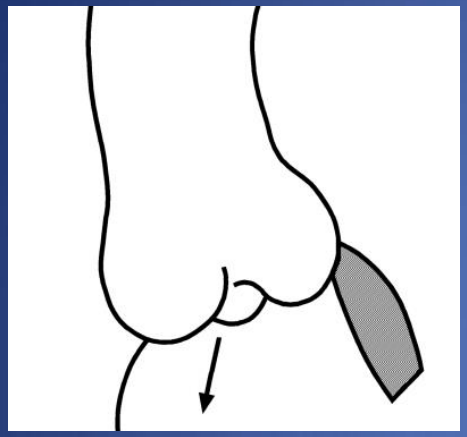
Commissural pathologies

The Effective Height Concept

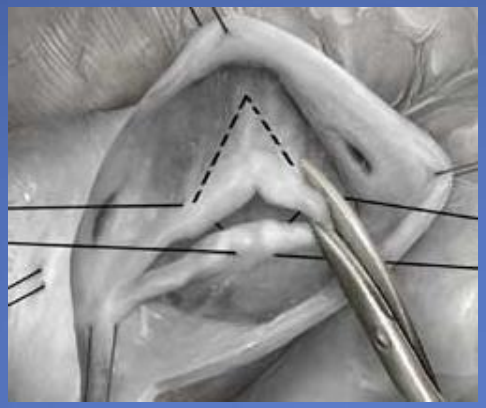




BAV Cusps Pathology

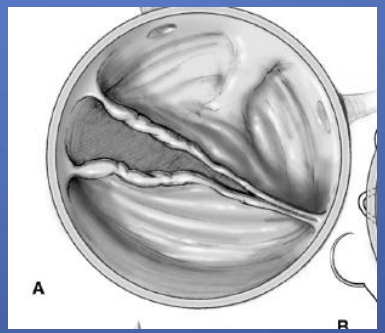


1. Cusp Prolapse



2.Raphe fibrosis and caification

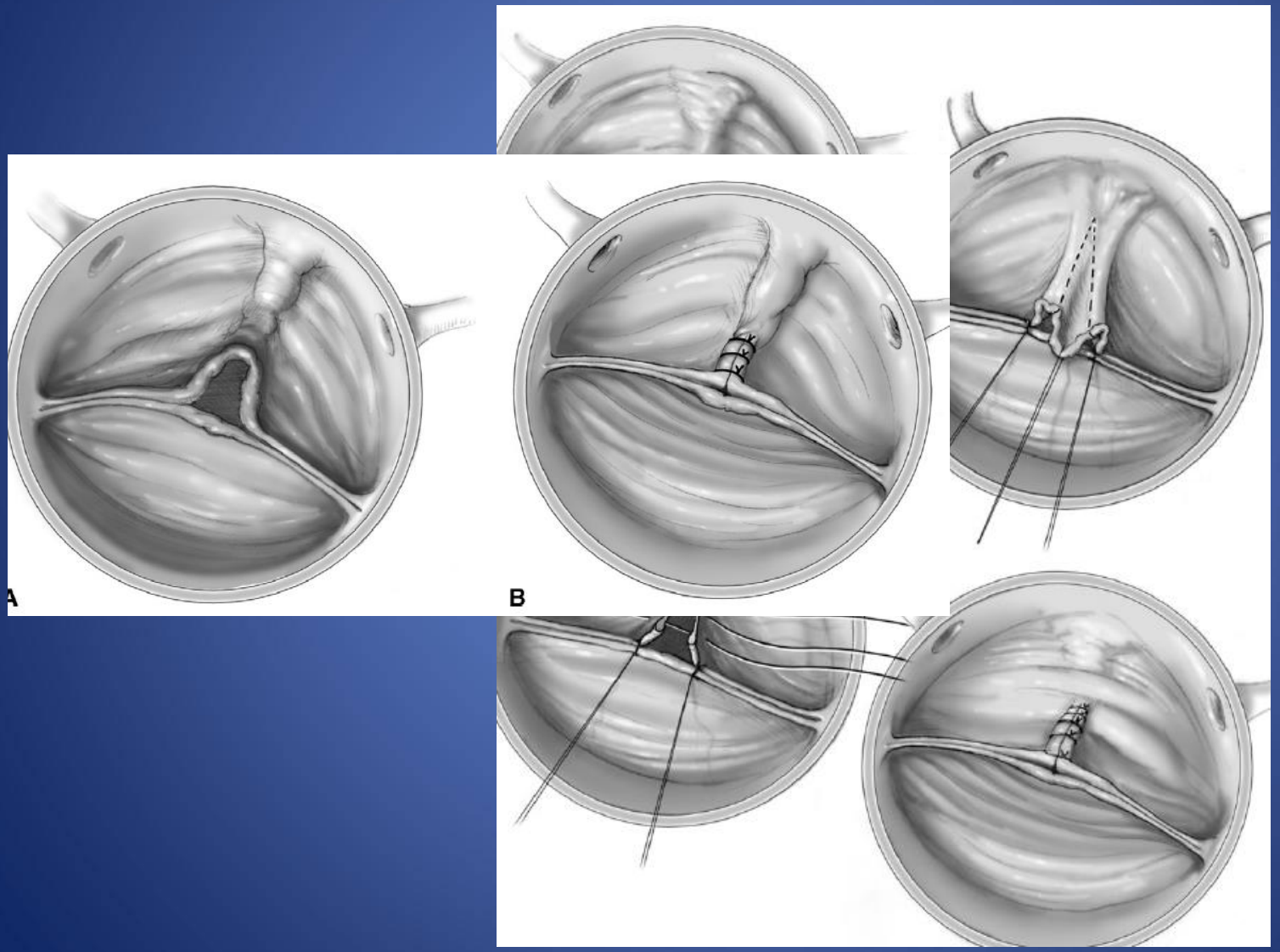
Fenestrations



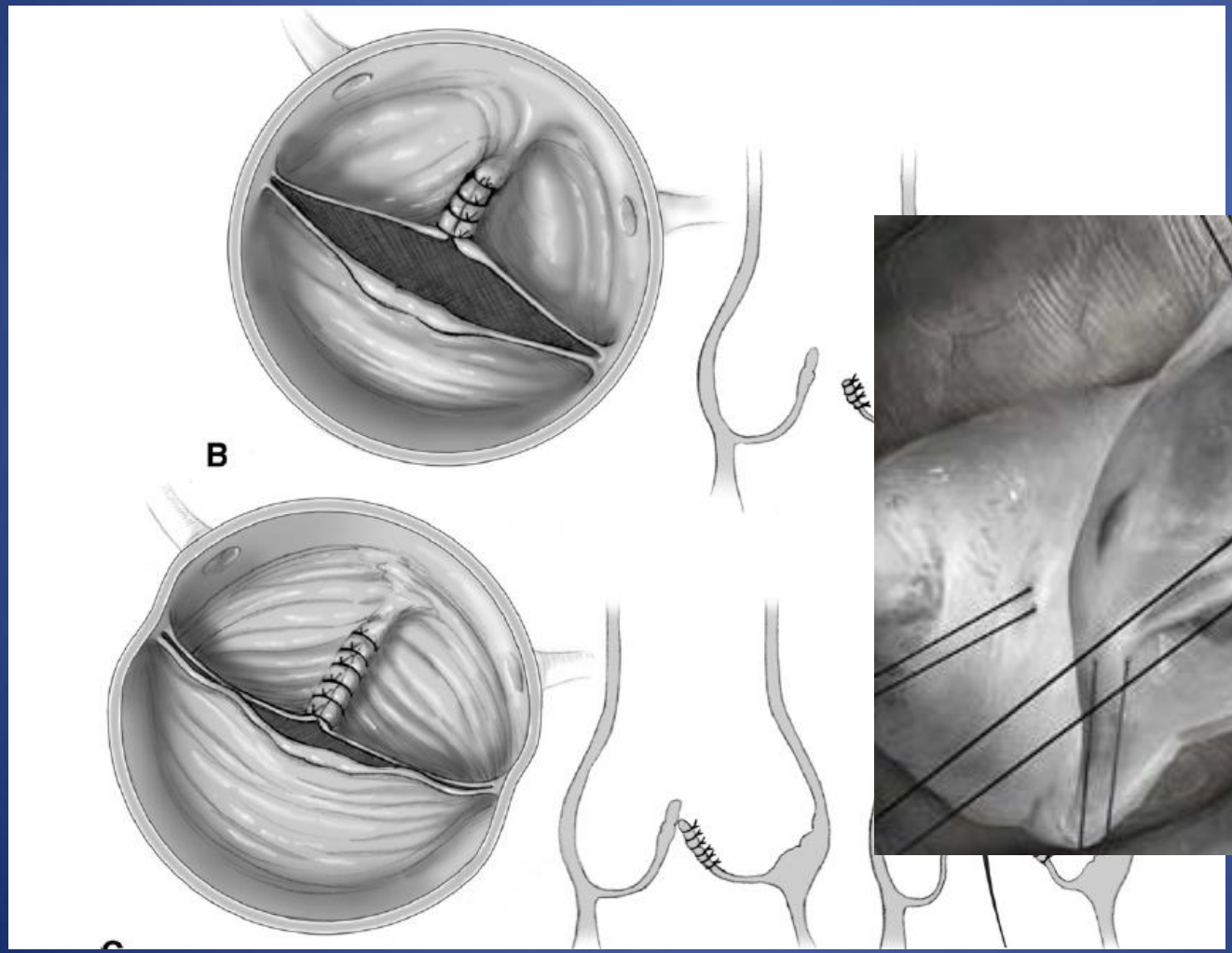
3.Commissural pathologies

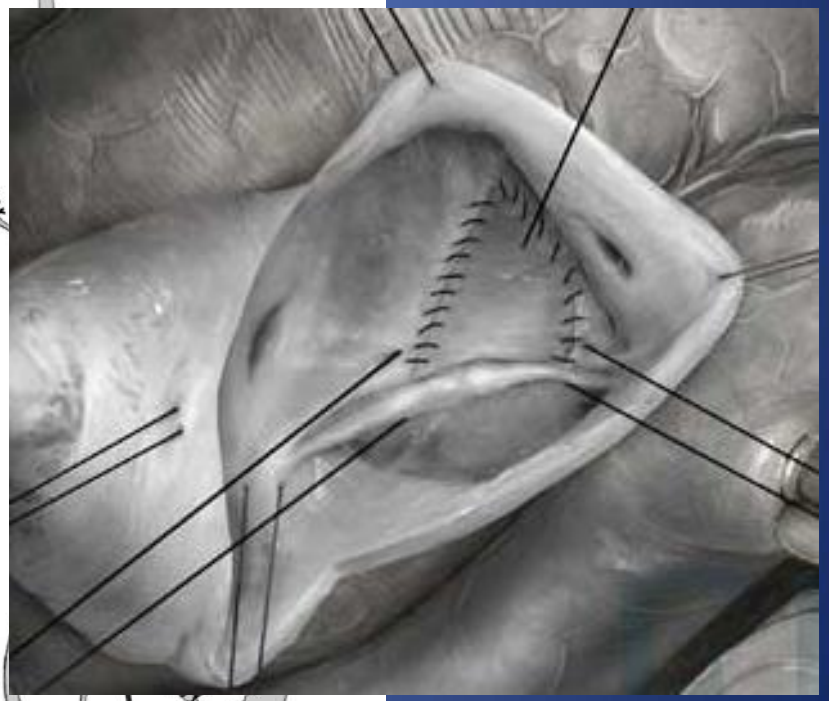
Cusp Prolapse

Fibrotic and Redundant Raphe

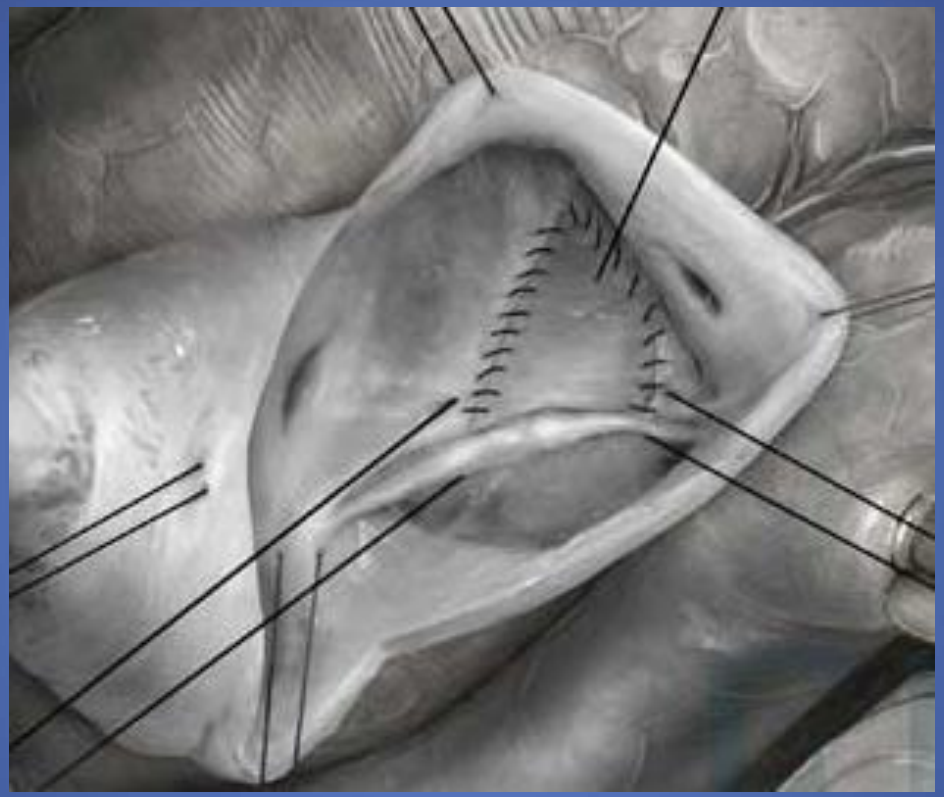


Tissue Deficiency (geometric height< 18-20mm)





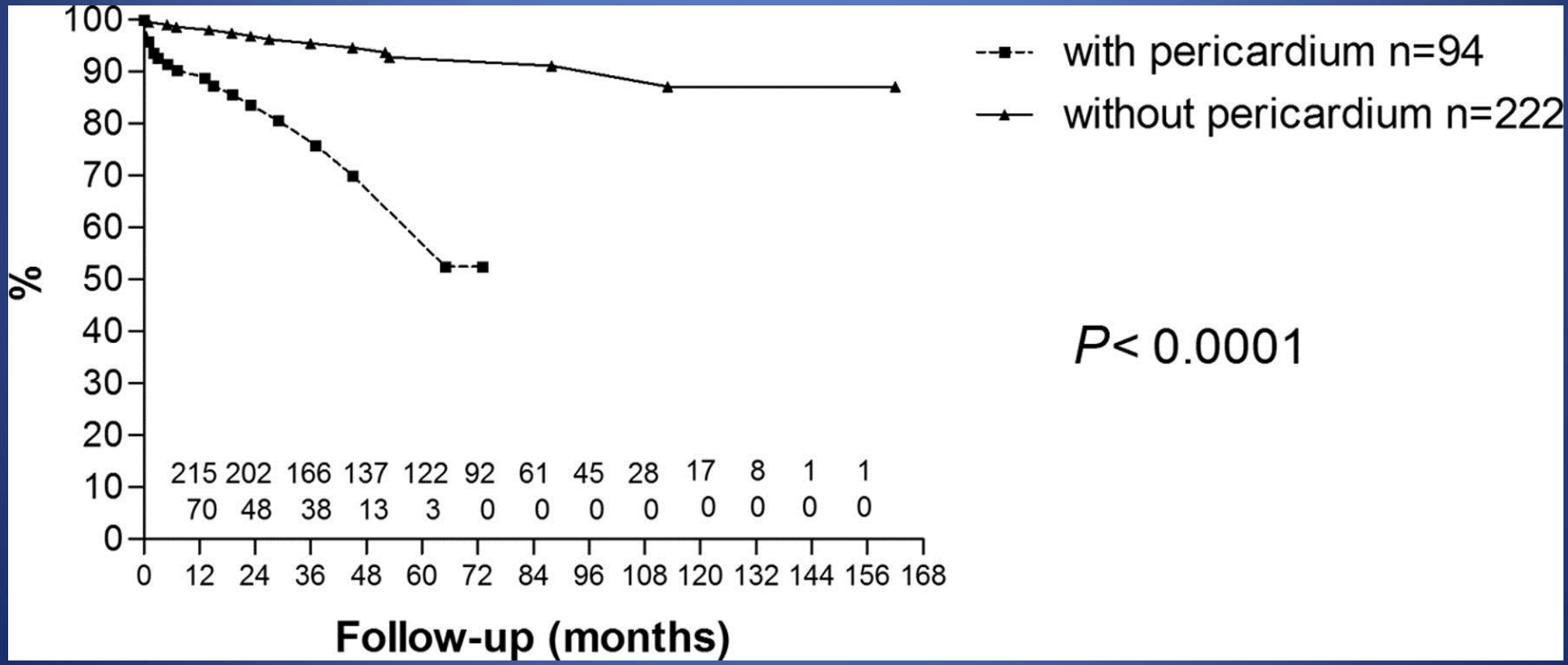
Calcified Raphe



Pericardial Patch Partial Cusp Replacement

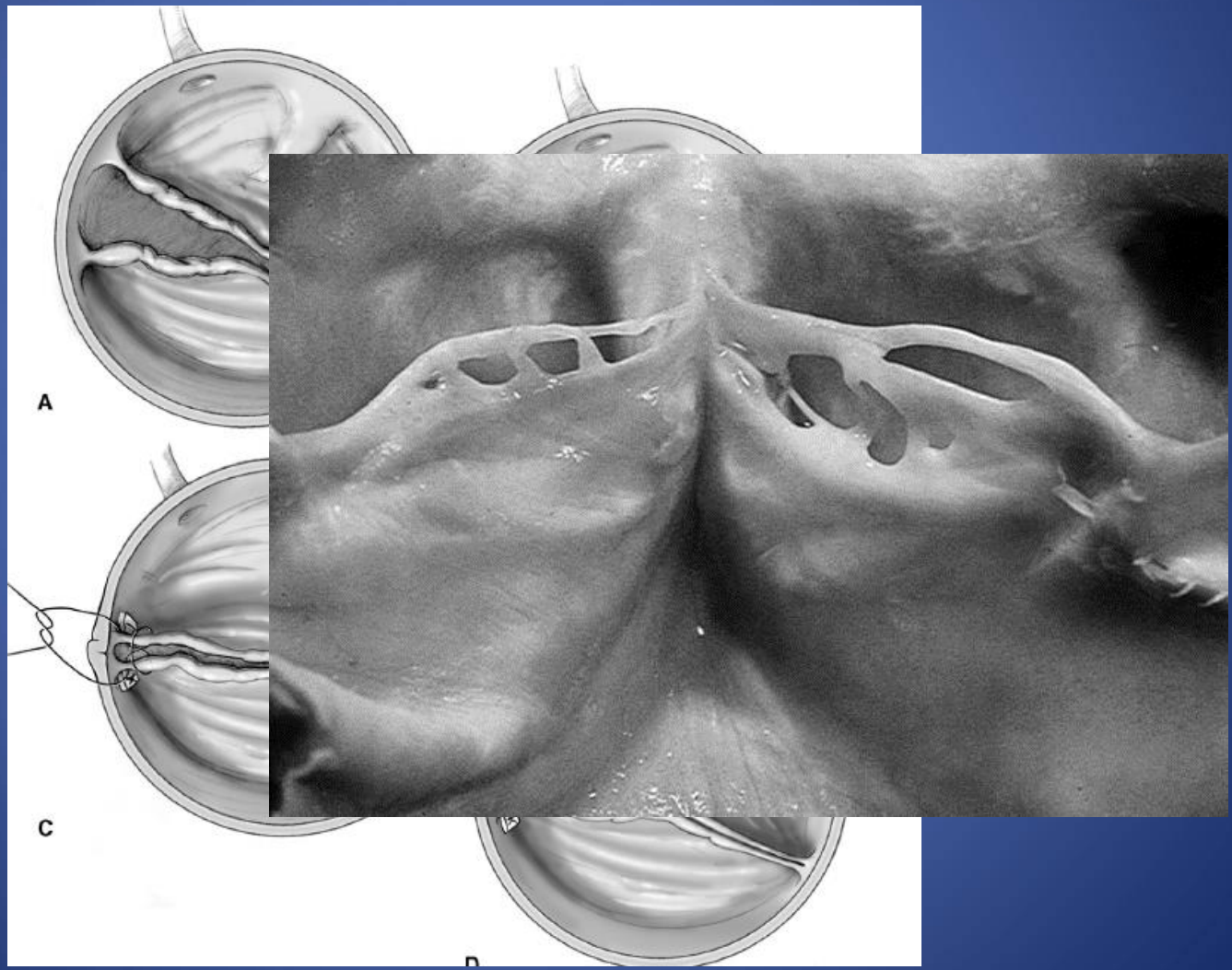
Freedom from reoperation after BAV repair depending on the use of a pericardial patch

Other materials(Cor-matrix, Gortex membrane, Cardiocell)



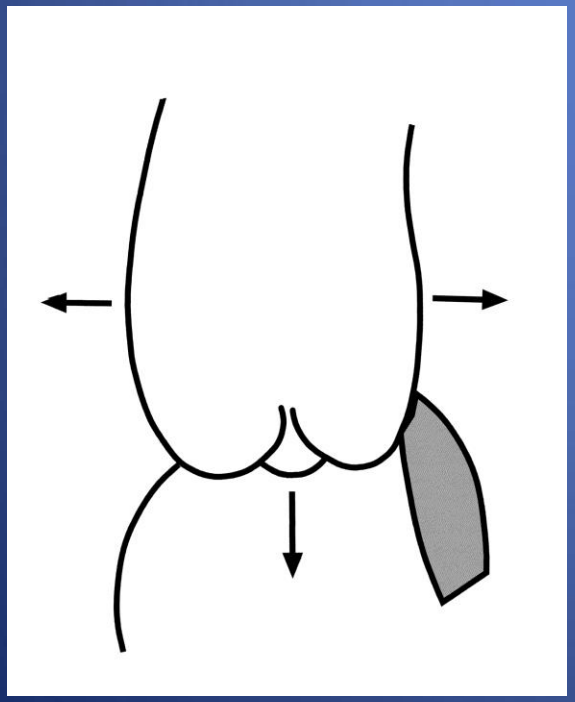
Aicher D et al. Circulation 2011;123:178-185

Commissural Pathologies

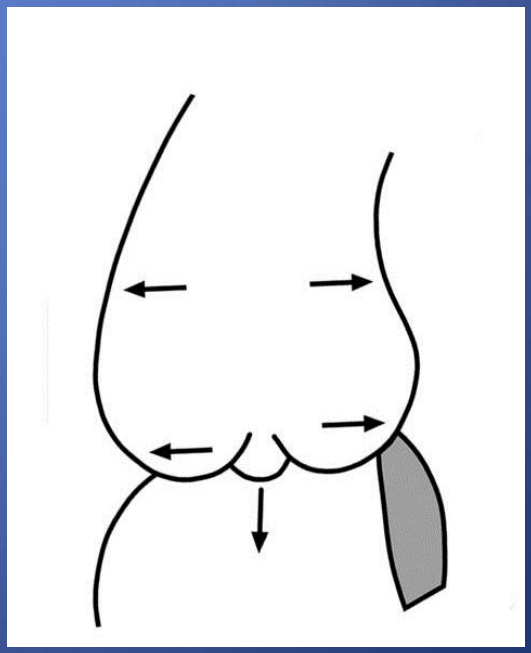


Dysfunction of Aortic Root Causing AR

Sinu-tubular Dilatation

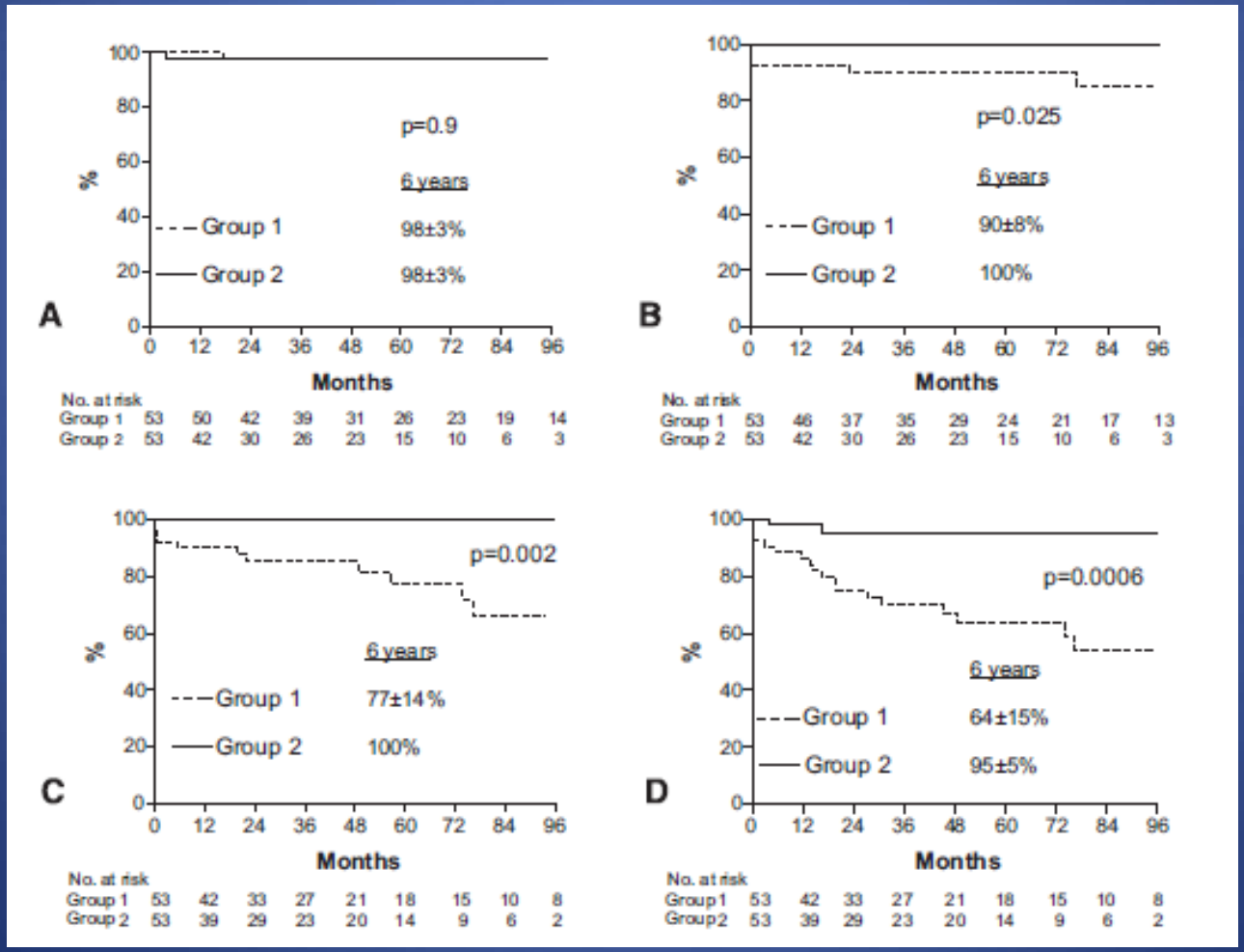


Sinu-tubular +/or Annular Dilatation



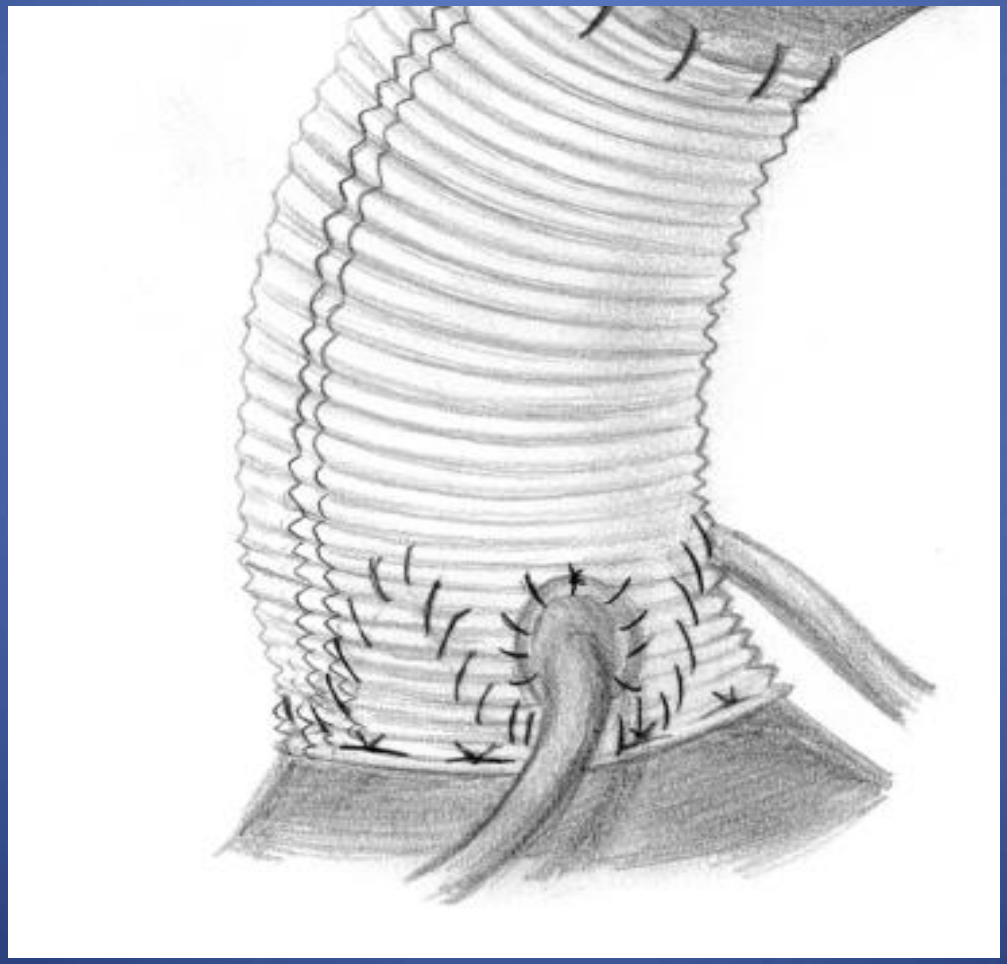
Valve sparing-root replacement with the reimplantation technique to increase the durability of bicuspid aortic valve repair

Laurent de Kerchove, MD,[a] Munir Boodhwani, MD, MMSC,[d] David Glineur, MD,[a] Michel Vandyck, MD,[b] Jean-Louis Vanoverschelde, MD, PhD,[c] Philippe Noirhomme, MD,[a] and Gebrine El Khoury, MD[a]

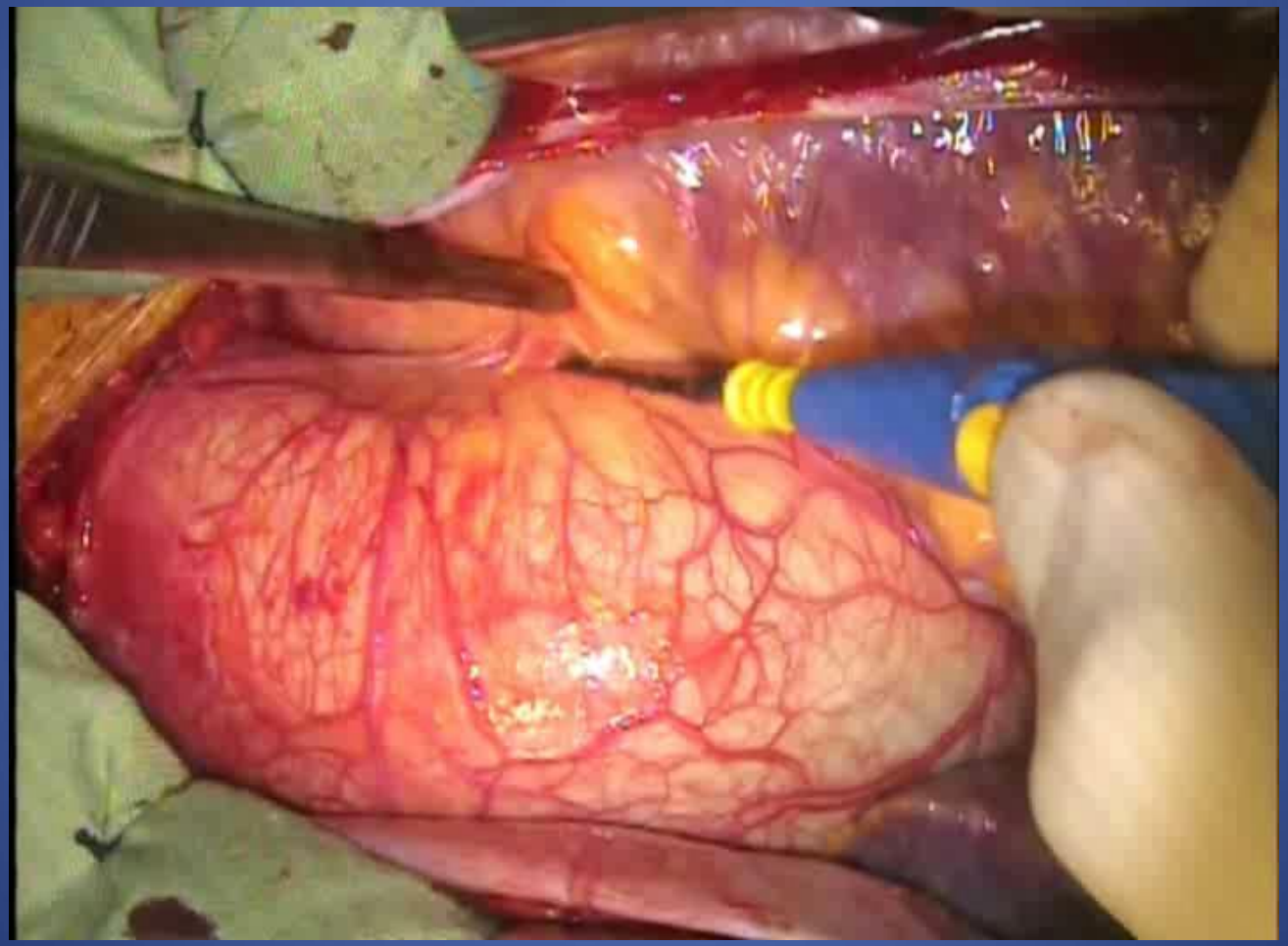


JTCVS 2011

Re-Implantation (David)

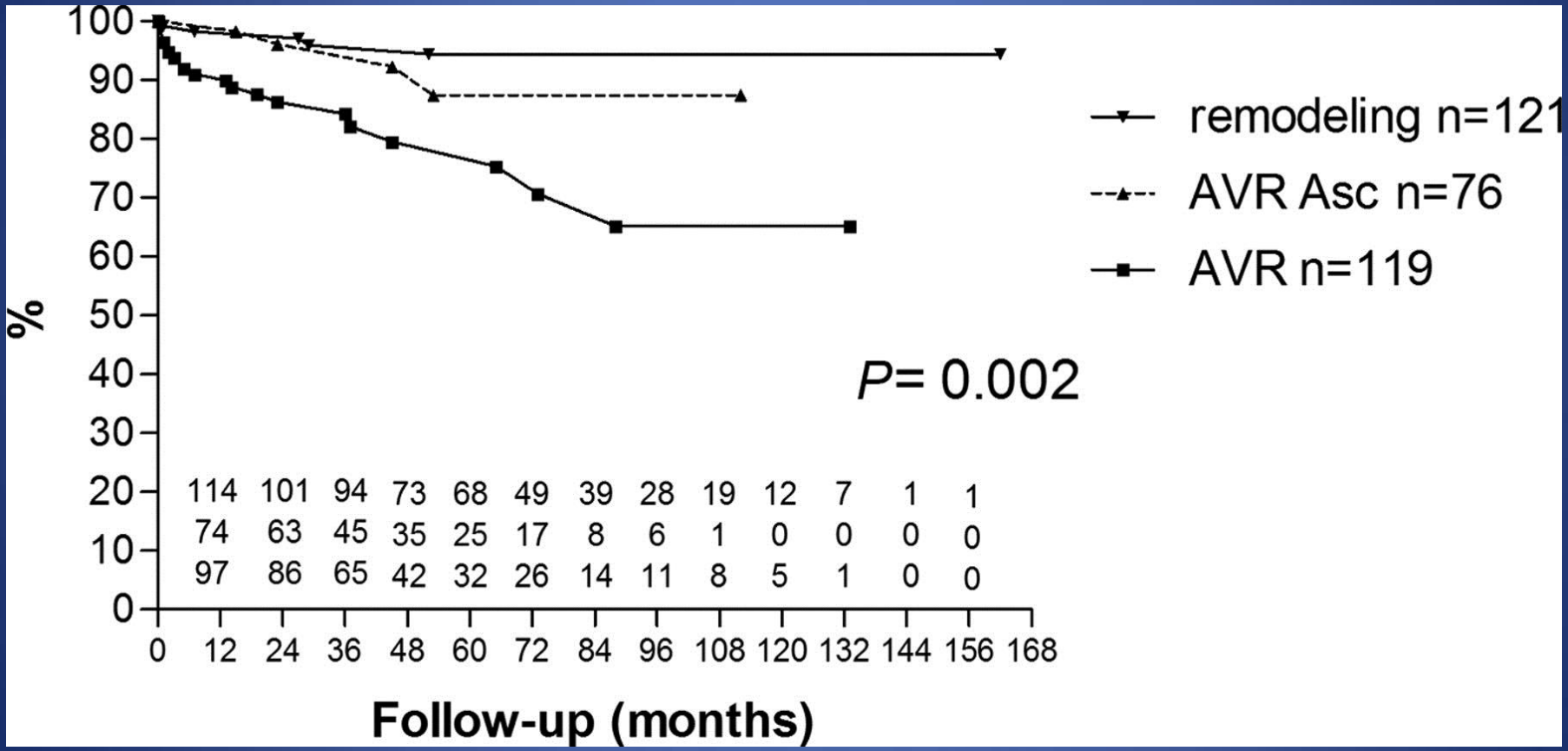


Reimplantation BAV



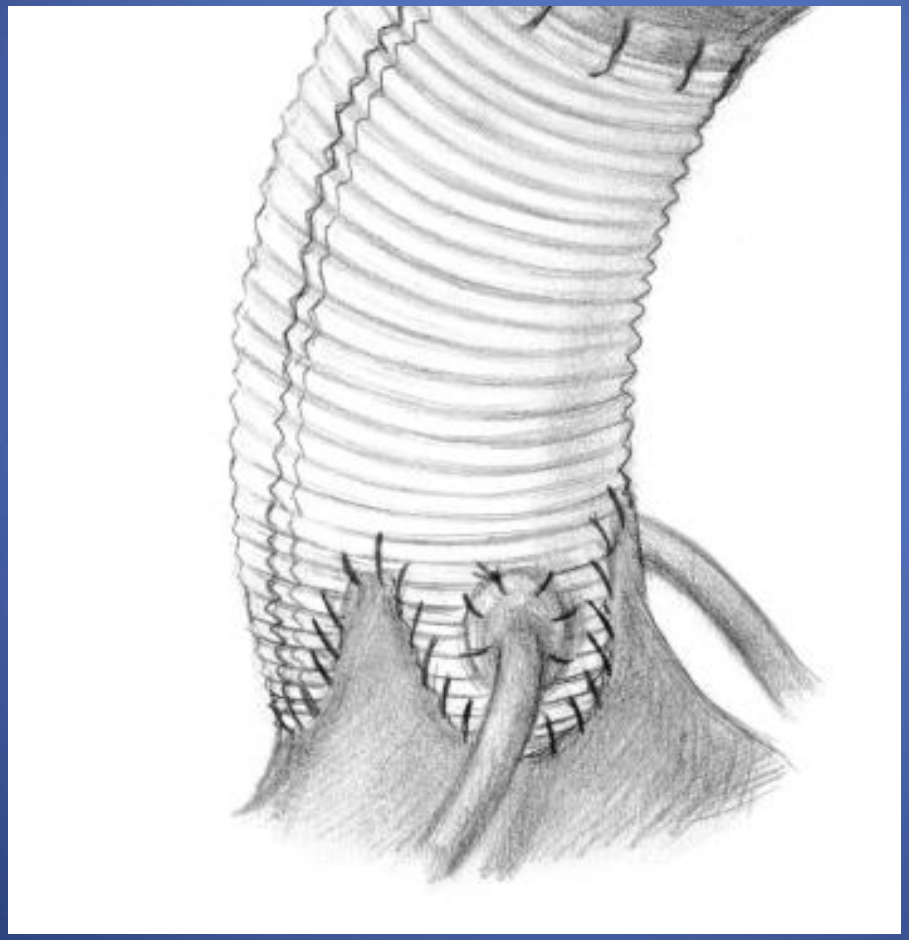
Freedom from reoperation after BAV repair depending on operative technique.

Root stabilization is important

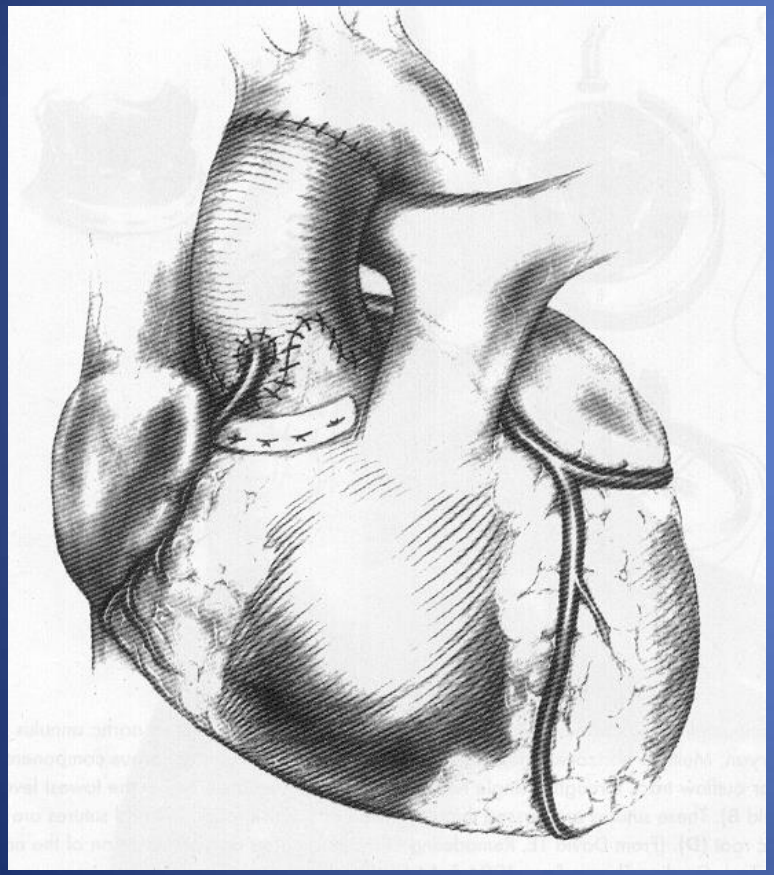


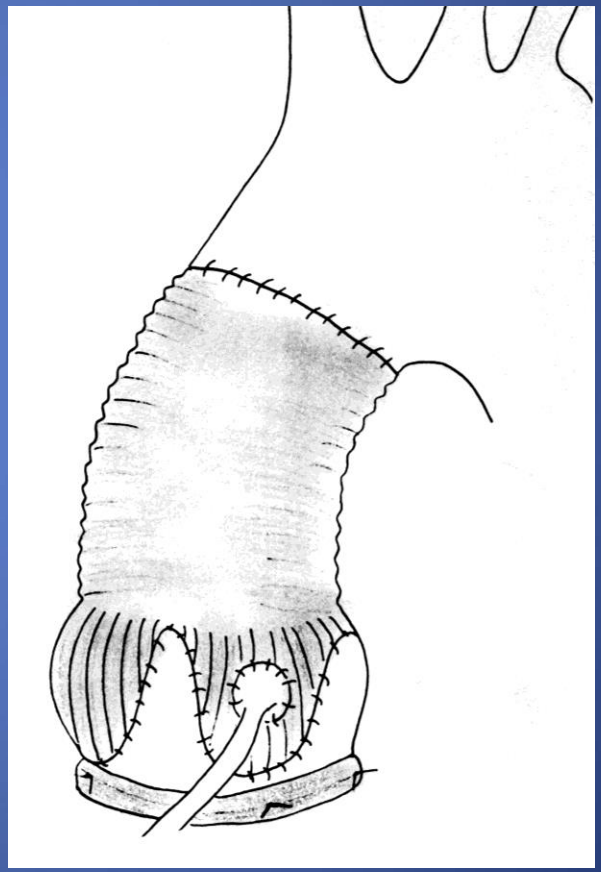
Aicher D et al. Circulation 2011;123:178-185

Root Remodeling (Yaacoub)



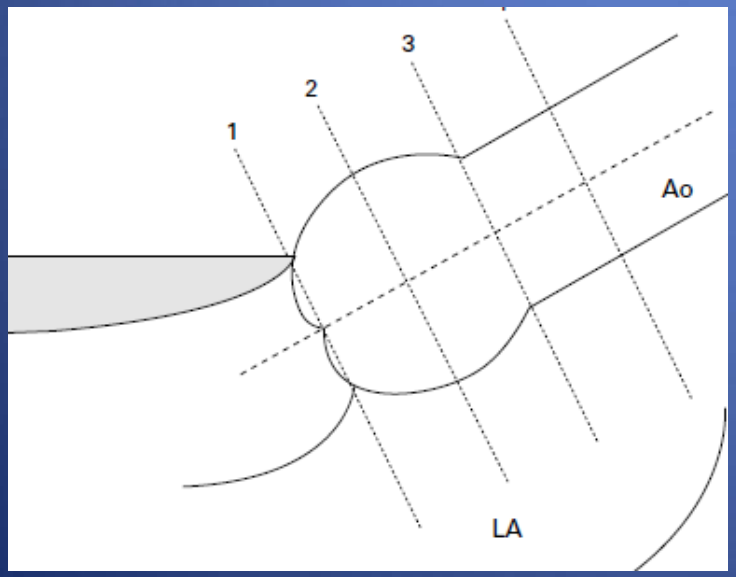
Remodeling and Correction of Dilated Annulus (D3, Lansac)





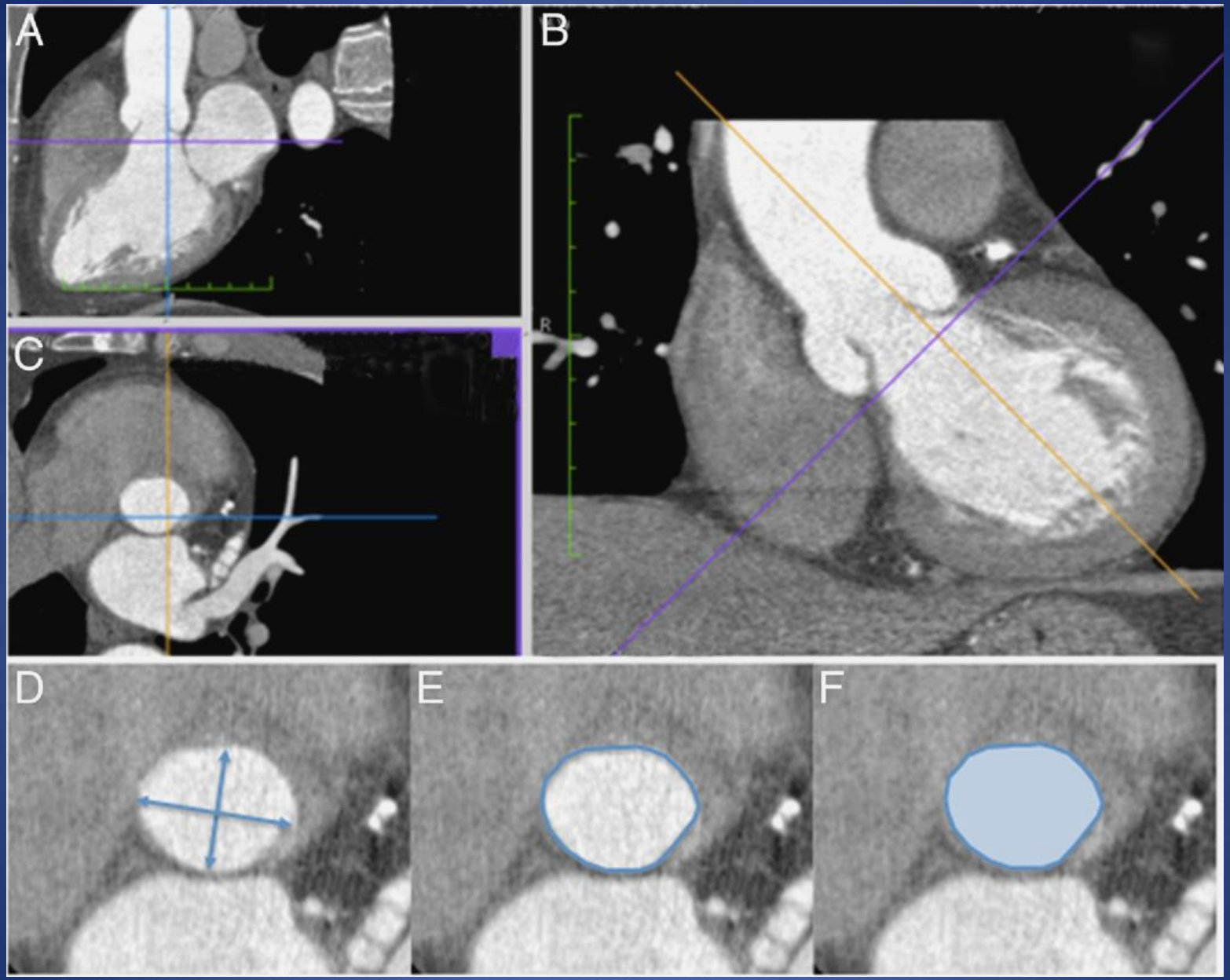
What are normal annular diameters?

	Roman 1987	Kim 1996	Nistri 1999	Varnous 2003	Maselli 2005	Babaee 2007	Tamas 2007	Soncini 2009	Bierbach 2010	Zhu 2011
N	1132									
Annular Ø	22.3±1,4 (20.5-32.4)									
STJ Ø	26.7±2.2 (31.2-23.4)									
STJ/ annulus	1.2±0.1 (1.1-1.3)									



Courtesy E Lansac

BAV have dilated AV junction:25-30mm

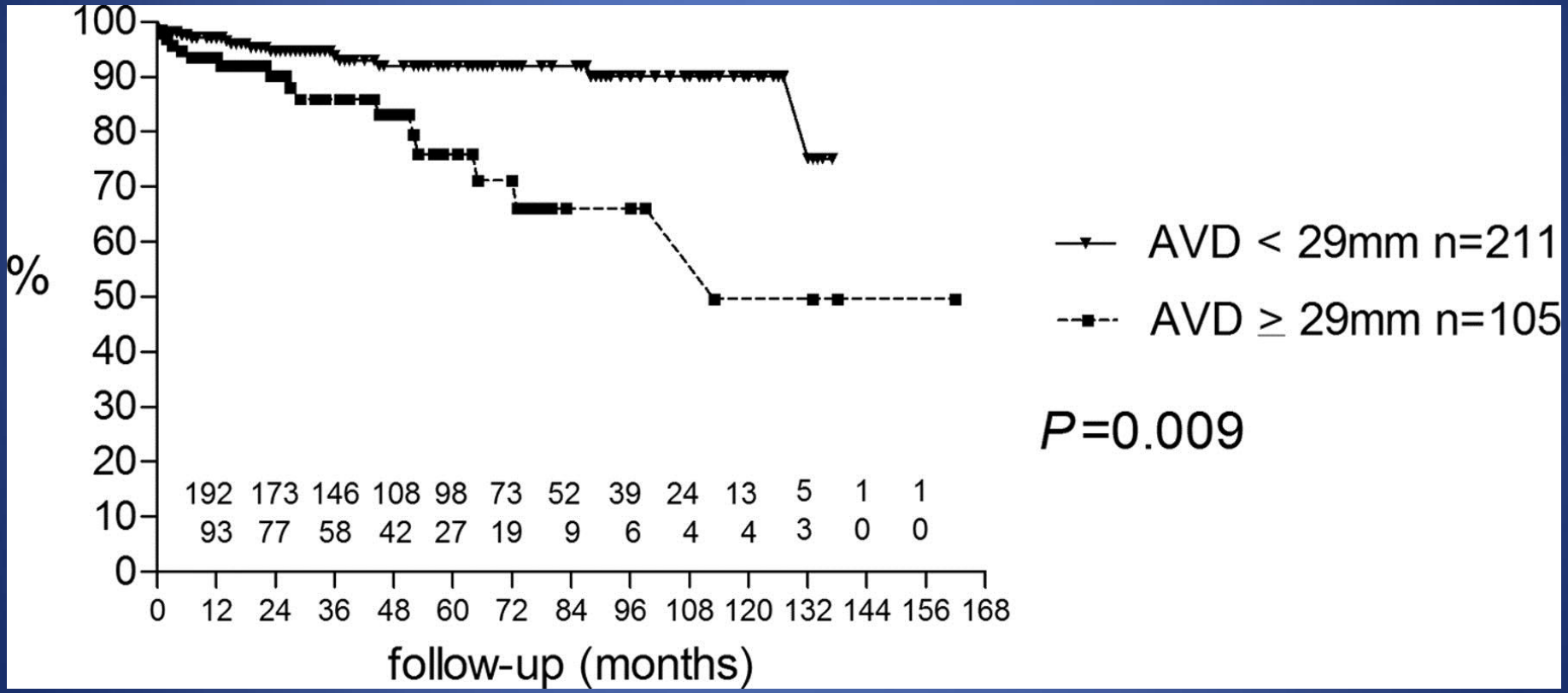


Courtesy A. Hamdan

Dilated Aortic Annulus
Is Very Common
in Patients with BAV and AI

Is it Important?

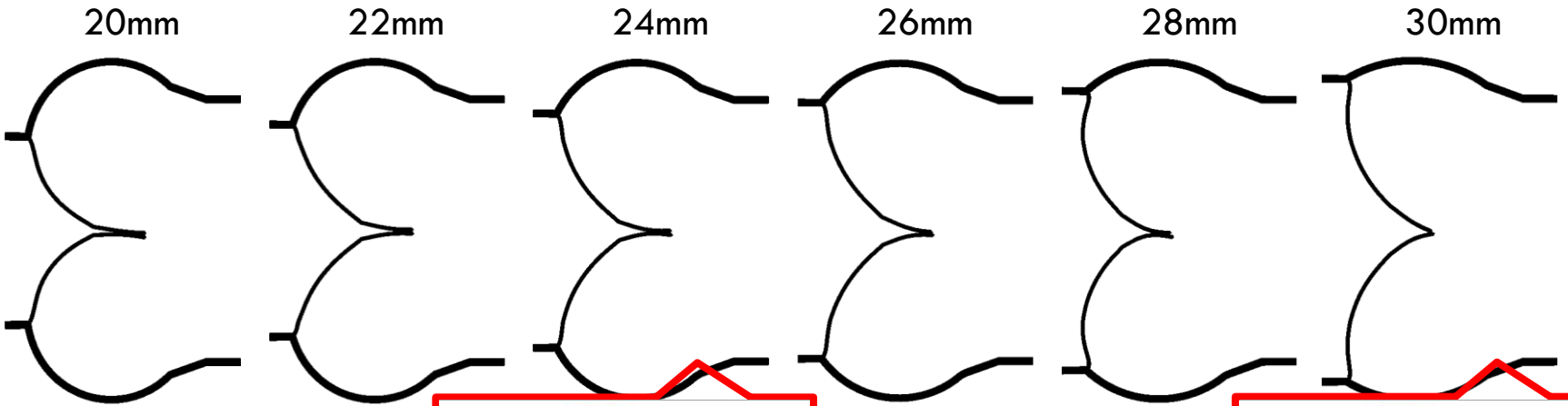
Freedom from reoperation after BAV repair depending on preoperative AVD.



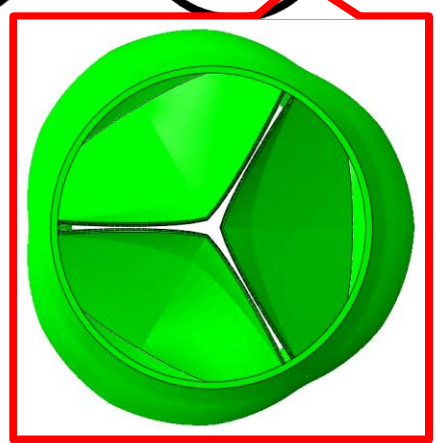
Aicher D et al. Circulation 2011;123:178-185

Effect of annulus diameter

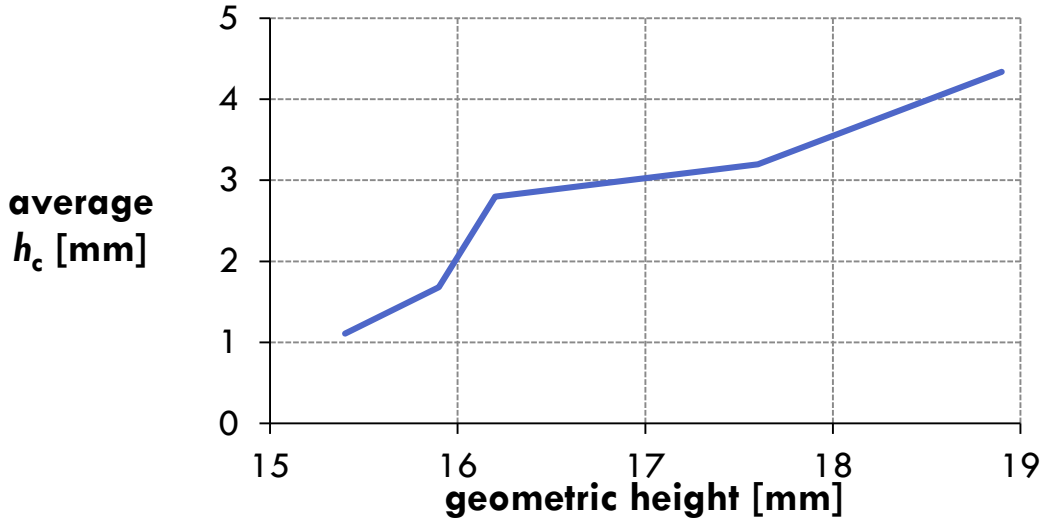
- Six geometries with different annulus diameters
  - Calculated by expanding or shrinking the AA of normal case (24mm)
  - The other dimensions were not changed

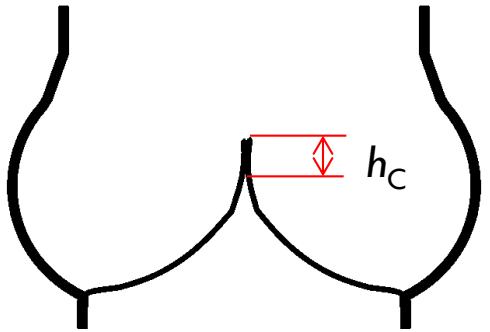


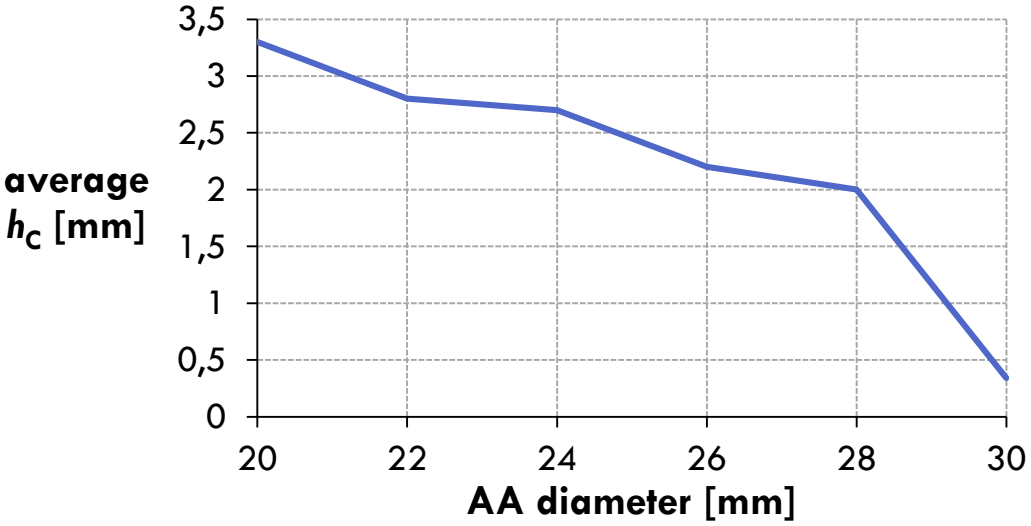
C-C section

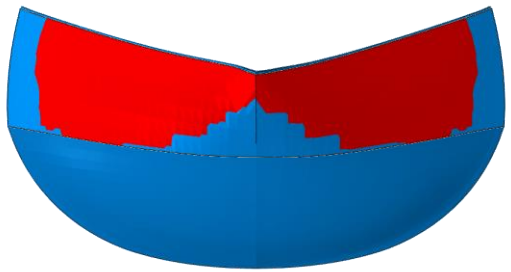


Influence of the geometry on coaptation



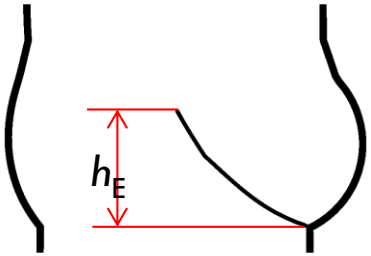


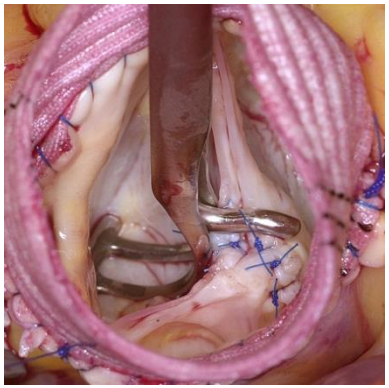


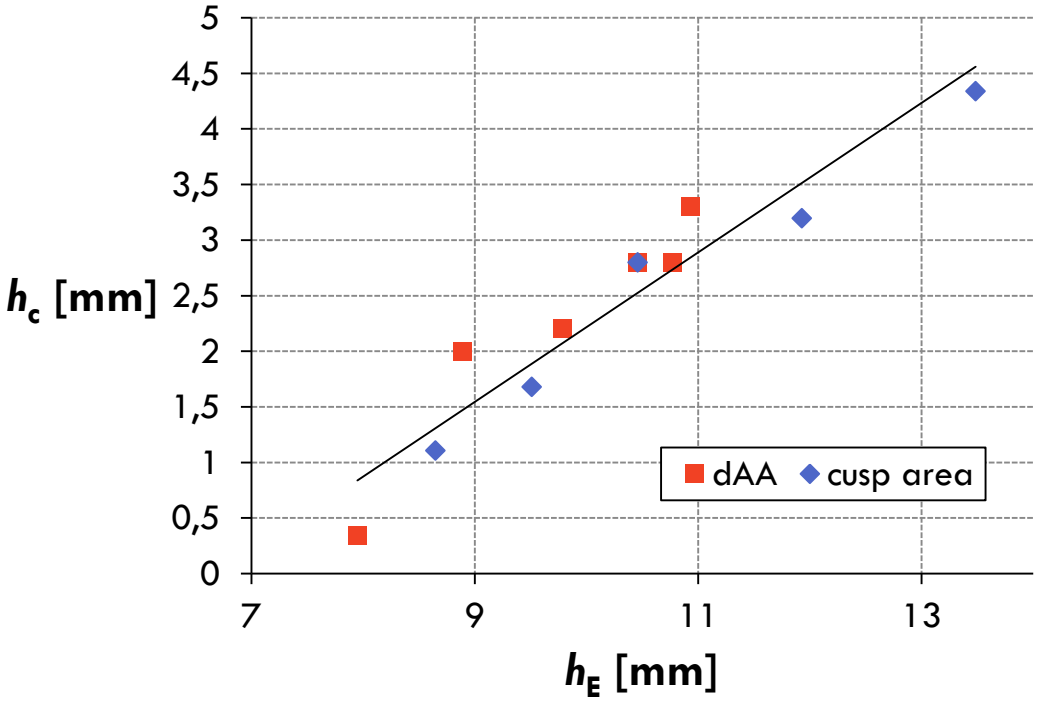


Coaptation vs. effective height

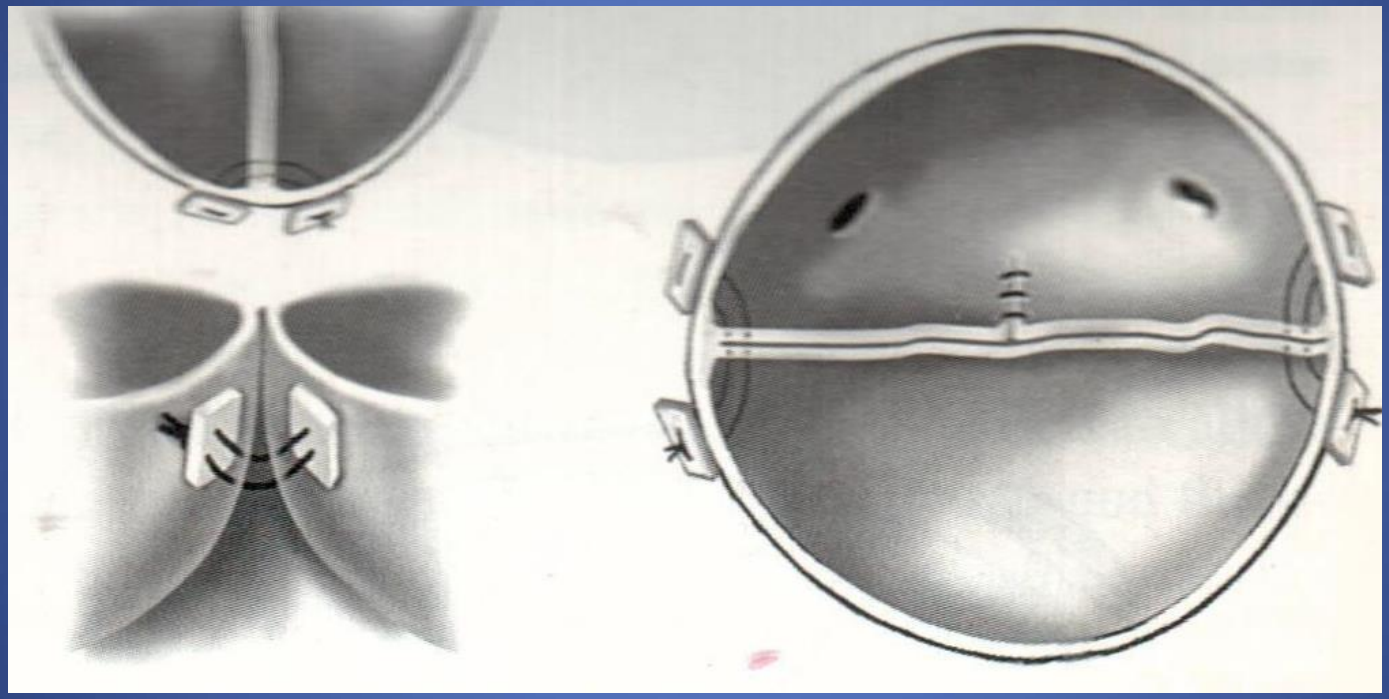
- Comparison of coaptation during diastole as a function of the effective height
- The effective height correlates well with valve coaptation
- The cusps in all the cases with h_E<9mm prolapsed during diastole





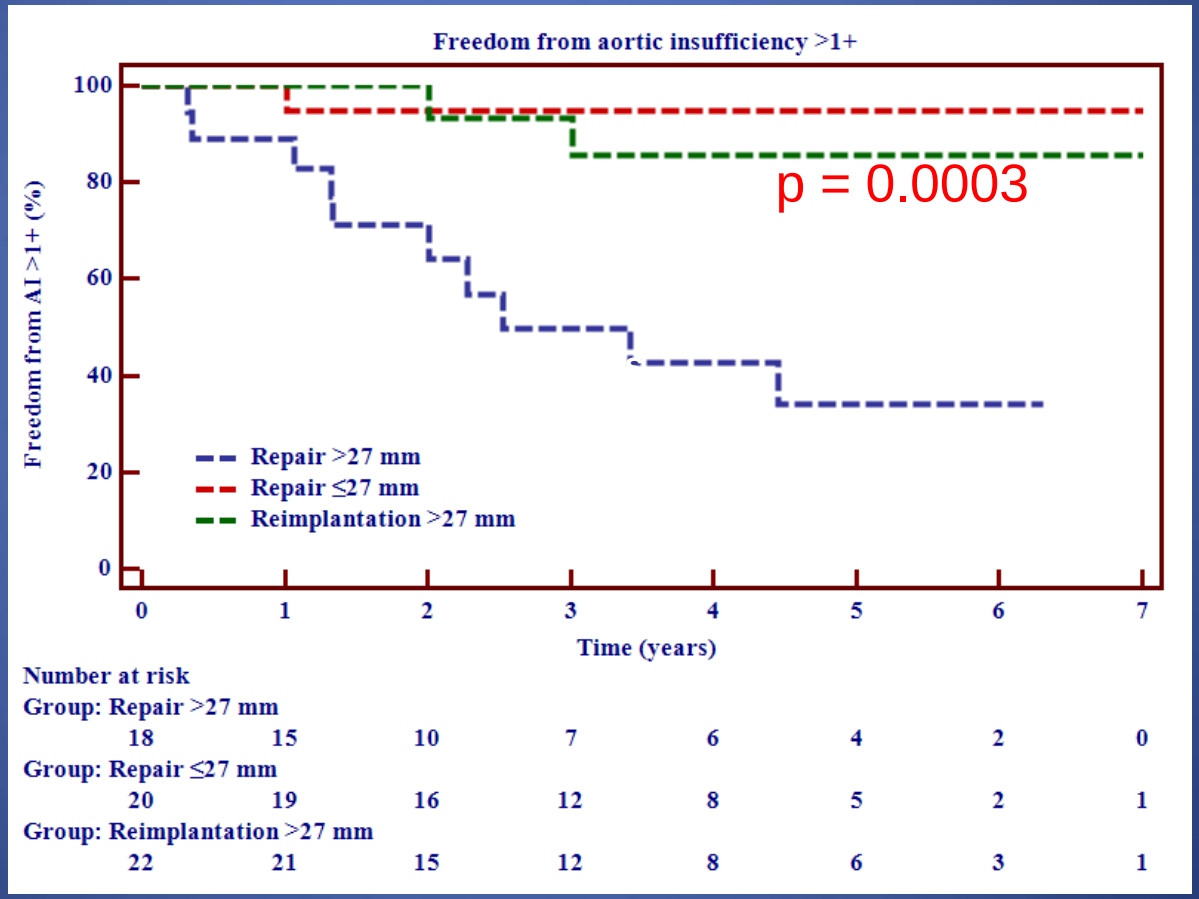


Dilated AVJ, What are the options?



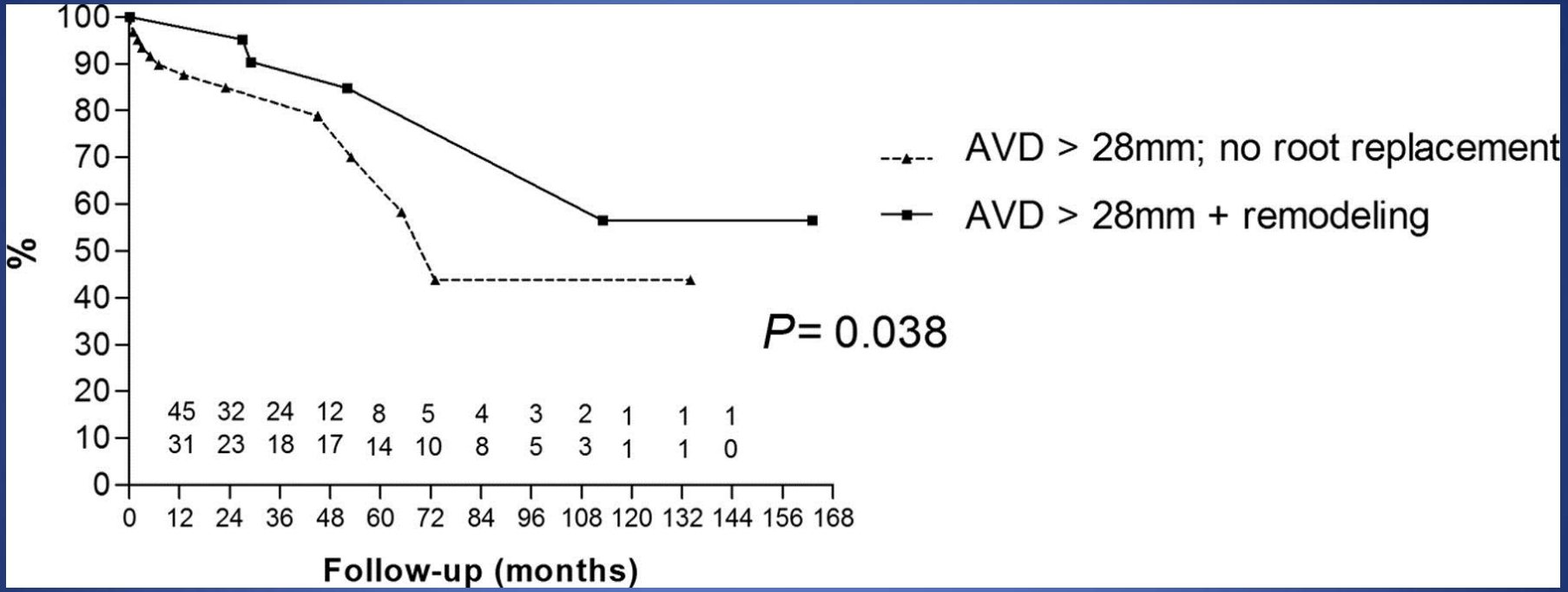
Sub-Commissural Annuloplasty

BAV repair (SCA) with dilated annulus (> 27mm): fails in short term



J. Bavaria et al: STS 2013

Freedom from reoperation after BAV repair in patients with preoperative AVD of >28 mm depending on the use of root replacement.

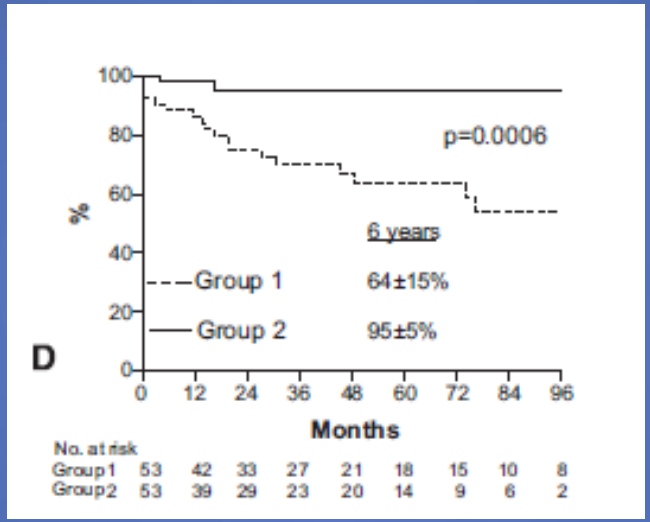


Significant failure in patients with a > 28 mm Annulus whether they have a SCA or “Remodeling” Root.

Aicher D et al. Circulation 2011;123:178-185

Valve sparing-root replacement with the reimplantation technique to increase the durability of bicuspid aortic valve repair

Laurent de Kerchove, MD,[a] Munir Boodhwani, MD, MMSC,[d] David Glineur, MD,[a] Michel Vandyck, MD,[b] Jean-Louis Vanoverschelde, MD, PhD,[c] Philippe Noirhomme, MD,[a] and Gebrine El Khoury, MD[a]

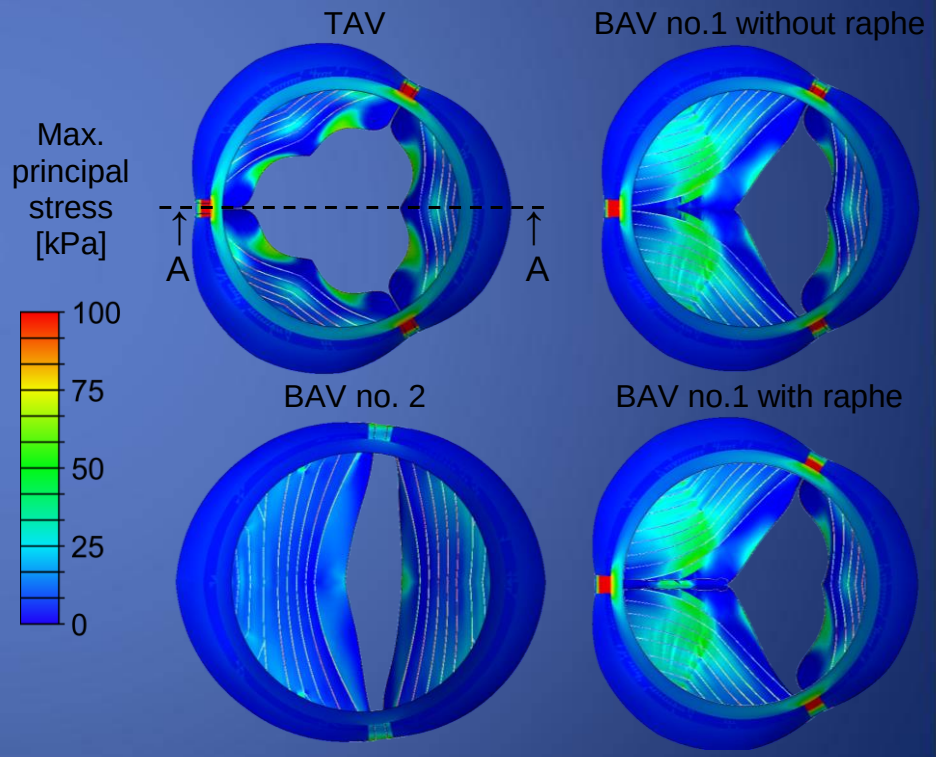


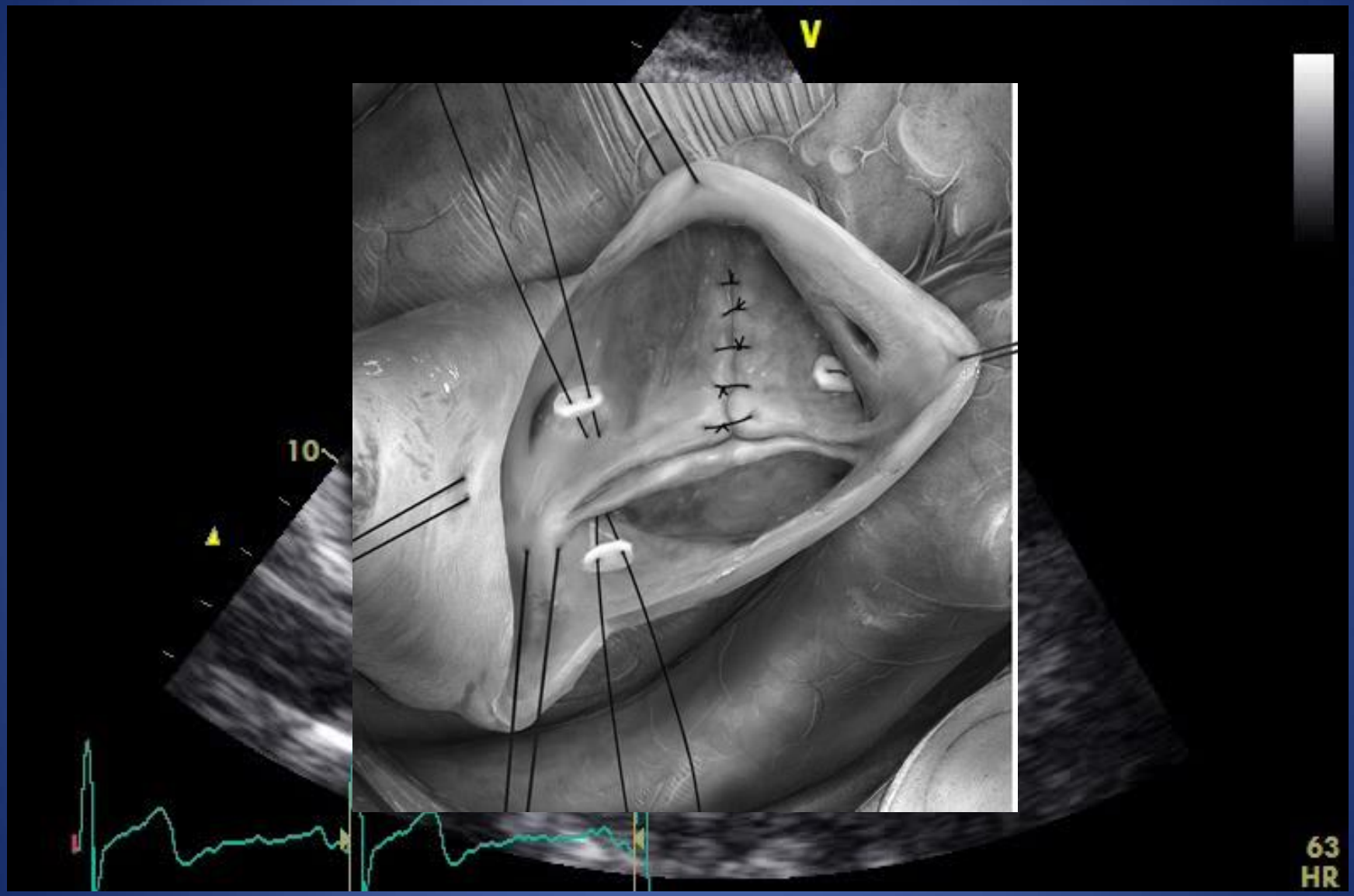
Peak gradient			
≤20 mm Hg	25 (51%)	42 (81%)	
21–30 mm Hg	14 (29%)	7 (13%)	.006
>30 mm Hg	10 (20%)	3 (6%)	

All data represent numbers and percentages of patients. *Early reoperation excluded.

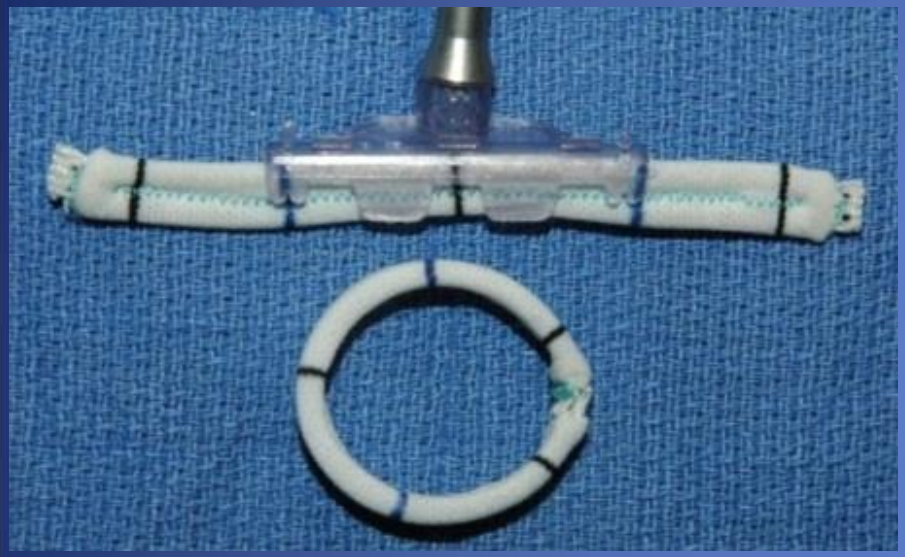
Computer Finite Element Model Stress during peak systole

- TAV has the largest opening area
- Highest stress values are found in BAVs with fused cusps
- Raphe region increases stress magnitudes



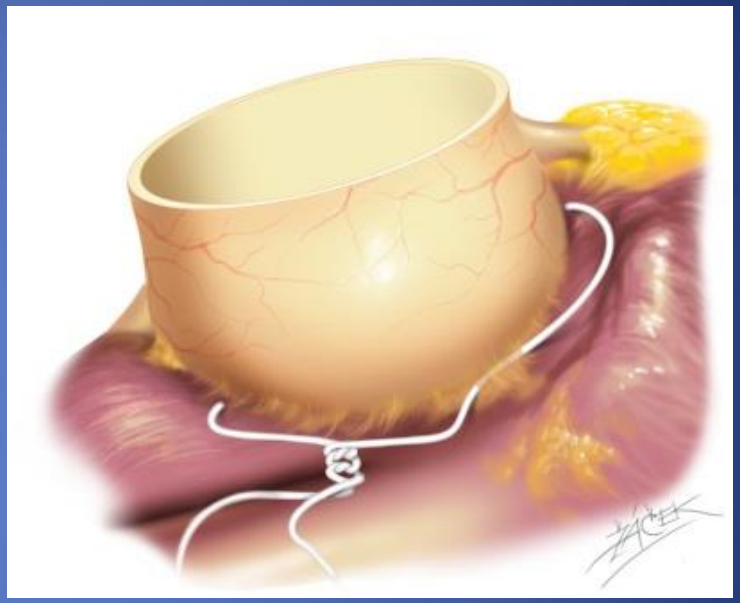

V
10
63
HR

Expansible Band



Lansac 2006

PTFE annuloplasty



Kazui, Svensson, Schäfers 2007

Summary: BAV AR Repair

- Usually requires cusp repair in combination of stabilization of the aortic root (STJ, VAJ)
- Relative contraindications where the results are sub-optimal:
  - Significant cusp calcification
  - The need for patch augmentation
  - Inter-commissural angle<160 degrees
  - The case of the Large Annulus (>28mm) specially in Normal Root Diameter
- Annular dilatation should be addressed but SCA is probably not the best technique

BAV Aortopathy

- Prevalence of dilatation 20-80%

- Genetic or hemodynamic related? Different phenotypes
- What are the “dangerous” size limits?
- Recent guidelines

Observations that May Support Genetic Etiology:

- All aorta segments are larger than in TAV
- Begins in childhood and is progressive
- Autosomal dominant, x-linked, familial modes of inheritances were reported
- Appears also in “normally” functioning AV
- Aortic dilation can occur in BAV pts even after AVR

Other Observations

- BAV frequent (10-15%) in pts with aortic aneurysms or dissections (only 1-2% prevalence of the general population)
- Aortic dissection can occur in BAV pts in the absence of large aneurysm (<4.5 cm)

Aortic root dilatation in young men with normally functioning bicuspid aortic valves

S Nistri, M D Sorbo, M Marin, M Palisi, R Scognamiglio, G Thiene

Table 2 Measurements at different levels in patients with bicuspid aortic valve and controls

	Controls (n = 70)	*Patients (n = 66)*	*p Value*
Annulus	2.27 (0.27)	2.36 (0.31)	NS
Sinuses of Valsalva	2.87 (0.31)	3.16 (0.37)	< 0.001
Supra-aortic ridge	2.47 (0.28)	2.64 (0.46)	0.01
Ascending aorta	2.69 (0.28)	3.12 (0.48)	< 0.001

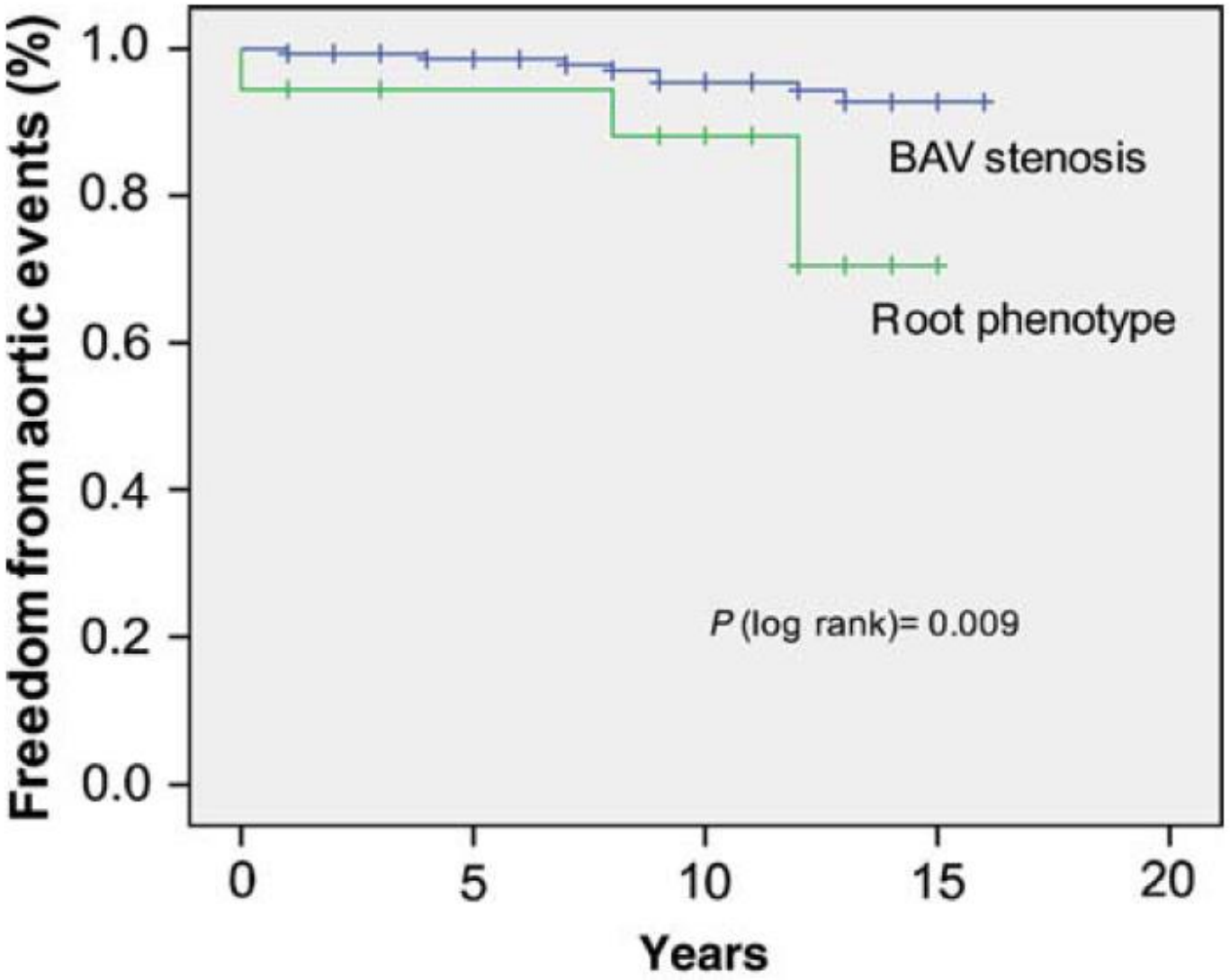
Table 3 Aortic root measurements at different aortic levels in group A and group B patients

	Group A (n = 32)	*Group B (n = 34)*	*p Value*
Annulus	2.23 (0.25)	2.72 (0.49)	< 0.001
Sinuses of Valsalva	2.94 (0.23)	3.35 (0.36)	< 0.001
Supra-aortic ridge	2.38 (0.26)	2.87 (0.46)	< 0.001
Ascending aorta	2.77 (0.2)	3.42 (0.44)	< 0.001

Group A, aortic root dimensions within control limits; group B, aortic root dimensions larger than control limits. Values are cm (mean (SD)).

Heart 1999

Risk of late aortic events after an isolated



the risk of subsequent adverse aortic events and the need for concomitant aortic replacement.

Keywords: Bicuspid aortic valve • Aorta • Aortic complication

Comparison of aortic media changes in patients with bicuspid aortic valve stenosis versus bicuspid valve insufficiency and proximal aortic aneurysm

Evaldas Girdauskas[a,*], Mina Rouman[a], Michael A. Borger[b] and Thomas Kuntze[a]

[a] Department of Cardiac Surgery, Central Clinic Bad Berka, Bad Berka, Germany
[b] Department of Cardiac Surgery, Heart Center Leipzig, Leipzig, Germany

* Correspondi
fax: +49-3645

l: +49-36458541114;

Received 7 Apr

Table 3: Predictors of moderate/severe elastic fibre loss (as determined by multiple regression analysis)

Variables	Odds ratio	*P*-value	95% CI	
BAV insufficiency	9.3	<0.001	3.2	29.8
Proximal aorta maximum diameter[a] (mm)	1.1	0.03	1.01	1.2
Age (years)	1.0	0.9	0.9	1.1
Hypertension	1.4	0.6	0.5	4.1

BAV: bicuspid aortic valve; CI: confidence interval.
[a]As defined by preoperative computed tomography/magnetic resonance tomography.

Abstract

OBJECTIVES: valve replace

METHODS: F men) with B replacement 40–50 mm u assessed (gra Follow-up (6

RESULTS: Me 2+/3+) was fo as the strong Group I vs 93 went redo ac

CONCLUSIO compared to

ts who underwent aortic
y.

age 52.3 ± 13 years, 81%
nt AVR and simultaneous
ding aortic dilatation of
astic fibre loss (EFL) was
ciency (Group II, *n* = 35).

EFL (i.e. defined as grade
entified BAV insufficiency
e survival was 64 ± 8% in
d 1 from Group II) under-

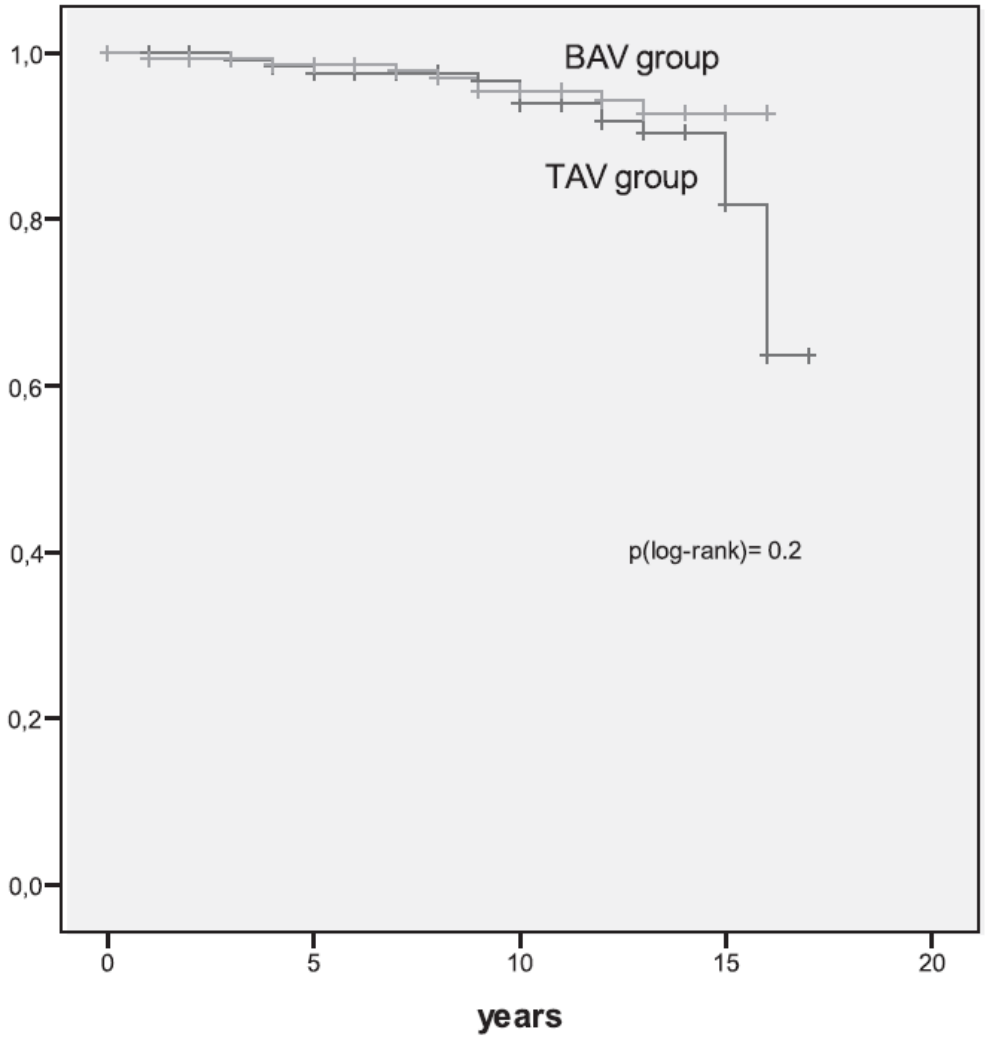
f moderate/severe EFL as

Keywords: Bicuspid aortic valve • Aorta • Aortic complication

Long-term **r aortic valve**
replacemer **stenosis**

Evaldas Girdausk Thomas Kuntze, MD[a]

1995-2 rta 40-
50mm
153 BA
172 TA
FU 356



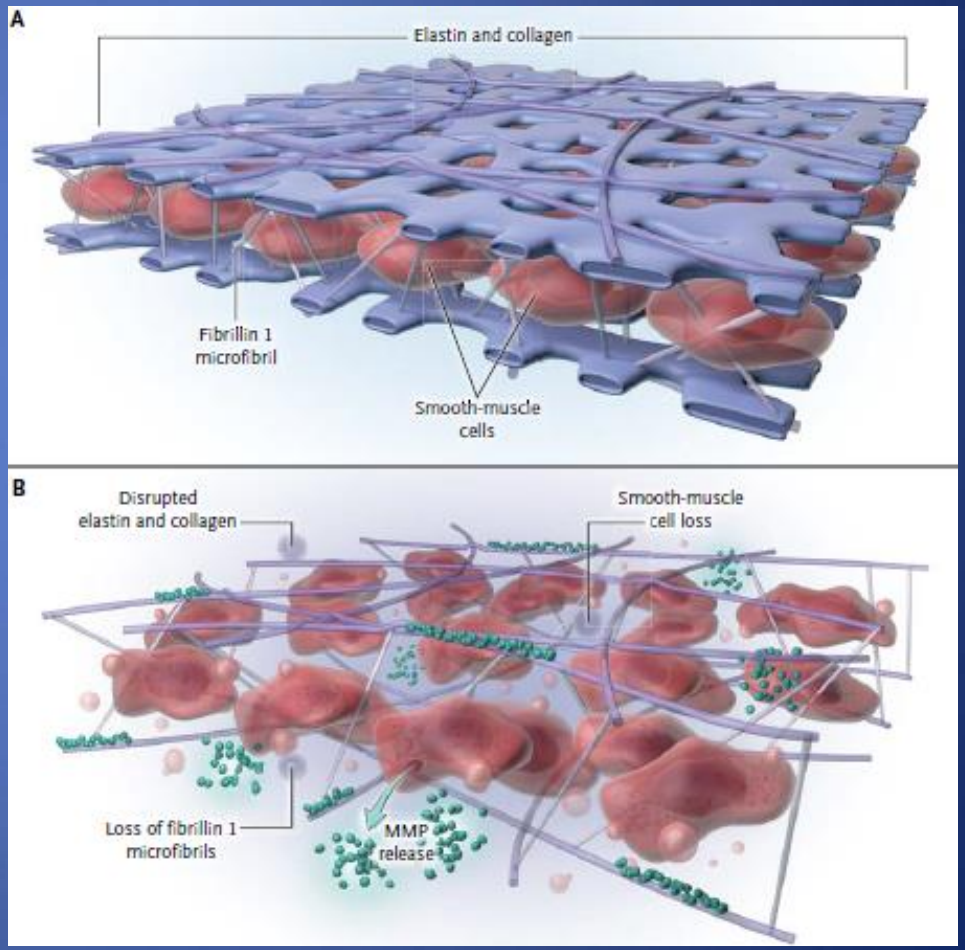
	0	5	10	15
BAV	153	133	113	22
TAV	172	120	102	20

FIGURE 2. Freedom from adverse aortic events (Kaplan-Meier). *BAV,* Bicuspid aortic valve; *TAV,* tricuspid aortic valve.

JTCVS 2014

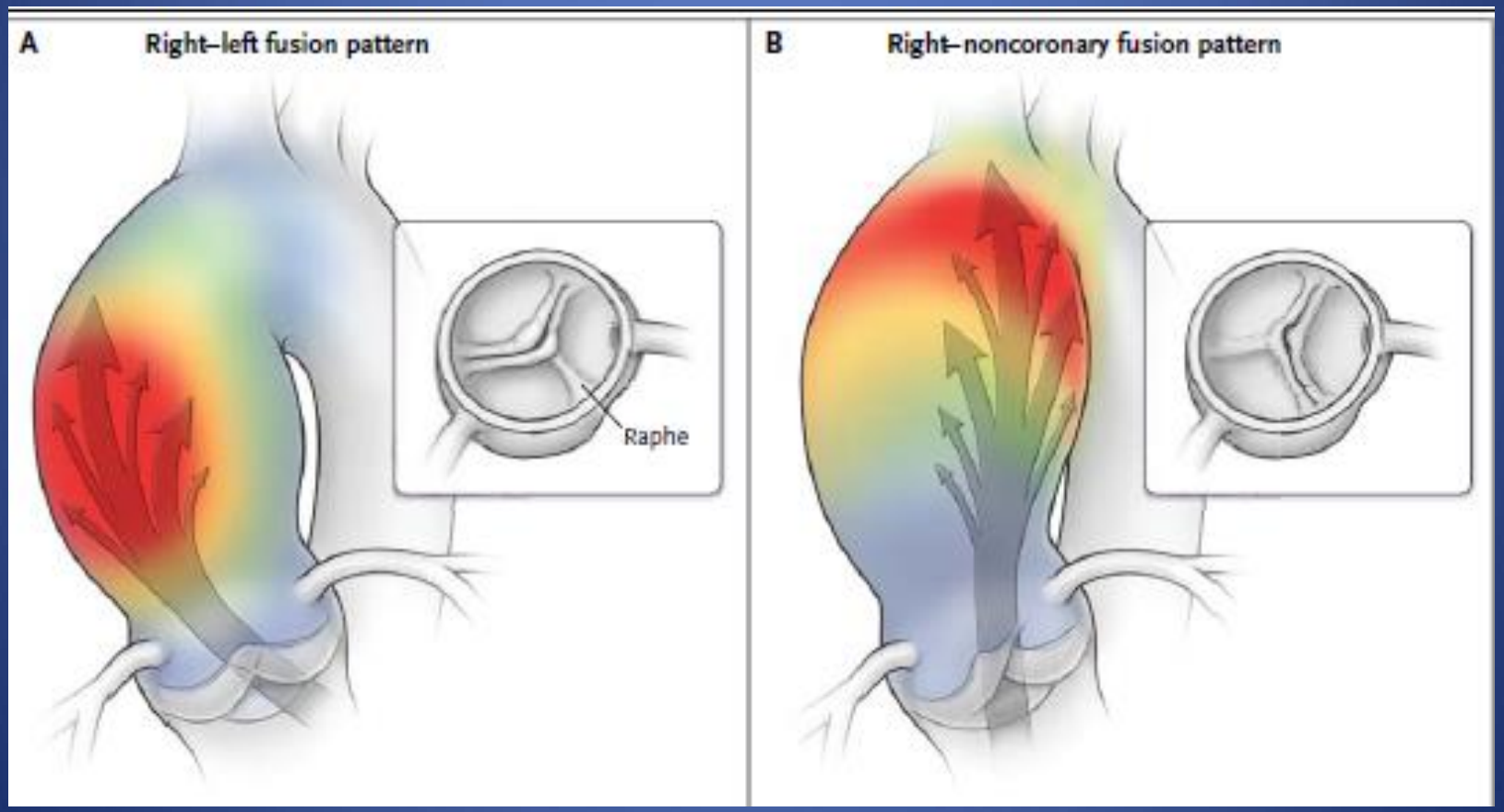
Histology (cystic medial necrosis)

- Abnormal processing of ECM fibrillin 1
- Detachment of smooth muscle layer from ECM
- Release of MMP's and tissue inhibitors
- Disruption of matrix, elastin and all media layer



Verma S, NEJM 2014

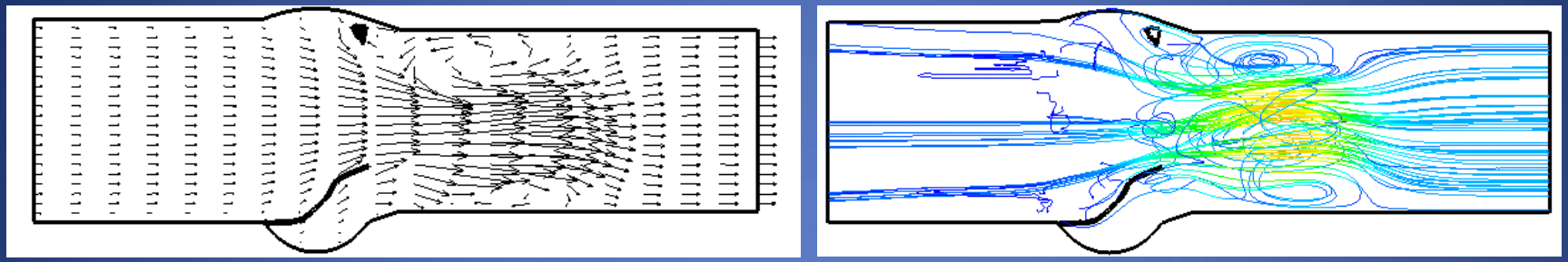
MRI
asymmetric flow jet direction



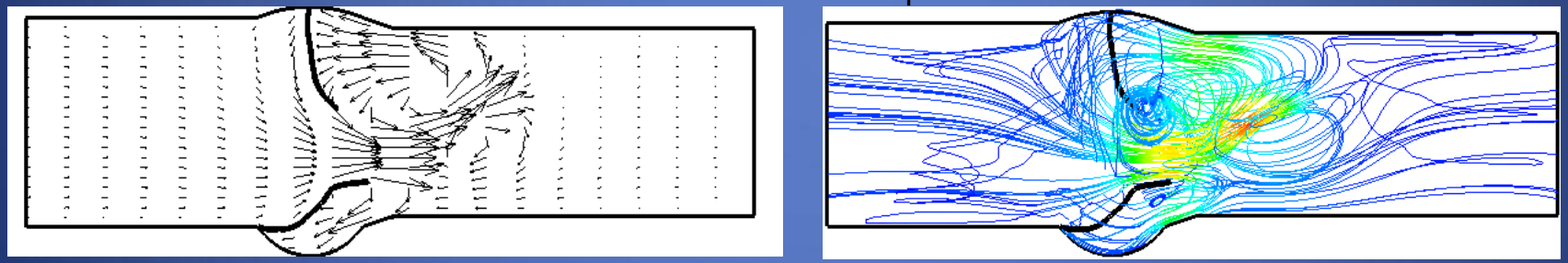
Hope MD radiology 2010
Barker AJ, Circ Cardiovasc Imaging 2012

Abnormal Trans-Valvular Flow Pattern:

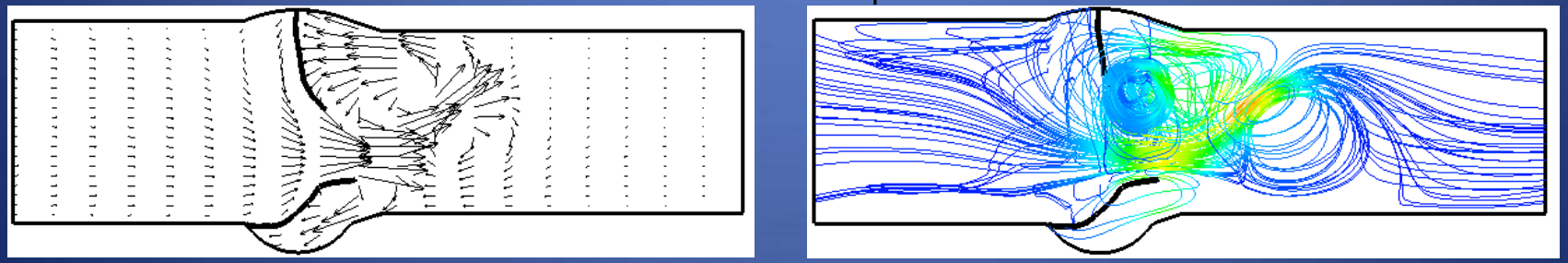
TAV



BAV no. 1 without raphe



BAV no. 1 with raphe



595 BAV patients

Aortopathy and bicuspid aortic valve: haemodynamic burden is main contributor to aortic dilatation

Yong-Giun Kim,[1]
Jong-Min Song,[1]

ABSTRACT

Objective To evaluate enlargement in patients and the impact of isolat

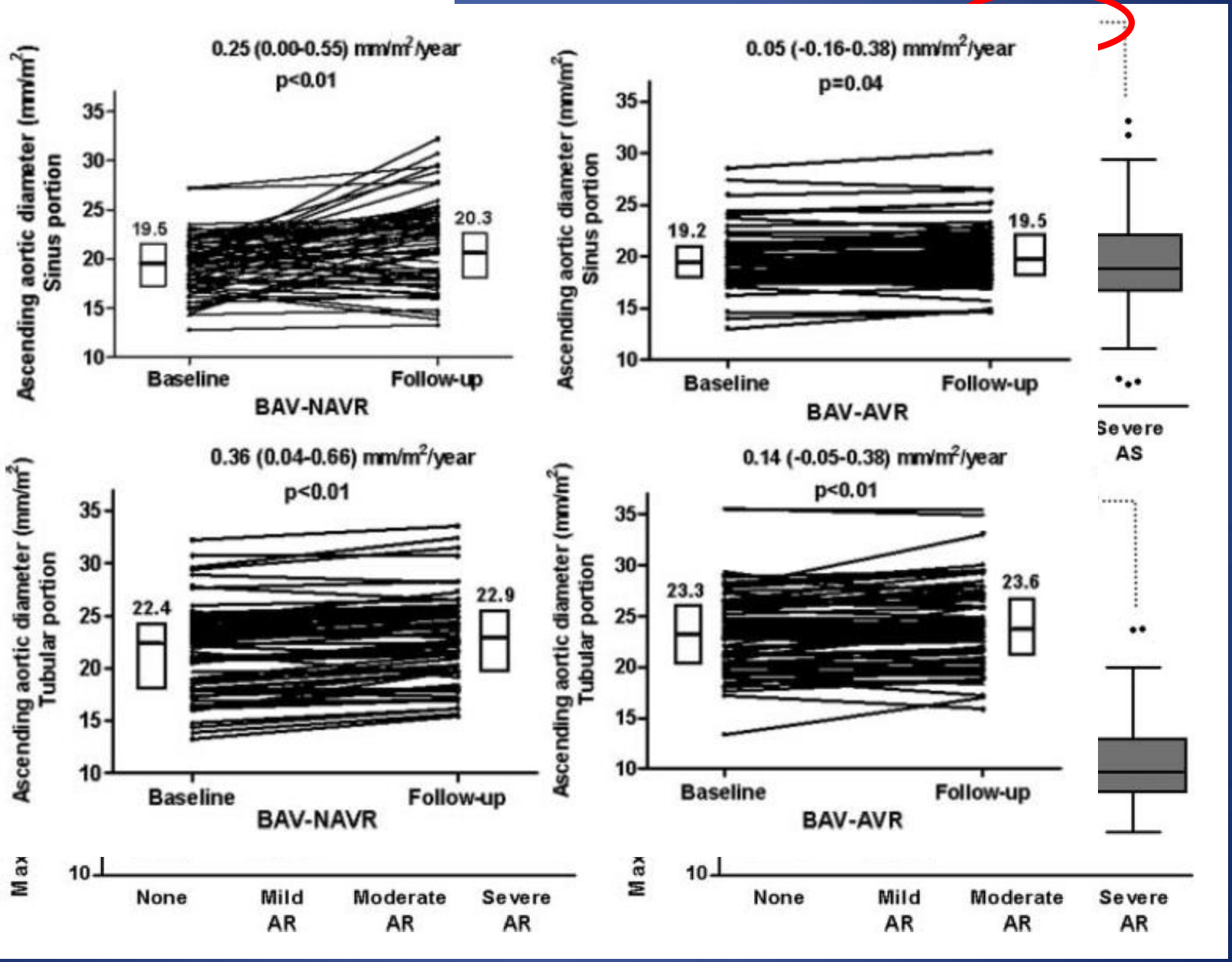
Design and setting data in a tertiary referra

Patients and main ou performed a cross-secti BAV to assess variables aortic dimension. To me baseline and follow-up 70 patients with BAV (B tricuspid aortic valve (T isolated AVR, and comp who did not undergo AV

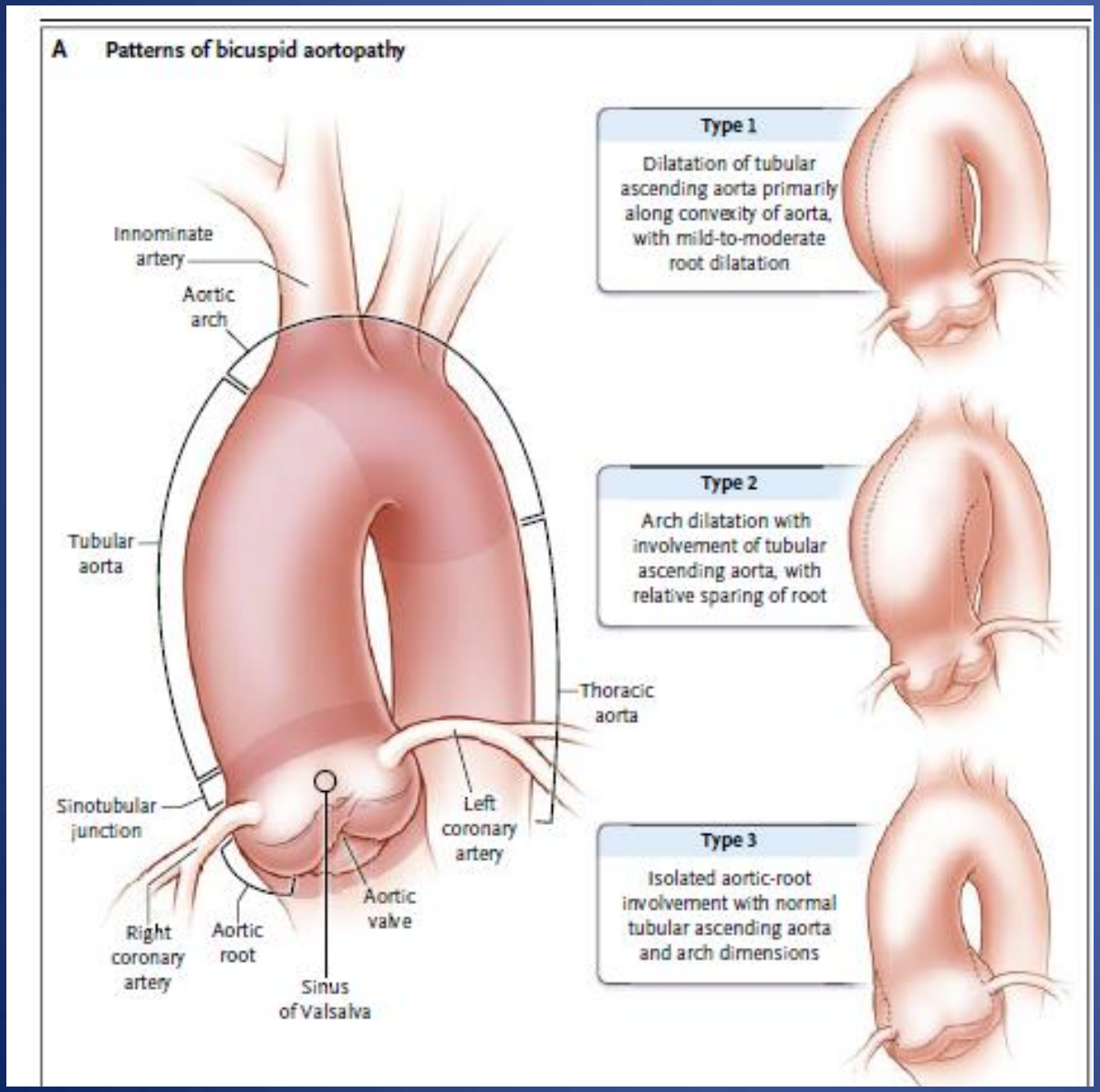
Results Aortic regurgi associated with aortic s whereas aortic stenosis ($p<0.001$). Multivariate independent factor for b with AR severity being moderate to severe aort tubular diameter. Despit prevalence of moderate baseline, the annual dila part were significantly h BAV-AVR and TAV-AVR g not differ in the BAV-AVI for sinus and $p=0.394$

Conclusions Age-dep associated with significa protective effects of iso indicate that valvular dy the development of aort

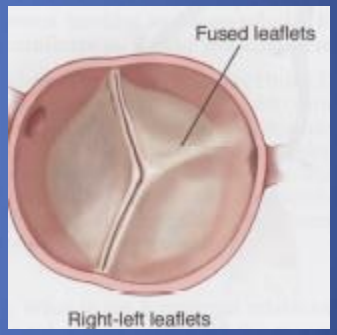
Aortopathy in the b challenging clinical i significantly higher have larger aortic di normal trileaflet aort is an inherent disorde supported by an assc tion in the NOTCH BAV.[4 5] Moreover, reported to be dispro lesions or to be pres cant valve dysfuncti valve replacement (A thought to indicate result of a genetic di



Bicuspid Aortopathy: Different Phenotypes



AS, male, age>50



R-N pattern

AI, male, <40 y genetic

Verma S, NEJM 2014

What is the dangerous size limit?

Aortic Complications After Bicuspid Aortic Valve Replacement: Long-Term Results

Claudio F. Russo, MD, Simone Mazzetti, MD, Andrea Garatti, MD, Elena Ribera, MD, Angela Milazzo, MD, Giuseppe Bruschi, Marco Lanfranconi, MD, Tiziano Colombo, MD, and Ettore Vitali, MD

Division of Cardiovascular Surgery and Division of Cardiology, Echocardiography Service, Niguarda Hospital, Milan, Italy

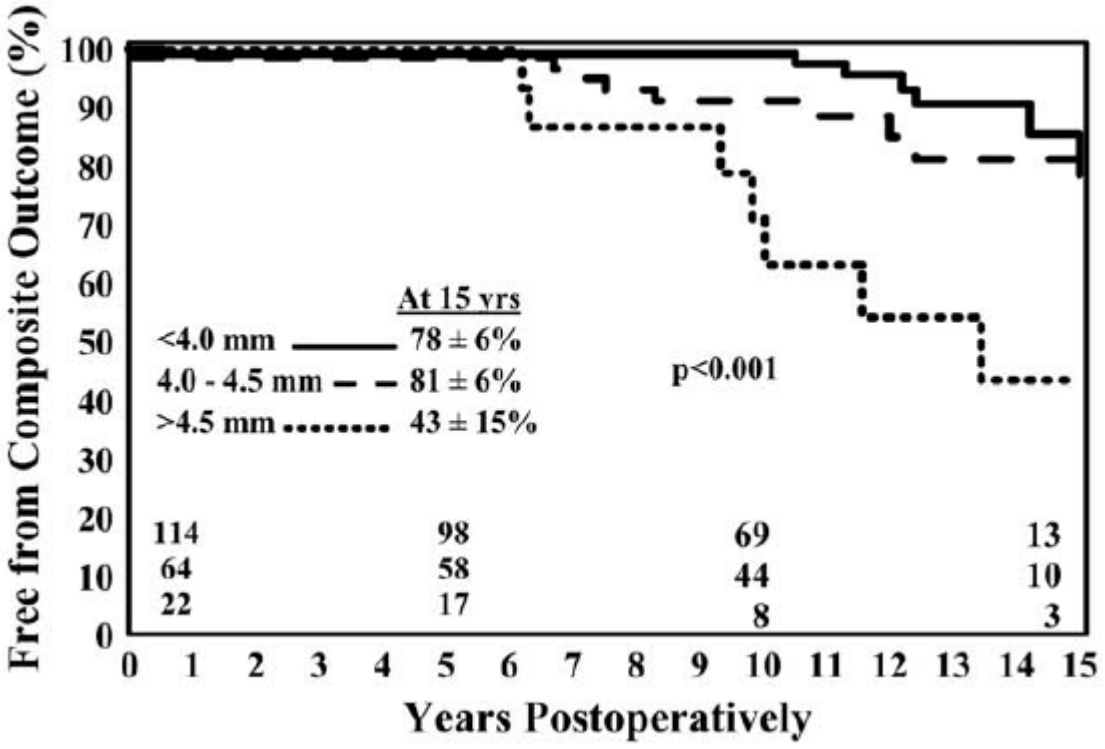
50 BAV (aorta 48.4mm)
50 TAV (aorta 36.8mm)
mean FU˜240 months
BAV -10 events(dissection, sudden death, aorta operation
Recommended prophylactic aorta replacement!!

Ann Thorac Surg 2002

Should the ascending aorta be replaced more frequently in patients with bicuspid aortic valve disease?

Michael A. Borger, MD, PhD[a,b]

201 BAV patients,
underwent AVR with no aorta
followed for mean of 10.3
M
Tu
ed

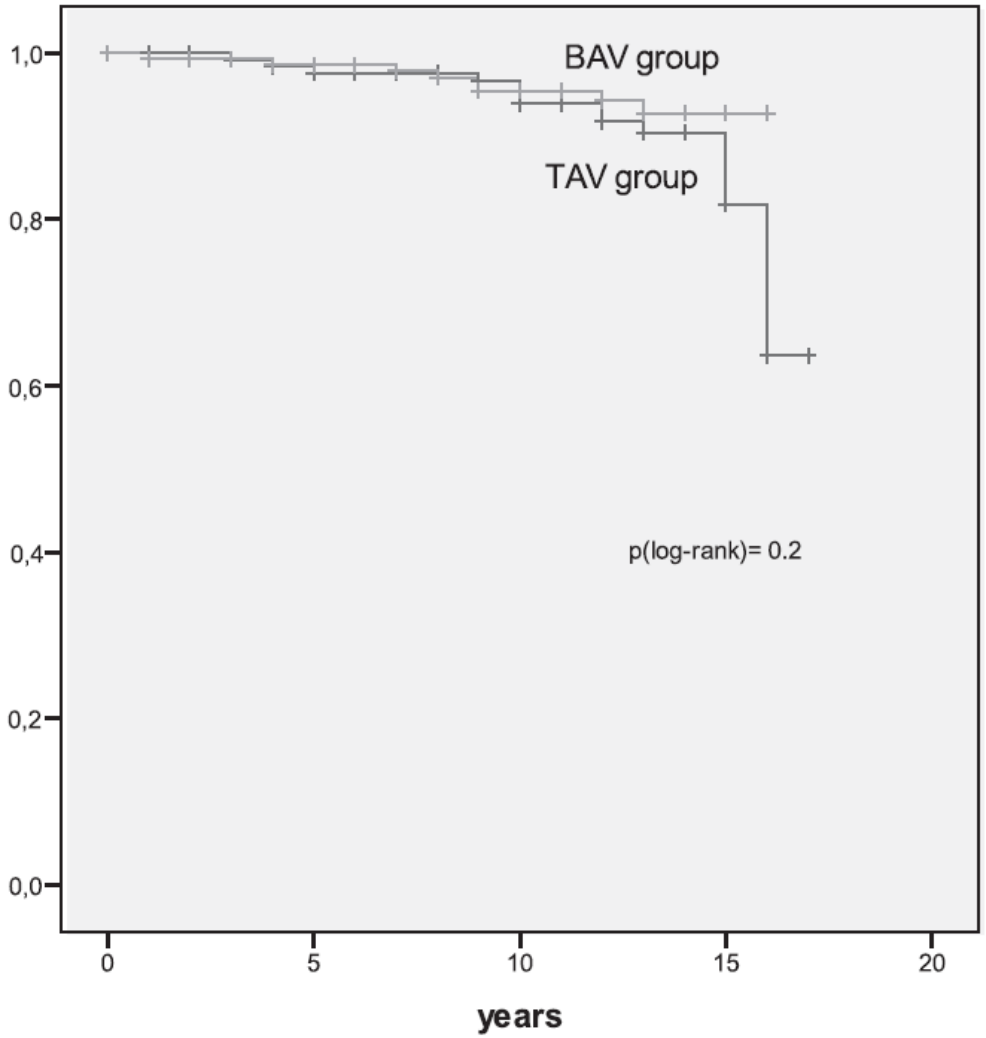


JTCVS 2004

Long-term **r aortic valve**
replacemer **stenosis**

Evaldas Girdausk Thomas Kuntze, MD[a]

1995-2 rta 40-
50mm
153 BA
172 TA
FU 356



	0	5	10	15
BAV	153	133	113	22
TAV	172	120	102	20

FIGURE 2. Freedom from adverse aortic events (Kaplan-Meier). *BAV,* Bicuspid aortic valve; *TAV,* tricuspid aortic valve.

JTCVS 2014

2014 AHA/ACC Guideline for the Management of Patients With Valvular Heart Disease

Class IIa

Class IIa

2. Replacement of the ascending aorta is reasonable in patients with a bicuspid aortic valve who are undergoing aortic valve surgery because of severe AS or AR (Sections 3.2.3 and 4.3.3) if the diameter of the ascending aorta is greater than 4.5 cm. *(Level of Evidence: C)*

European Heart Journal (2012) **33**, 2451–2496
doi:10.1093/eurheartj/ehs109

ESC/EACTS GUIDELINES

Guidelines on the management of valvular heart disease (version 2012)

Table 8 Indications for surgery in (A) severe aortic regurgitation and (B) aortic root disease (whatever the severi aortic regurgitation)

Surgery should be considered in patients who have aortic root disease with maximal ascending aortic diameter:
≥45 mm for patients with Marfan syndrome with risk factors[f]
≥50 mm for patients with bicuspid valve with risk factors[g]
≥55 mm for other patients

LVEDD >70 mm, or LVESD >50 mm or LVESD >25 mm/m² BSA.[d]	IIa	C
B. Indications for surgery in aortic root disease (whatever the severity of AR)		
Surgery is indicated in patients who have aortic root disease with maximal ascending aortic diameter[e] ≥50 mm for patients with Marfan syndrome.	I	C
Surgery should be considered in patients who have aortic root disease with maximal ascending aortic diameter: ≥45 mm for patients with Marfan syndrome with risk factors[f] ≥50 mm for patients with bicuspid valve with risk factors[g] ≥55 mm for other patients	IIa	C

- For patients who have an indication for surgery on the aortic valve, lower thresholds can be used for concomitant aortic replacement (>45mm) depending on age, BSA, aetiology of valvular disease, presence of a bicuspid aortic valve, and intraoperative shape and thickness of the ascending aorta.[74]
- Lower thresholds of aortic diameters may also be considered in low-risk patients, if valve repair is likely and performed in an experienced centre with high repair rates.

In the “Gray zones” Important Factors to Consider:

- Age
- AR phenotype
- Indexed to body size (area/height): >10 cm^2/m
- Risk factors:
  - HTN
  - Smoking
  - Any vascular disease (PVD, CAD, CVA)
  - Family history
  - Sport activity
  - Growth rate> 5mm /year
- Surgeon experience

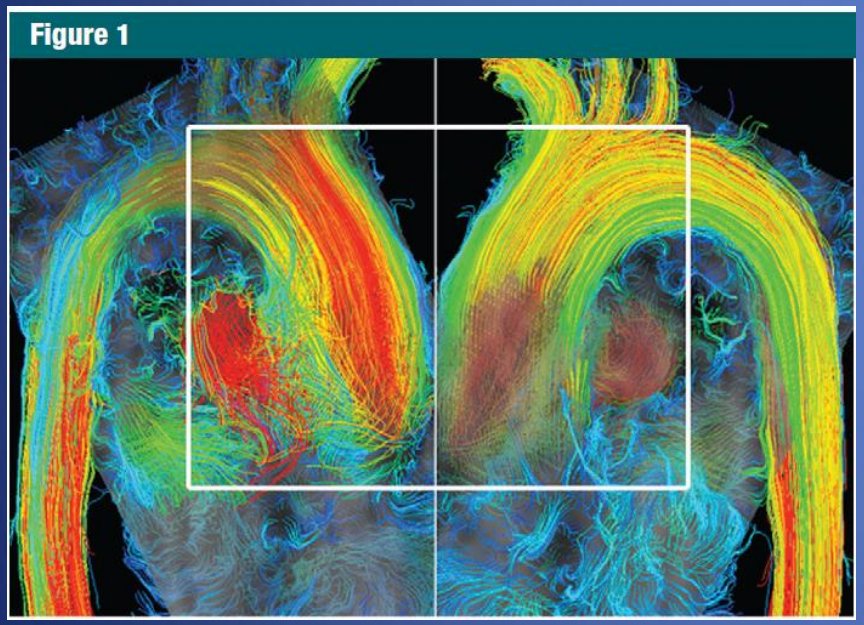
Cases

- 75 y old severe AS, aorta 48mm, no risk factors
  - AVR
- 50 y old severe AS, aorta 48mm, W/O risk factors
  - AVR +ascending replacement
- 30 y old, AR, root 45 mm
  - Repair and replace root
- 40 y old, AR, root 43mm
  - AV repair

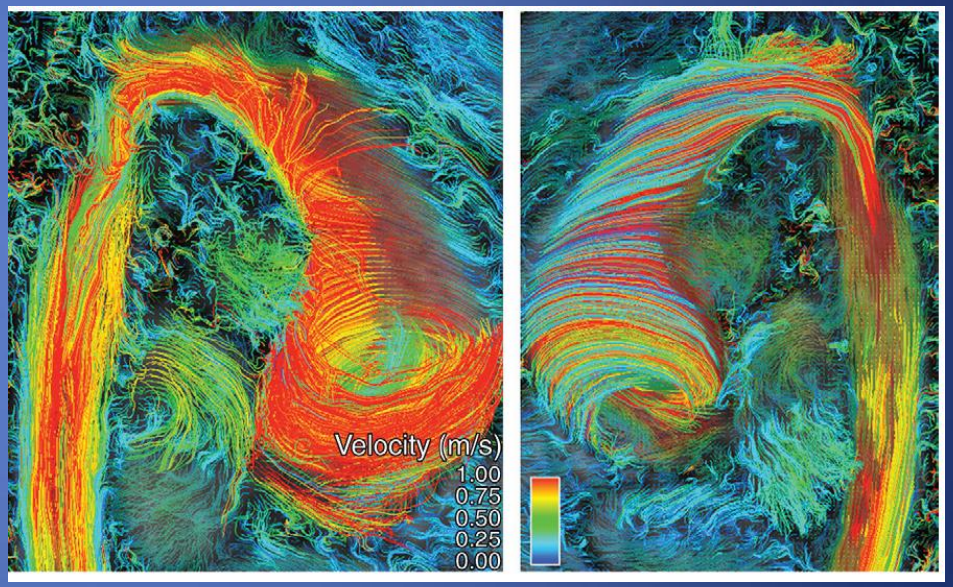
Thank you

Bicuspid Aortic Valve:

Four-dimensional MR Evaluation of Ascending Aortic Systolic Flow Patterns[1]



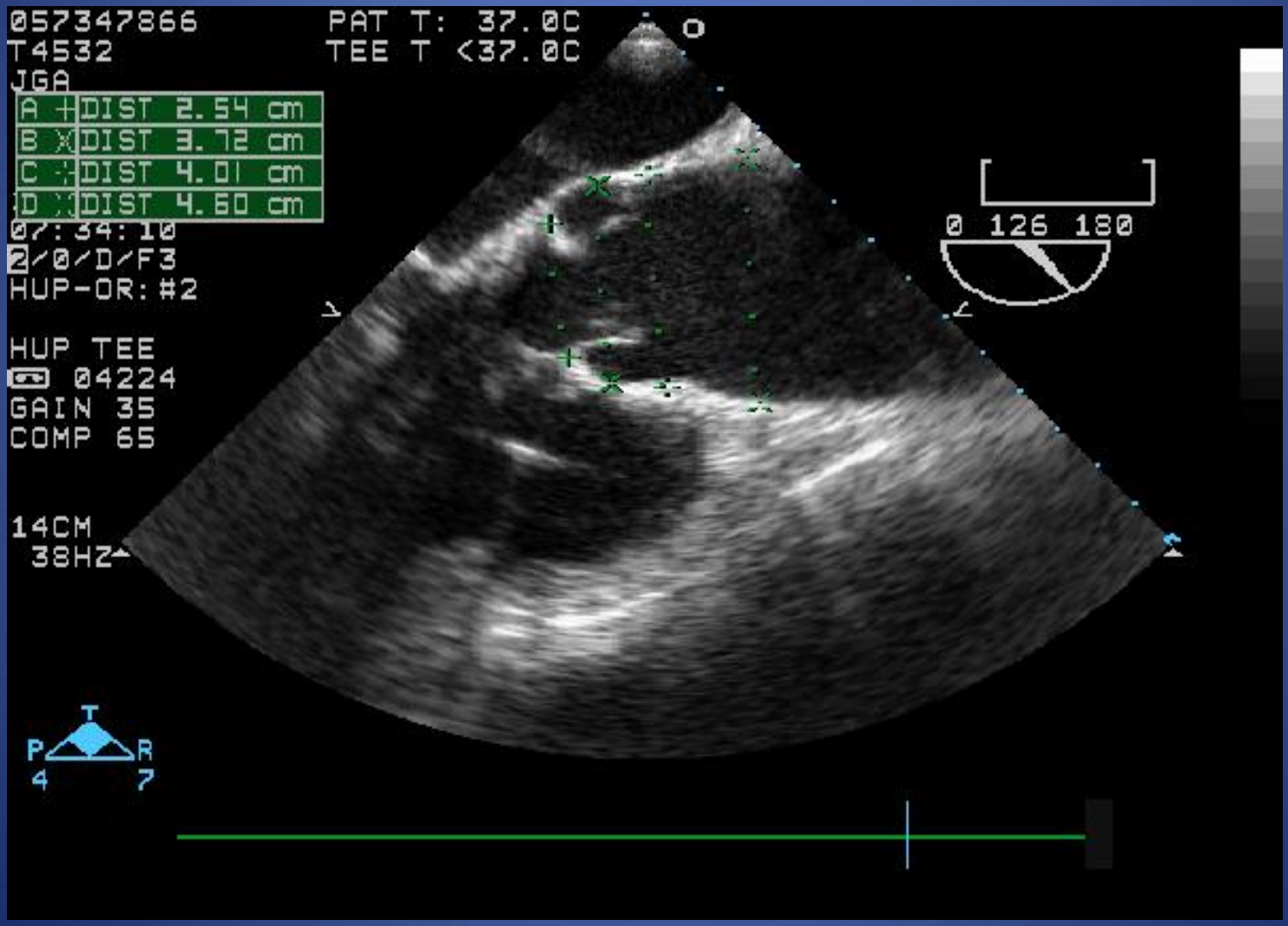
Normal TAV with normal aorta



BAV with Aneurysm

Hope MD radiology 2010

To “root”? If yes when?



Bicuspid Aortic Valves Are Associated With Aortic Dilatati esions

Martin C , MD;

Background— aortic aneur lesions (aort BAVs accou

Methods and R aorta were n by planimet Seventy-sev regurgitatio regurgitatio demonstrate ($P<0.05$) bu at all ascend

Conclusions— aortic valve patients, int factors. (***Circulation***. 2000;102[suppl III]:III-35-III-39.)

nd ascending ched valvular normalities in and proximal vas measured annular area. l severity of g degrees of riate analysis lvancing age ntrol patients s of tricuspid ation in BAV emodynamic

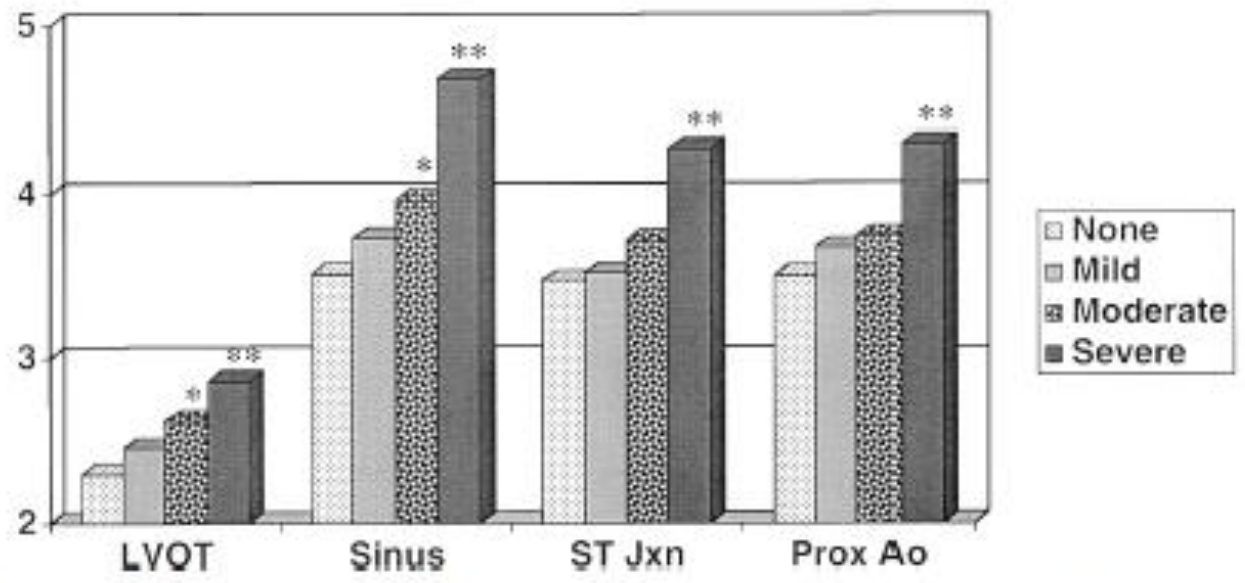
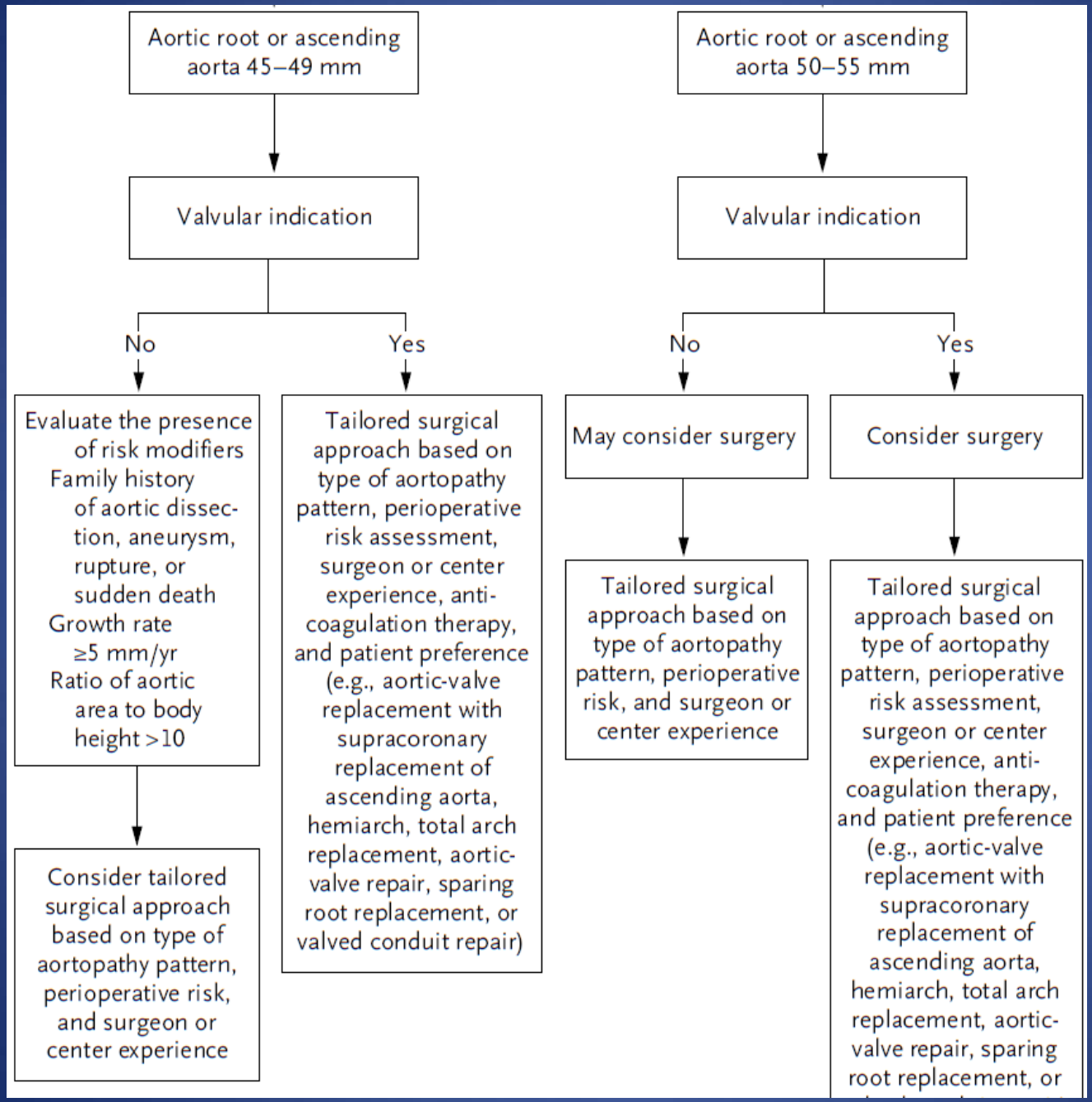
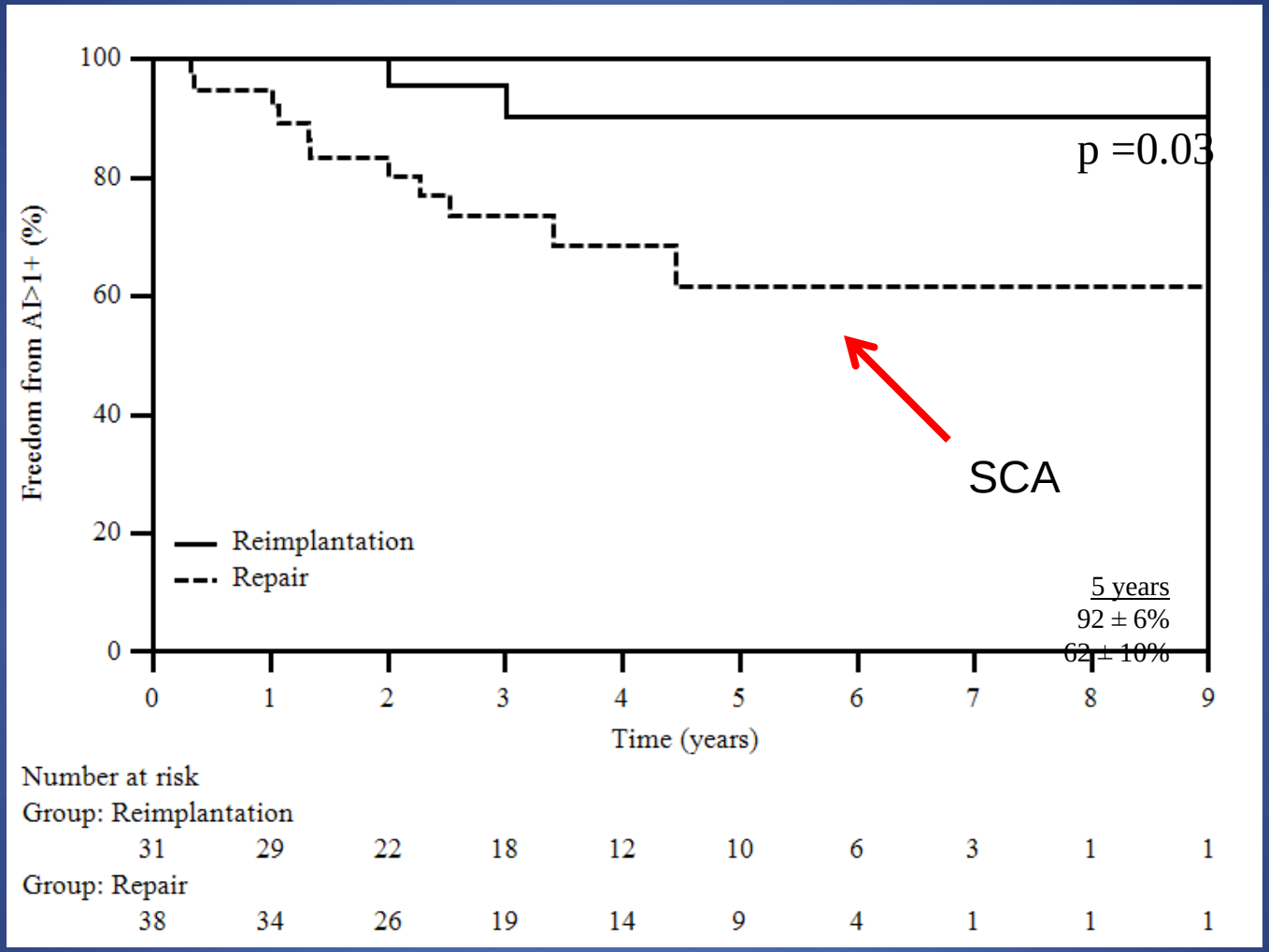


Figure 3. Association between aortic regurgitation and aortic size in BAV patients. LVOT indicates left ventricular outflow tract; sinus, sinus of Valsalva; ST Jxn, sinotubular junction; and Prox Ao, proximal aorta. Increasing severity of aortic regurgitation was associated with increases in root dimensions. *$P<0.005$ and **$P<0.001$ vs nonregurgitant valves.


Aortic root or ascending aorta 45–49 mm
Valvular indication
No
Yes
Evaluate the presence of risk modifiers
Family history of aortic dissection, aneurysm, rupture, or sudden death
Growth rate ≥5 mm/yr
Ratio of aortic area to body height >10
Consider tailored surgical approach based on type of aortopathy pattern, perioperative risk, and surgeon or center experience
Tailored surgical approach based on type of aortopathy pattern, perioperative risk assessment, surgeon or center experience, anti-coagulation therapy, and patient preference (e.g., aortic-valve replacement with supracoronary replacement of ascending aorta, hemiarch, total arch replacement, aortic-valve repair, sparing root replacement, or valved conduit repair)
Aortic root or ascending aorta 50–55 mm
Valvular indication
No
Yes
May consider surgery
Consider surgery
Tailored surgical approach based on type of aortopathy pattern, perioperative risk, and surgeon or center experience
Tailored surgical approach based on type of aortopathy pattern, perioperative risk assessment, surgeon or center experience, anti-coagulation therapy, and patient preference (e.g., aortic-valve replacement with supracoronary replacement of ascending aorta, hemiarch, total arch replacement, aortic-valve repair, sparing root replacement, or

Sub-Commissural Annuloplasy (SCA) vs Reimplantation on AI



Bavaria et al; Presented at STS 2013;

Bicuspid aortic valve surgery with proactive ascending aorta repair

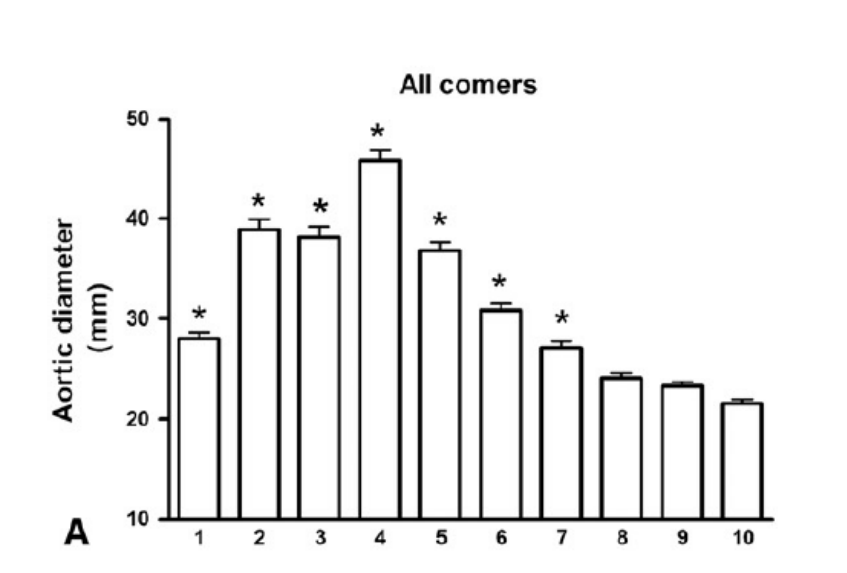
Lars G. Svensson, MD, PhD,[a,b] Kyung-Hwan Kim, MD,[a] Eugene H. Blackstone, MD,[a,d] Jeevanantham Rajeswaran, MSc,[d] A. Marc Gillinov, MD,[a] Tomislav Mihaljevic, MD,[a] Brian P. Griffin, MD,[c] Richard Grimm, DO,[c] William J. Stewart, MD,[c] Donald F. Hammer, MD,[c] and Bruce W. Lytle, MD[a,b]

Objectives: Bicuspid aortic valves are associated with aortic catastrophes, particularly dissection. We examined whether proactive repair of associated dilatation would reduce risk of subsequent aortic dissection or reoperation and whether more aggressive resection is needed in patients undergoing bicuspid aortic valve surgery alone.

Methods: From January 1993 to June 2003, 1989 patients (of our total experience of 4316) underwent bicuspid aortic valve surgery. Long-term outcomes of 1810 were analyzed according to aortic size and whether bicuspid aortic valve surgery was performed alone or with aortic repair.

Results: In-hospital 30-day survival was similar (98.8% valve alone vs 98.9% with aortic repair), with no penalty incurred for concomitant aortic repair. Bicuspid aortic valve–alone patients had worse late survival (75% vs 85% at 10 years, $P = .0001$), but in the matched cohort survival was nearly identical (85% vs 86%; $P = .7$). With this strategy, freedom from late aortic events was high in both groups (99% valve alone vs 97% with aortic repair at 10 years; P[log-rank] $= .06$) and similar in the matched cohort (95% vs 97%; $P = .2$). Approximately 95% of patients undergoing valve-alone surgery had aortic diameters smaller than 4.6 cm or cross-sectional area/height ratios less than 9.4 cm^2/m; 80% undergoing valve surgery plus aortic repair had diameters larger than 4.1 cm or ratios greater than 7.3 cm^2/m. Only 0.2% of events occurred at an aortic diameter size of less than 4.5 cm.

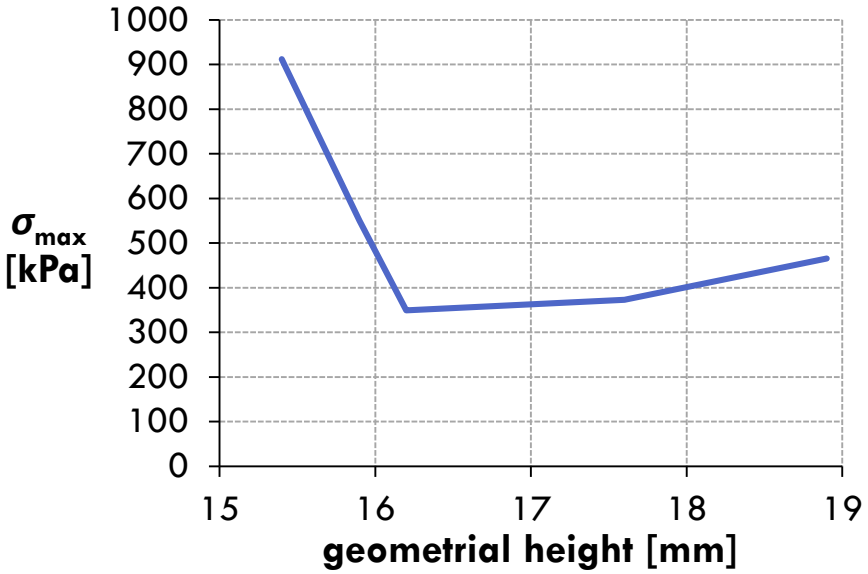
Conclusions: Aortic size larger than 4.5 cm or aortic cross-sectional area/height ratio greater than 8 to 10 should be considered triggers for concurrent aortic repair, because there is no added risk, and late survival is better; however, more aggressive resection is unwarranted. (J Thorac Cardiovasc Surg 2011;142:622-9)

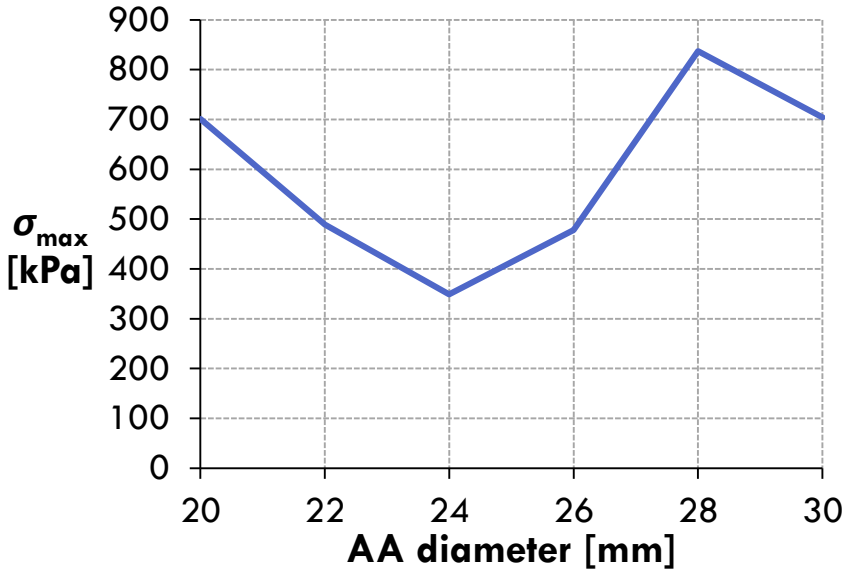


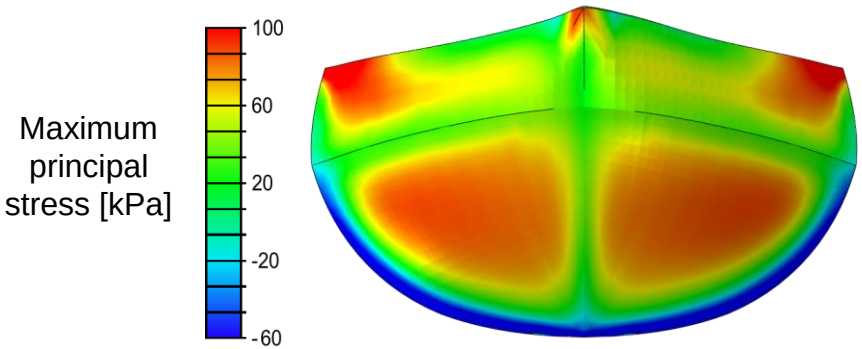
Fazel SS JTCVS 2008

Influence of the geometry on the max. principal stress

- The average dimensions case (h_G=16.2mm, d_{AA}=24mm) has the lowest mechanical stress

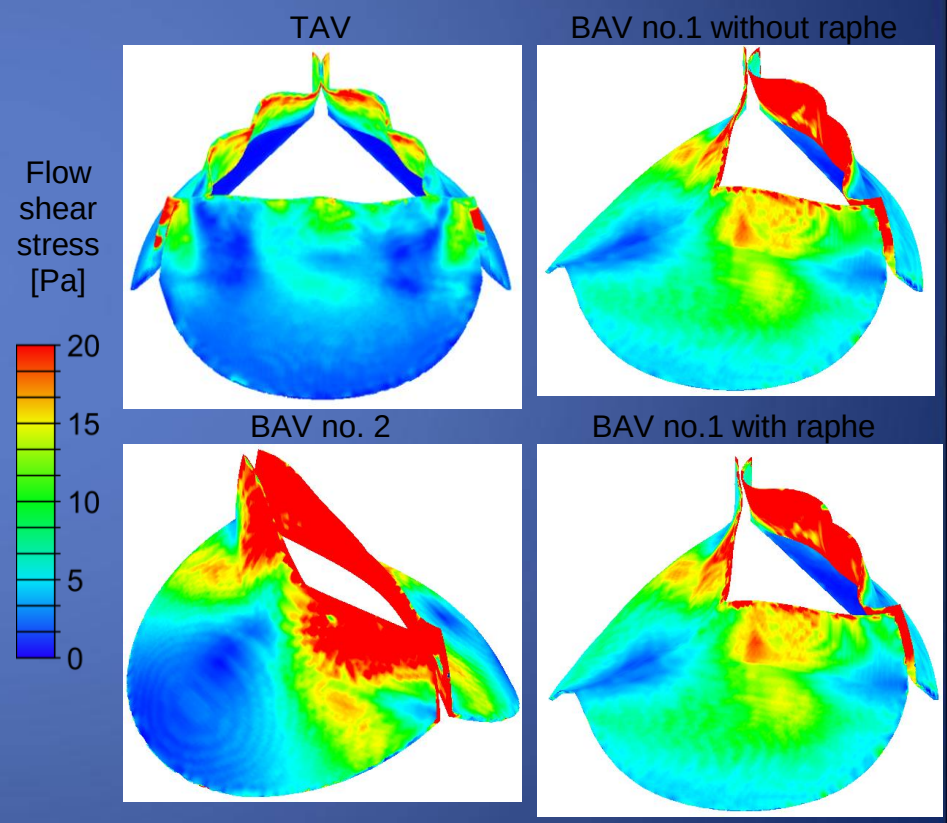




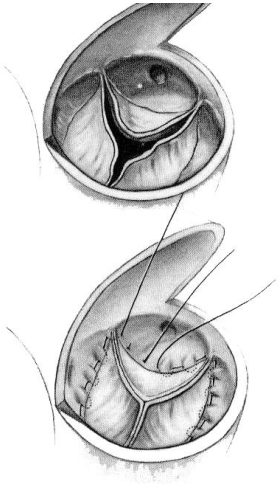


Flow shear stress during peak systole

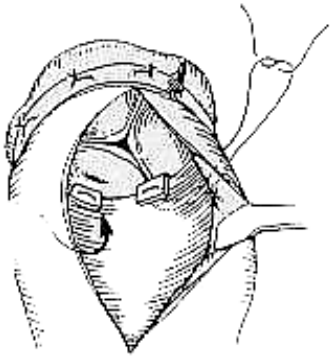
- Higher systolic flow shear stresses are found on the cusps of BAVs
- The TAV model has the lowest shear stress, specifically on the coapting regions



Techniques for Aortic Annuloplasty

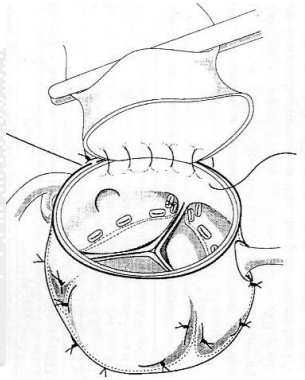


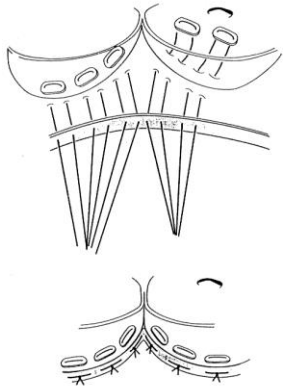
Carpentier
1983



Frater
1986

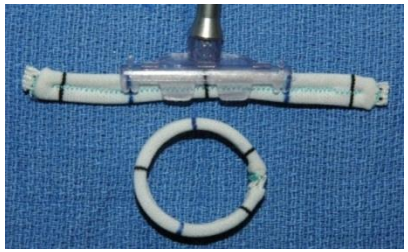
Haydar
1997



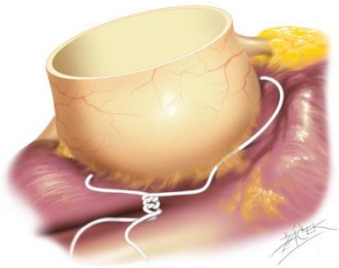


Izumoto
2002

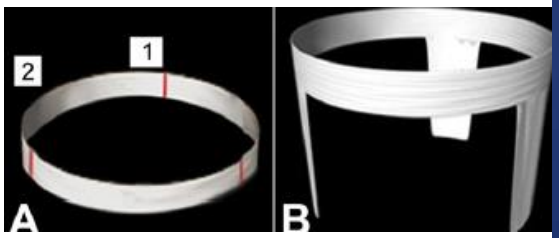
Hahm
2006



Lansac
2007



Schäfers
2009



Fattouch
2011

Courtesy E Lansac

Should the proximal arch be routinely replaced in patients with bicuspid aortic valve disease and ascending aortic aneurysm?

Chan B. Park, MD,[a,b] Kevin L. Greason, MD,[a] Rakesh M. Suri, MD,[a] Hector I. Michelena, MD,[c] Hartzell V. Schaff, MD,[a] and Thoralf M. Sundt III, MD[a]

Objectives: Bicuspid aortic valve is frequently associated with underlying aortopathy. Data support an aggressive approach to replacement of the ascending aorta. However, the natural history of the unreplaced aortic arch is unknown, and some have advocated routine replacement of the proximal arch in this setting.

Methods: We identified patients with bicuspid aortic valve undergoing repair or replacement of the ascending aorta with or without aortic valve replacement or root replacement between January1988 and December 2007 at our institution. Follow-up was by review of clinical records and postal questionnaire.

Results: Of 470 patients identified, 48 patients had hemiarch or total arch replacement and were excluded. Of the remaining 422 patients, 227 had separate aortic valve replacement or repair and ascending aortoplasty (76) or ascending aortic graft replacement (175), 107 a valved conduit, 40 a homograft root, and 21 a valve-sparing root replacement. The mean age was 56 ± 15 years, and 80% were male. Follow-up was up to 17 (median 4.2) years. There were 23 (5.5%) late reoperations, of which none were for arch dilatation. Survival at 1, 5, 10, and 12 years was 96.5%, 89.6%, 77.7%, and 74.0%. Freedom from late reoperation was 98.7%, 94.1%, 81.0%, and 81.0%. Paired echocardiographic measurements of aortic arch diameter (n = 58) were 33.3 mm preoperatively versus 31.9 mm postoperatively ($P = .135$) at a mean 4 years.

Conclusions: Progressive dilatation of the aortic arch leading to reoperation after repair of ascending aortic aneurysm in patients with bicuspid aortic valve is uncommon. A selective approach to transverse aortic arch replacement is appropriate. (J Thorac Cardiovasc Surg 2011;142:602-7)

Fate of nonreplaced sinuses of Valsalva in bicuspid aortic valve disease

Chan B. Park, MD,[a,b] Kevin L. Greason, MD,[a] Rakesh M. Suri, MD,[a] Hector I. Michelena, MD,[c] Hartzell V. Schaff, MD,[a] and Thoralf M. Sundt III, MD[a]

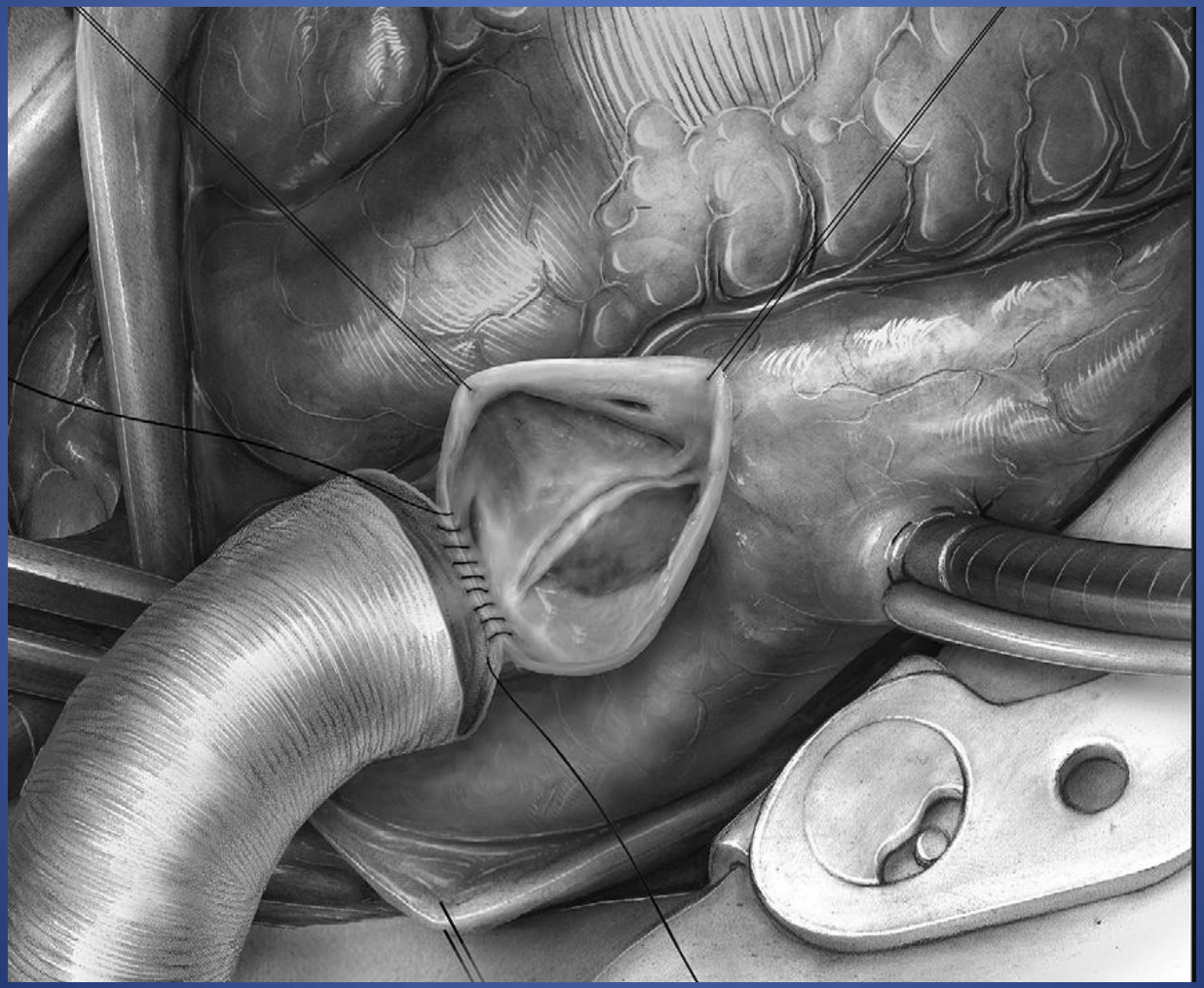
Objective: There is growing consensus that the ascending aorta should be replaced at the time of aortic valve replacement for bicuspid aortic valve even if it is only moderately dilated; the natural history of nonreplaced sinuses of Valsalva is less clear.

Methods: We identified patients without defined connective tissue disorder undergoing primary aortic valve replacement for bicuspid aortic valve and separate repair of the ascending aorta without root replacement at the Mayo Clinic between January 1, 1988, and December 31, 2007.

Results: Among 218 patients, 65 underwent ascending aortoplasty and 153 underwent separate graft replacement of the ascending aorta. Of the latter group, 15 also had graft replacement of the noncoronary sinus. The mean age at operation was 62 ± 13 years. Valvular dysfunction was predominantly stenosis in 151 patients (70%), regurgitation in 54 patients (25%), and mixed in 12 patients (5%). At a follow-up of up to 17 years (median, 3.3 years; range, 0–17 years), 10 patients (5%) had undergone late reoperation, of whom 1 had replacement of the ascending aorta and 1 had replacement of the root for significant dilatation of the sinuses. Both patients had originally undergone aortoplasty. No other patient required root surgery. One-, 5-, and 10-year freedom from reoperation for any cause were 97.6%, 94.9%, and 85.5%, respectively.

Conclusions: Although progressive ascending aortic dilatation after aortic valve replacement for bicuspid aortic valve is well documented, progressive dilatation of nonreplaced sinuses is not evident. Separate valve and graft repair remains a reasonable surgical option in the setting of aortic valve replacement for bicuspid aortic valve with ascending aortic dilatation provided the sinuses of Valsalva are not significantly enlarged. (J Thorac Cardiovasc Surg 2011;142:278-84)

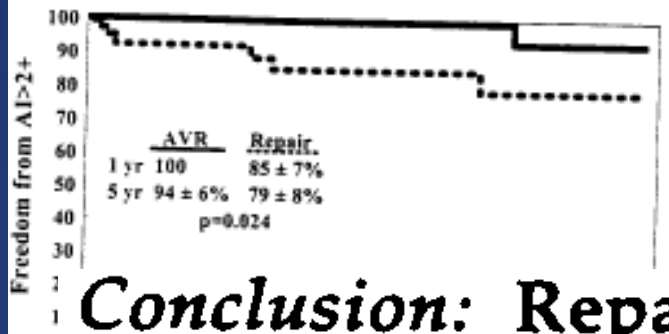
Ascending Aorta Replacement



Aortic Valve Repair versus Replacement in Bicuspid Aortic Valve Disease

Piroze M. Davierwala, Tirone E. David, Susan Armstrong, Joan Ivanov

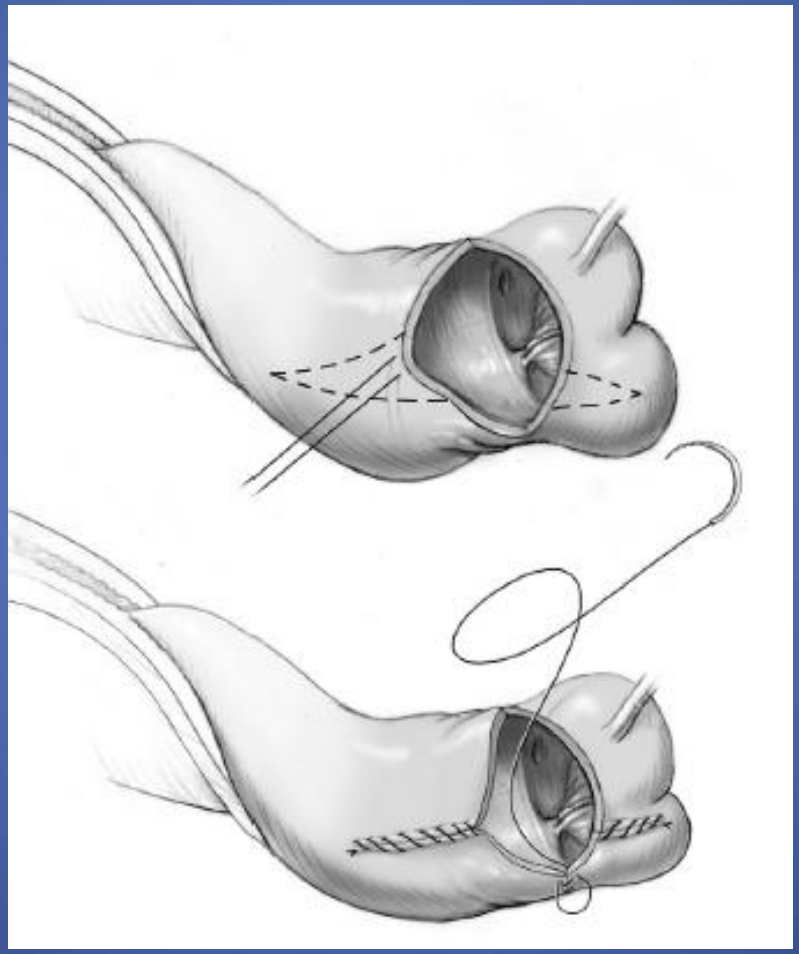
Division of Cardiovascular Surgery of Toronto General Hospital and University of Toronto, Toronto, Ontario, Can



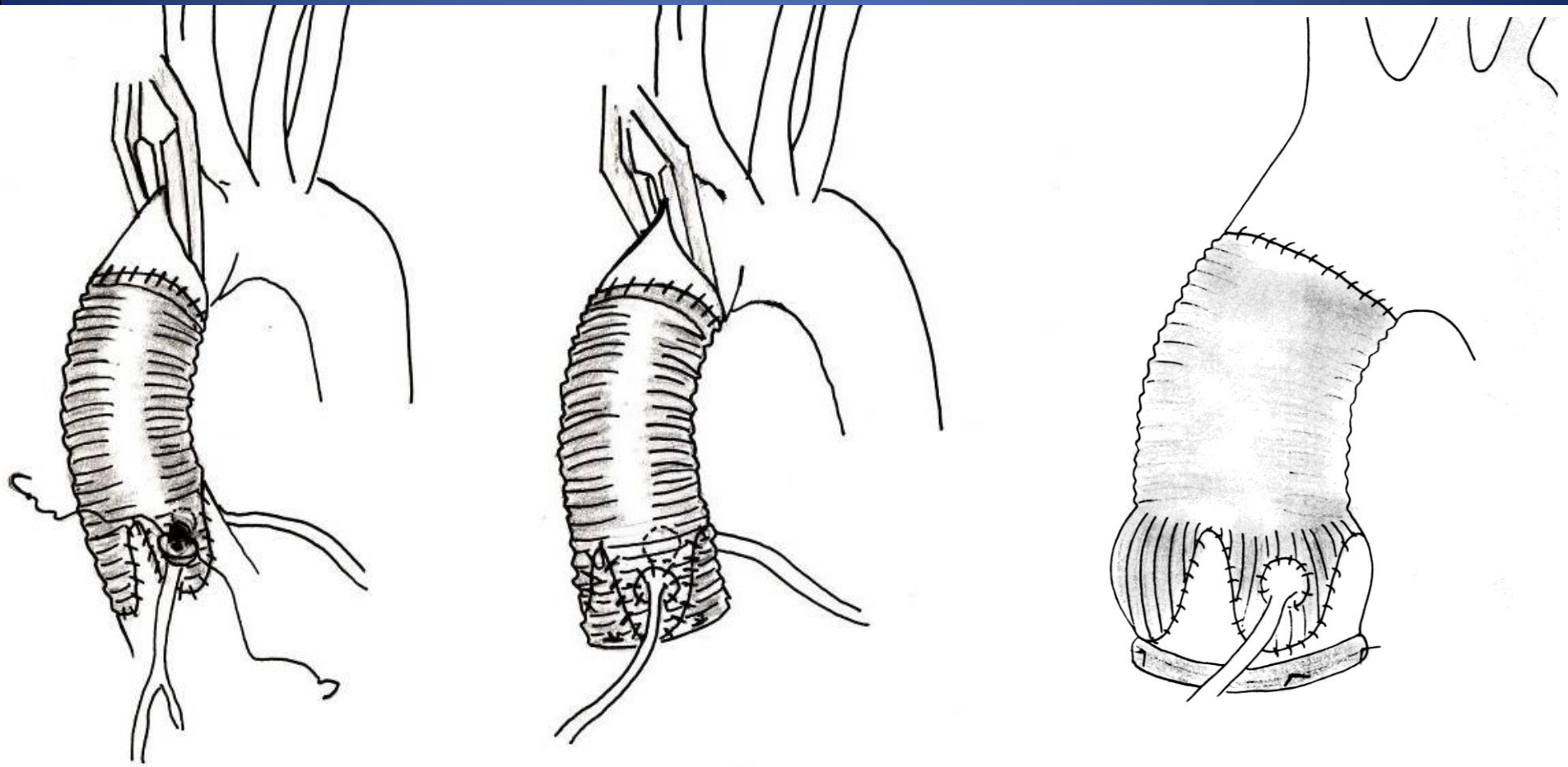
Conclusion: **Repair of BAV is feasible in certain patients with AI, but the hemodynamics and clinical outcomes do not appear to be superior to AVR with biological valves during the first five years of follow up.**

The Journal of Heart Valve Disease 2003;12:679-686

Ascending Aorta Plication for Moderate Dilatation(40-45mm)



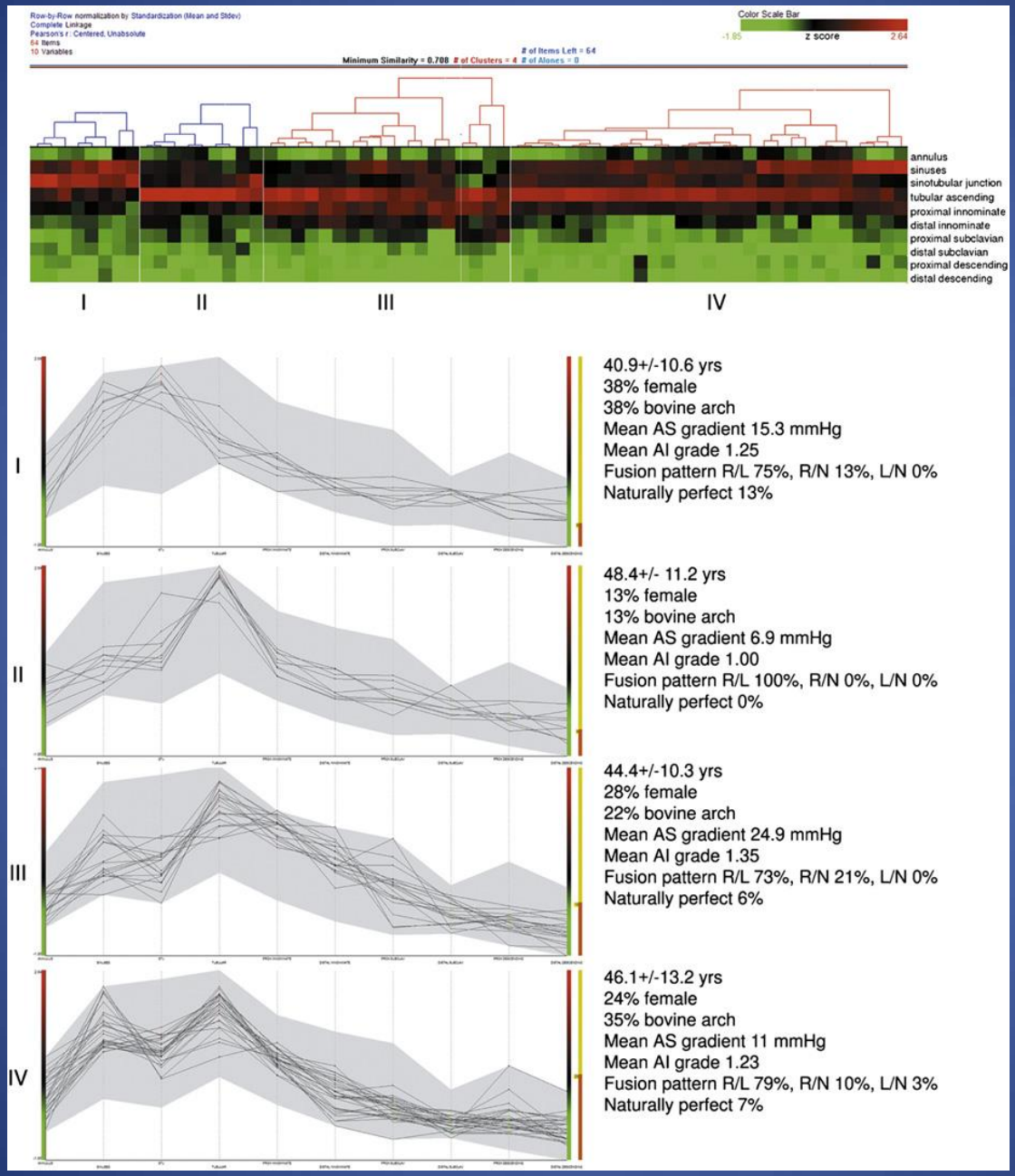
Physiological and standardized approach to aortic valve repair



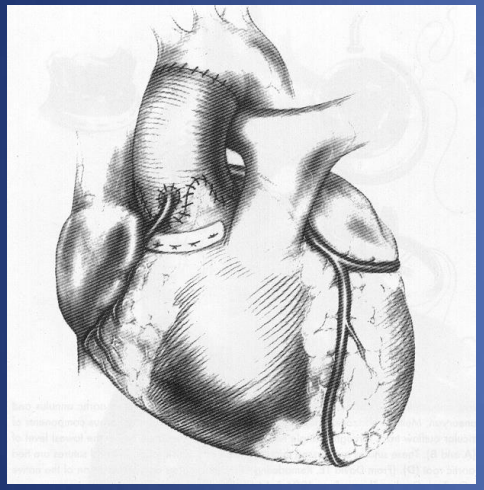
Remodeling

Reimplantation

Remodeling + subvalvular annuloplasty


Row-by-Row normalization by Standardization (Mean and Stdev)
Complete Linkage
Pearson's r, Centered, Unabsolute
64 Items
10 Variables
Color Scale Bar
-1.85
z score
2.64
# of Items Left = 64
Minimum Similarity = 0.708 # of Clusters = 4 # of Alones = 0
annulus
sinuses
sinotubular junction
tubular ascending
proximal innominate
distal innominate
proximal subclavian
distal subclavian
proximal descending
distal descending
I
II
III
IV
I
40.9+/-10.6 yrs
38% female
38% bovine arch
Mean AS gradient 15.3 mmHg
Mean AI grade 1.25
Fusion pattern R/L 75%, R/N 13%, L/N 0%
Naturally perfect 13%
II
48.4+/- 11.2 yrs
13% female
13% bovine arch
Mean AS gradient 6.9 mmHg
Mean AI grade 1.00
Fusion pattern R/L 100%, R/N 0%, L/N 0%
Naturally perfect 0%
III
44.4+/-10.3 yrs
28% female
22% bovine arch
Mean AS gradient 24.9 mmHg
Mean AI grade 1.35
Fusion pattern R/L 73%, R/N 21%, L/N 0%
Naturally perfect 6%
IV
46.1+/-13.2 yrs
24% female
35% bovine arch
Mean AS gradient 11 mmHg
Mean AI grade 1.23
Fusion pattern R/L 79%, R/N 10%, L/N 3%
Naturally perfect 7%

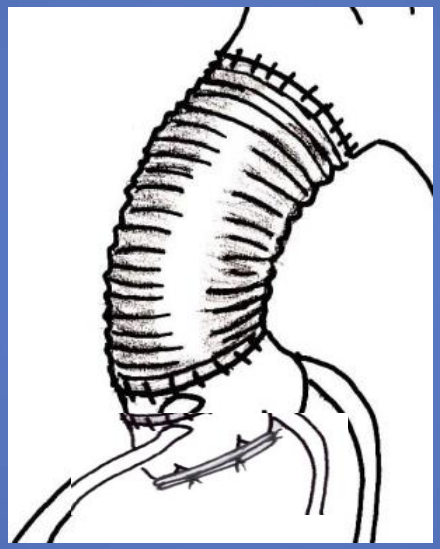
Valsalva ≥45 mm



Remodeling

+ subvalvular annuloplasty

Valsalva<40 mm



Supra-coronary graft

+ subvalvular annuloplasty

(annulus > 25 mm)

all Ø < 40 mm

Subvalvular annuloplasty

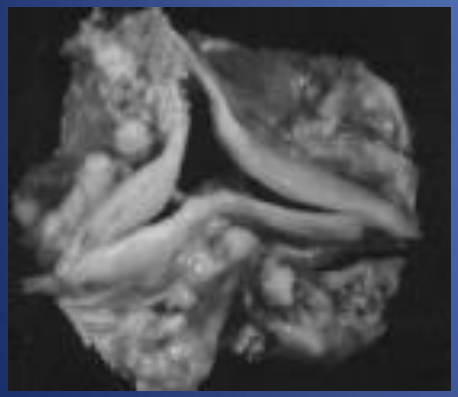
(annulus> 25 mm)

Frequency of BAV in AVR pts

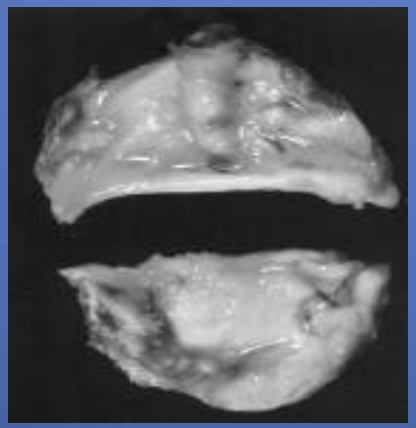
Valvular Heart Disease

Frequency by Decades of Unicuspid, Bicuspid, and Tricuspid Aortic Valves in Adults Having Isolated Aortic Valve Replacement for Aortic Stenosis, With or Without Associated Aortic Regurgitation

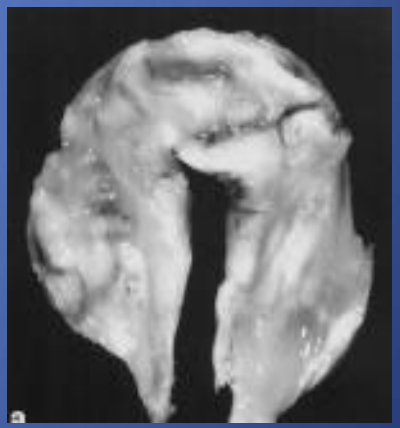
William C. Roberts, MD; Jong M. Ko, BA



TAV
45 %



BAV
49 %



UAV
5 %

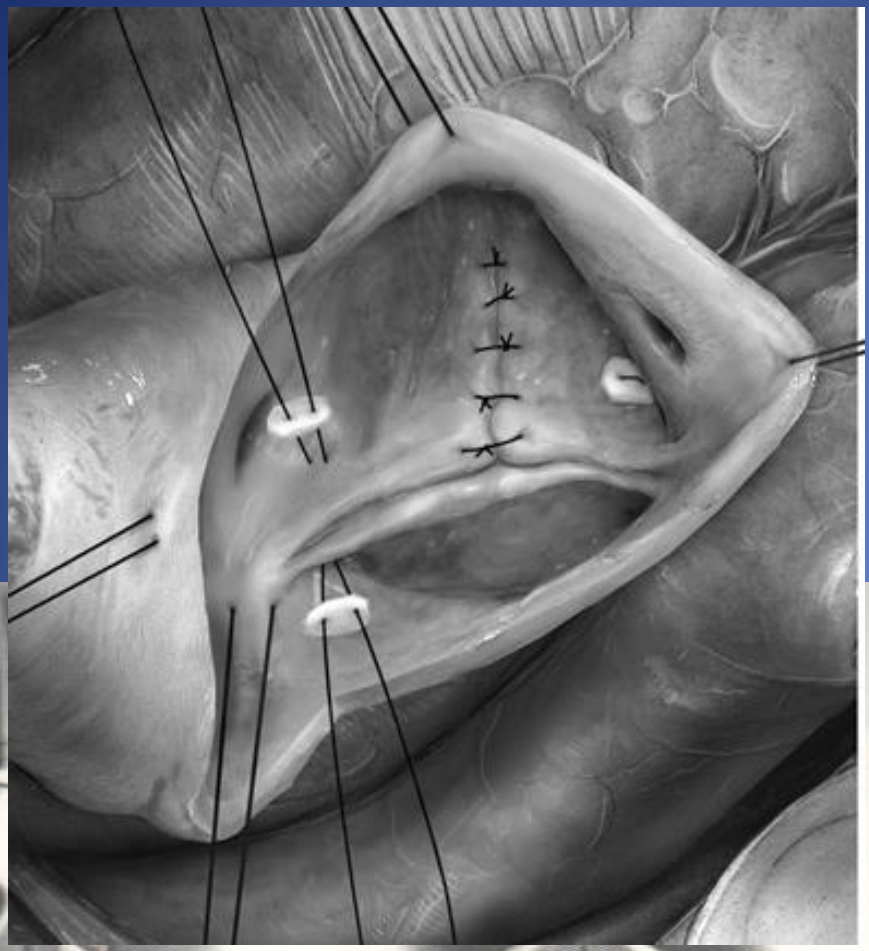
TABLE 1. Aortic Valve Structure in 584 Men and 348 Women Aged 26 to 91 Years With Operatively Excised Stenotic Aortic Valves Unassociated With Mitral Valve Disease and Excised From 1993 to 2004

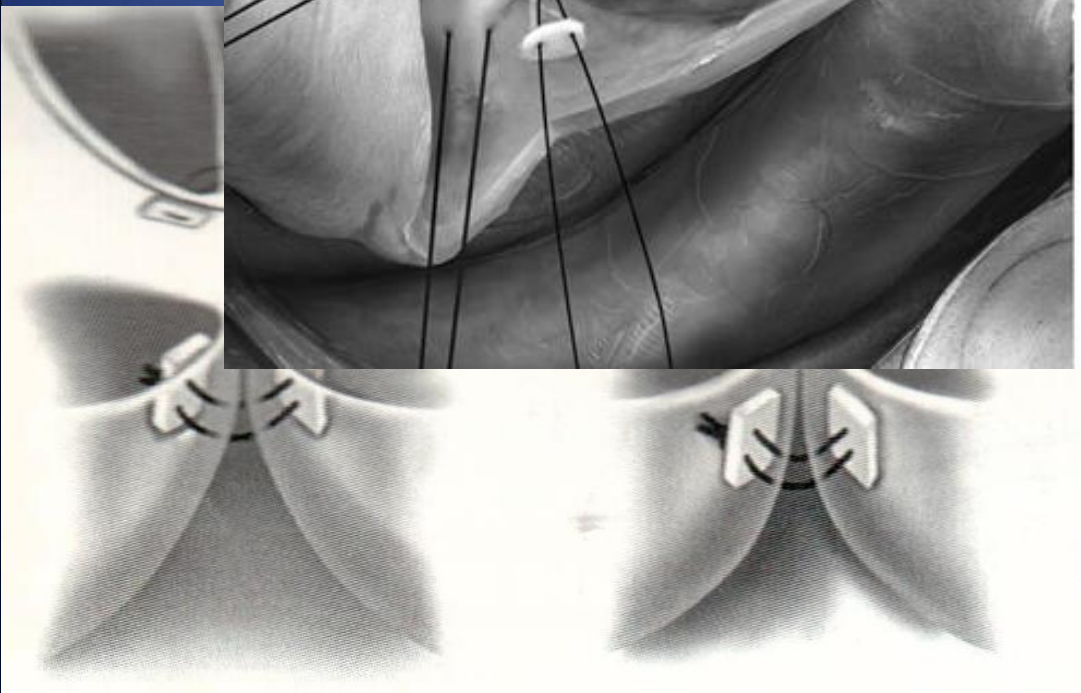
Aortic Valve Structure	Cases, n (%)	Ages (y) of Patients by Decades at Time of Aortic Valve Replacement							
		21–30	31–40	41–50	51–60	61–70	71–80	81–90	91–100
Men									
Unicuspid	34 (6)	3	4	11	8	4	4	0	0
Bicuspid	309 (53)	1	4	20	54	111	94	24	1
Tricuspid	234 (40)	0	0	0	14	50	119	51	0
Uncertain	7 (1)	0	0	0	0	3	2	2	0
Subtotals, n (%)	584 (100)	4 (<1)	8 (1)	31 (5)	76 (13)	168 (29)	219 (38)	77 (13)	1 (<1)
Women									
Unicuspid	12 (3)	1	2	3	1	4	1	0	0
Bicuspid	149 (43)	1	5	10	20	44	55	14	0
Tricuspid	183 (53)	0	0	2	11	43	79	47	1
Uncertain	4 (1)	0	0	1	0	0	3	0	0
Subtotals, n (%)	348 (100)	2 (<1)	7 (2)	16 (5)	32 (9)	91 (26)	138 (46)	61 (18)	1 (<1)

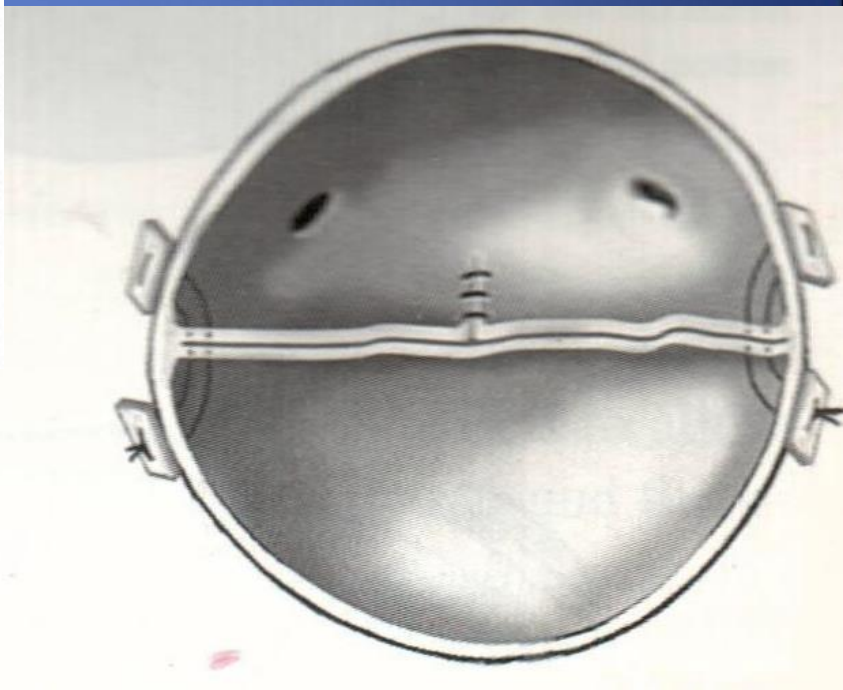
Values in parentheses are percentages.

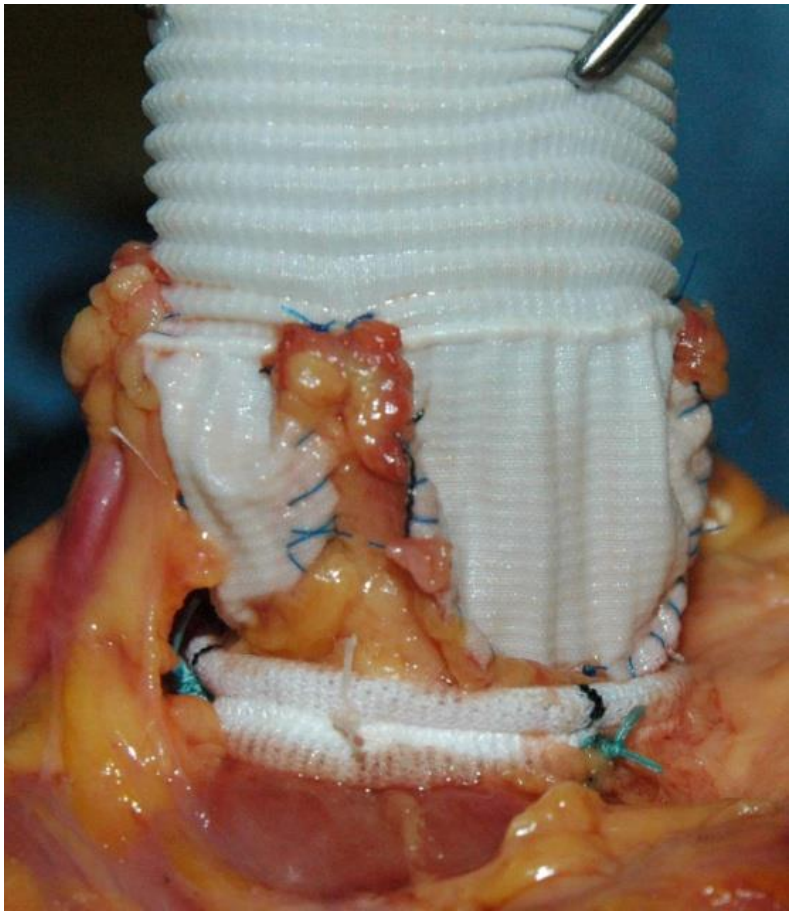
70% **45%** **33%**

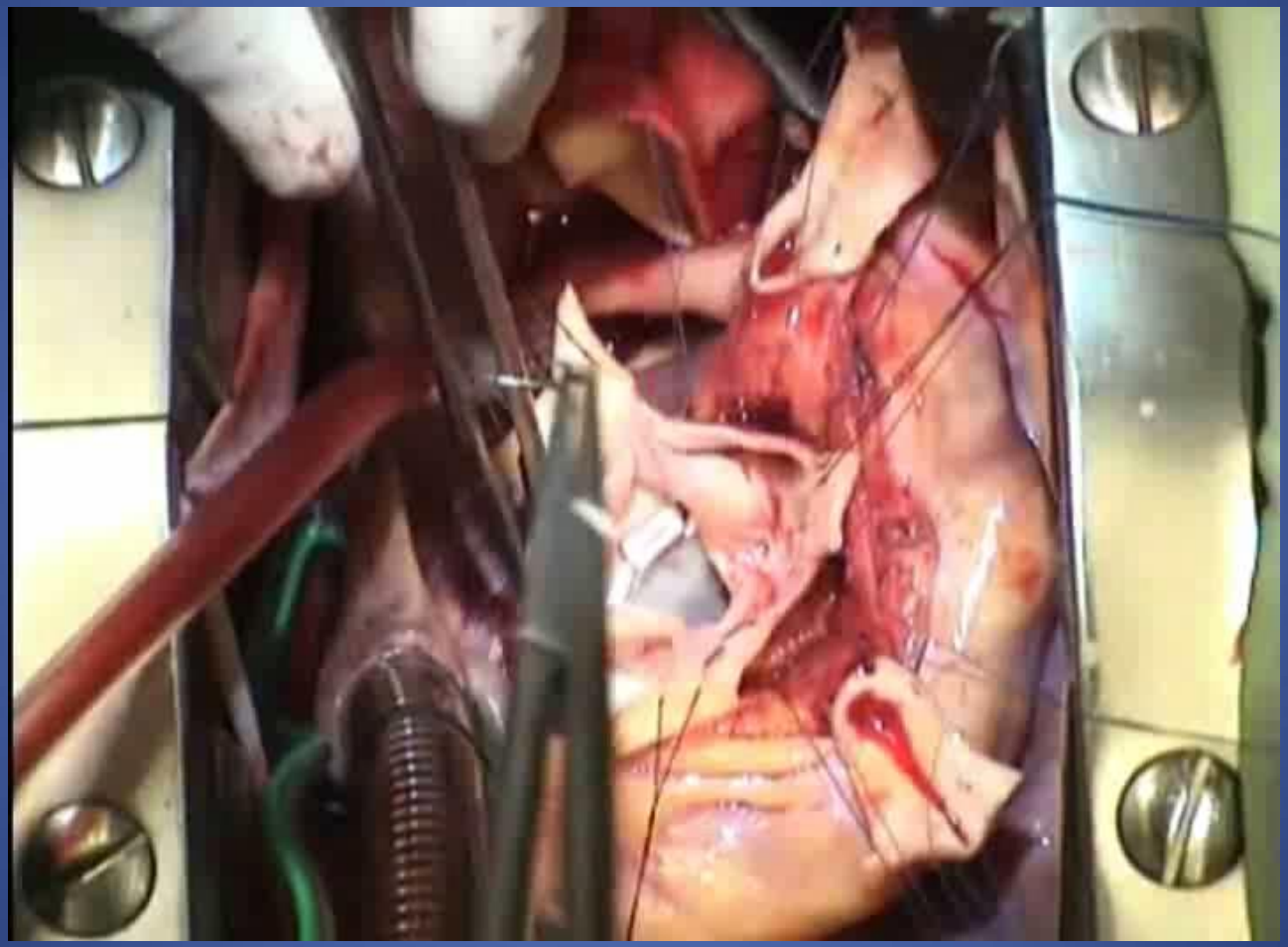
- 45% of patients between 71-80 years
- 70% of patients between 61-70 years!!



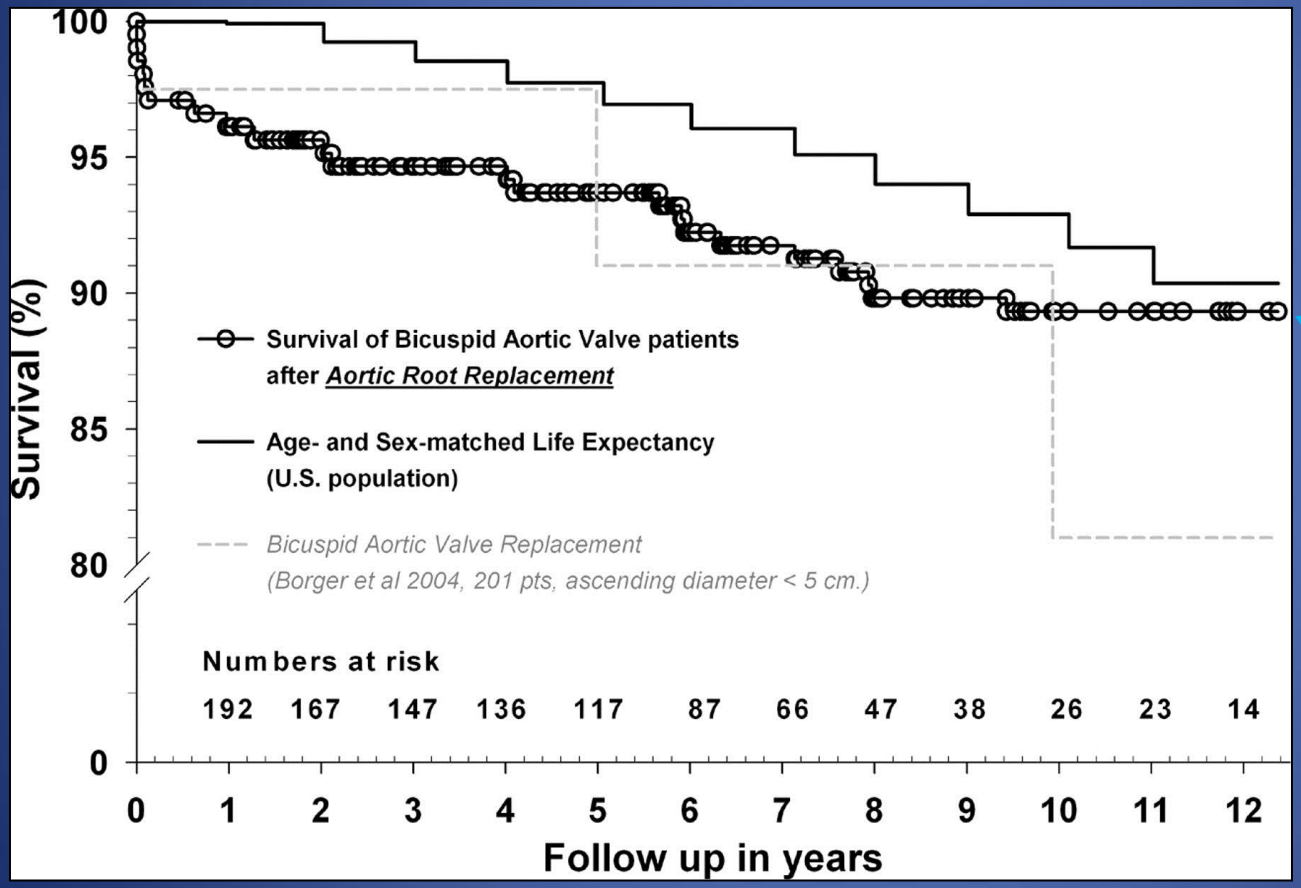








Survival After the Bentall Procedure in BAV



Survival nearly same as age and sex matched group at 12 years

[1]Etz C. D. Ann Thorac Surg 2007;84:1186-94

mount sinai NY

Excellent Aortic Bio-Root replacement outcomes in patients < 60y

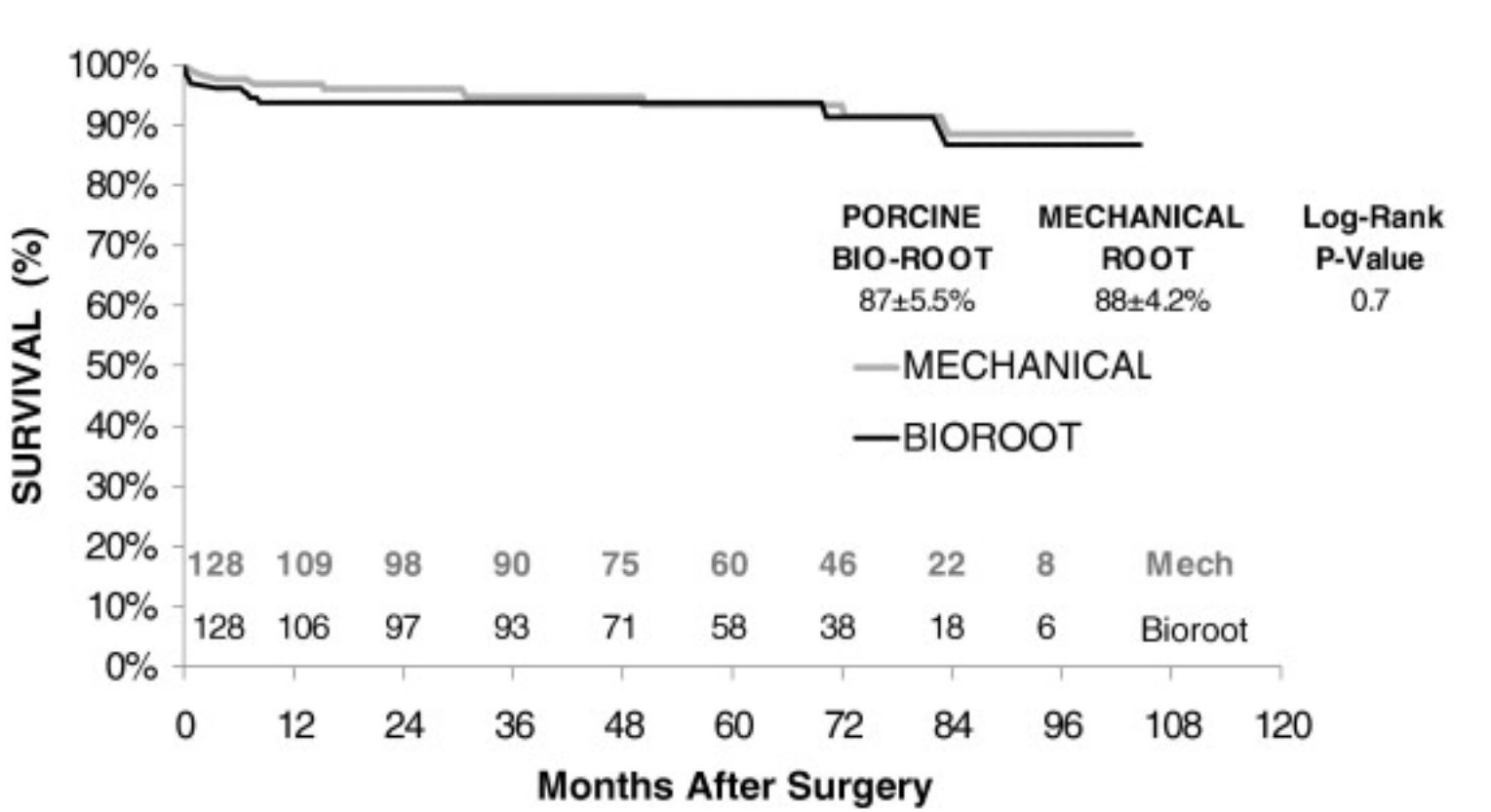
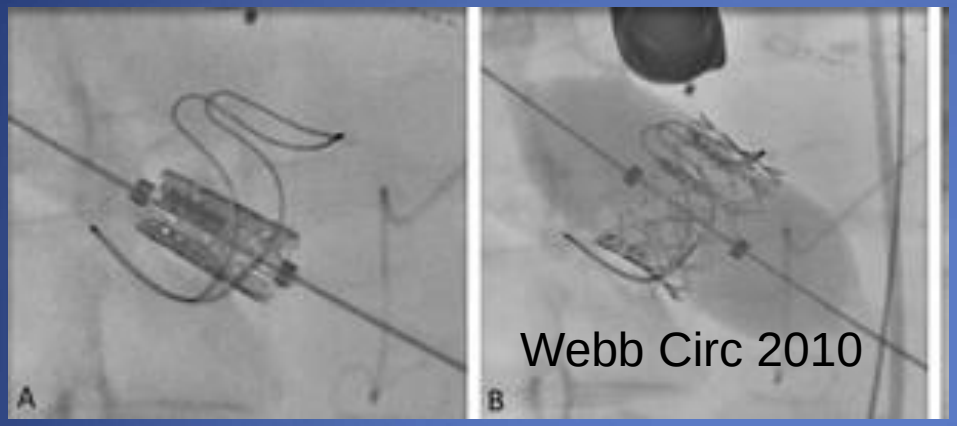


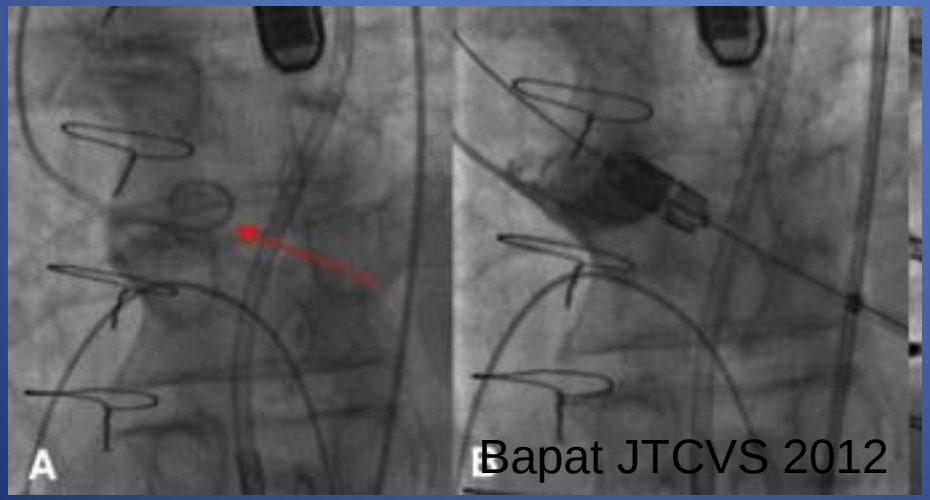
Fig 1. Long-term survival of the porcine bioroot (black line) and the mechanical root (gray line).

Desai , annals thorac surg 2011;92 2054-61
U-penn

TAVI Valve-in-Valve Adds More Years to the Index Operation

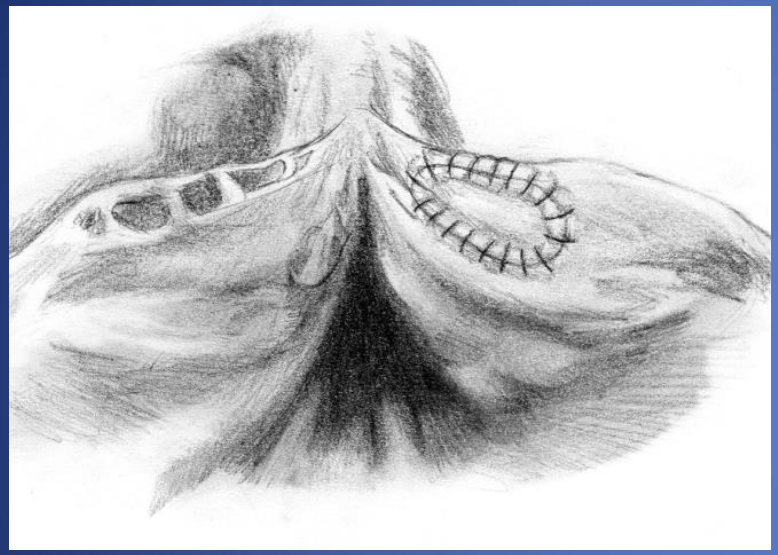


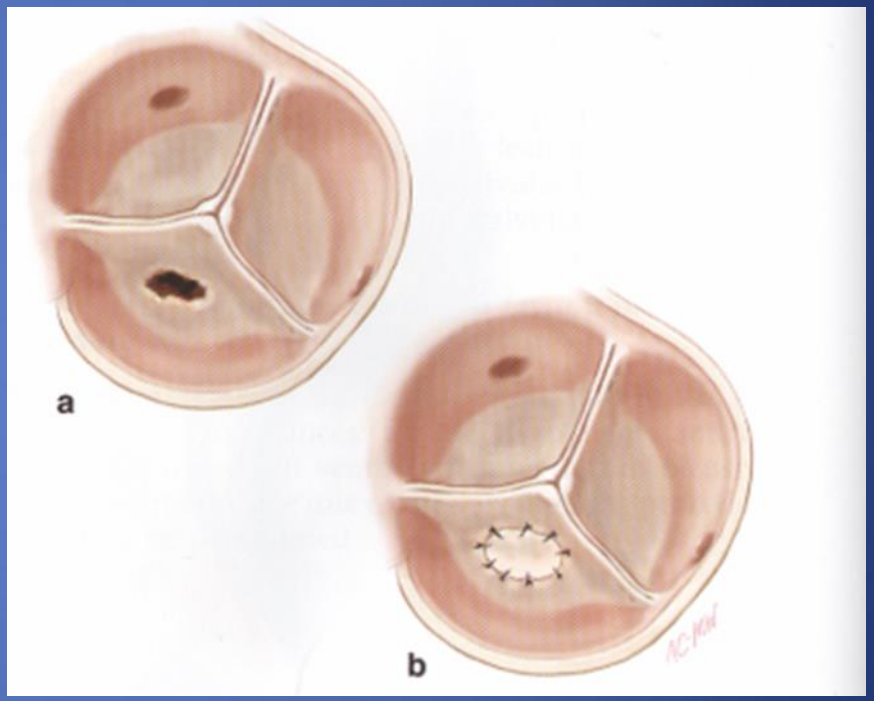
Webb Circ 2010



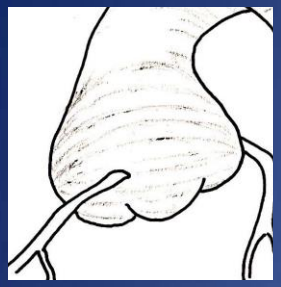
Bapat JTCVS 2012

Fenestration or Perforation





Closure and Stabilisation with pericardium

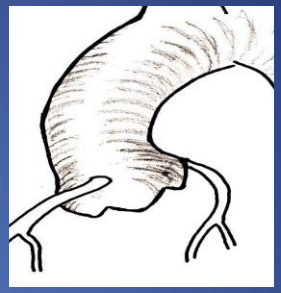


Aortic root aneurysm

Valsalva ≥45 mm

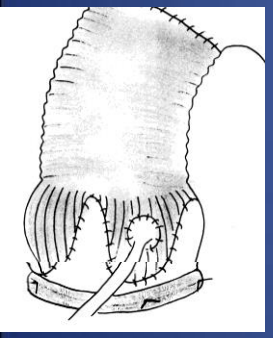
Supra-coronary aneurysm

Valsalva<40 mm



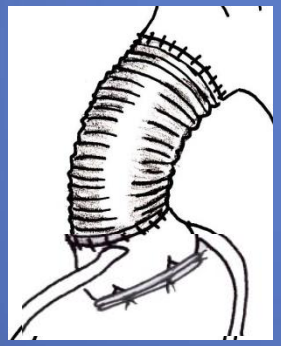
Isolated AI

all Ø < 40 mm



Remodeling

+ subvalvular annuloplasty



Supra-coronary graft

+ subvalvular annuloplasty

(annulus > 25 mm)

Subvalvular annuloplasty

(annulus> 25 mm)

Courtesy E. Lansac

Freedom from reoperation for SVD

All Patients < 60 years

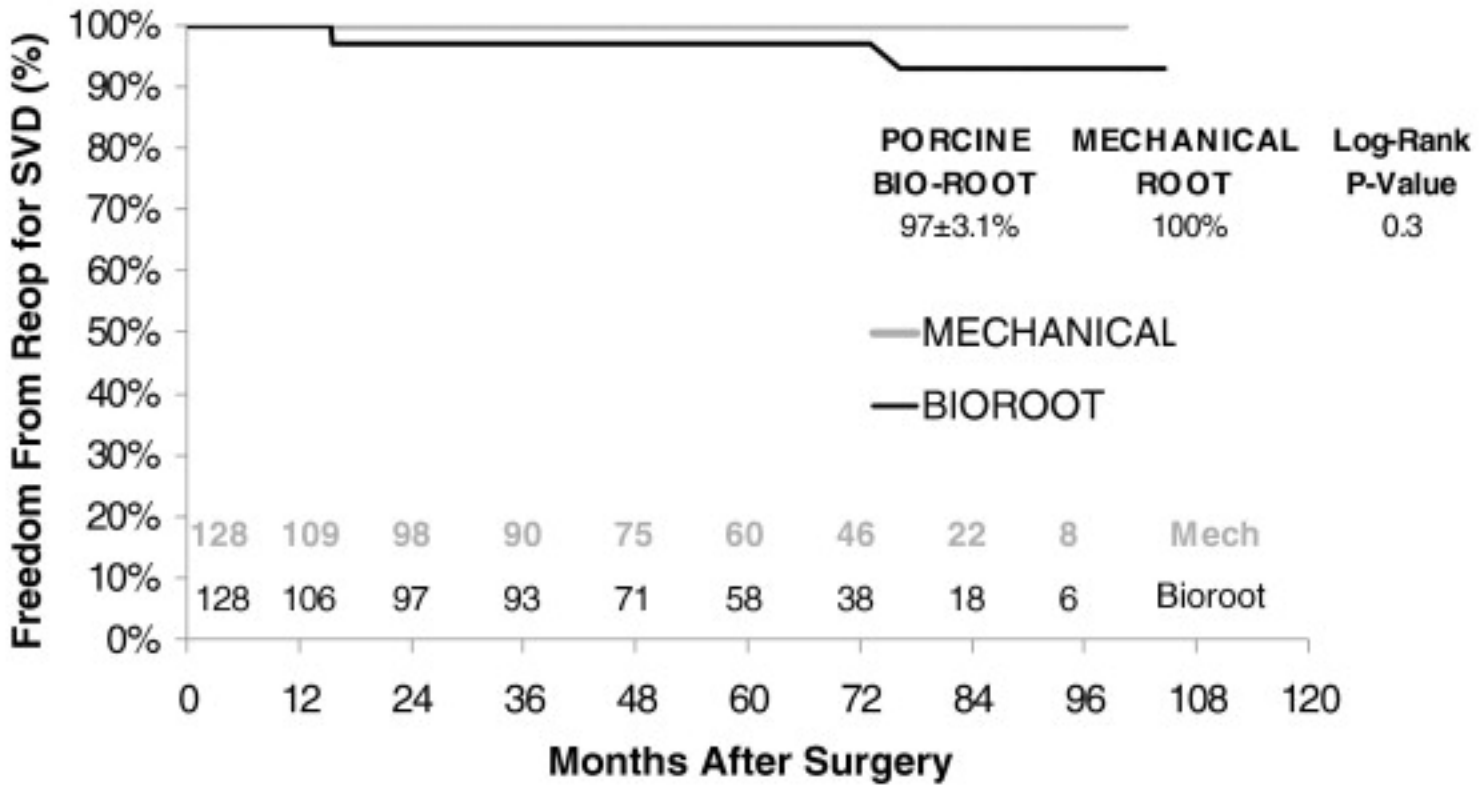
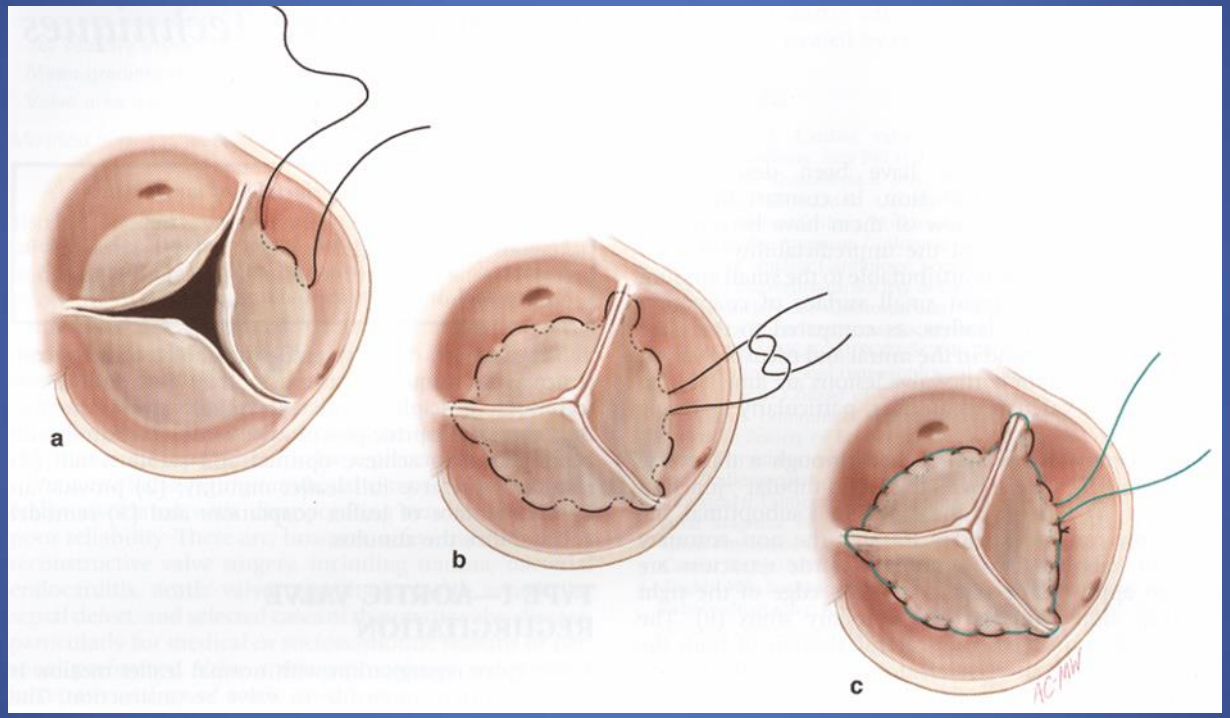
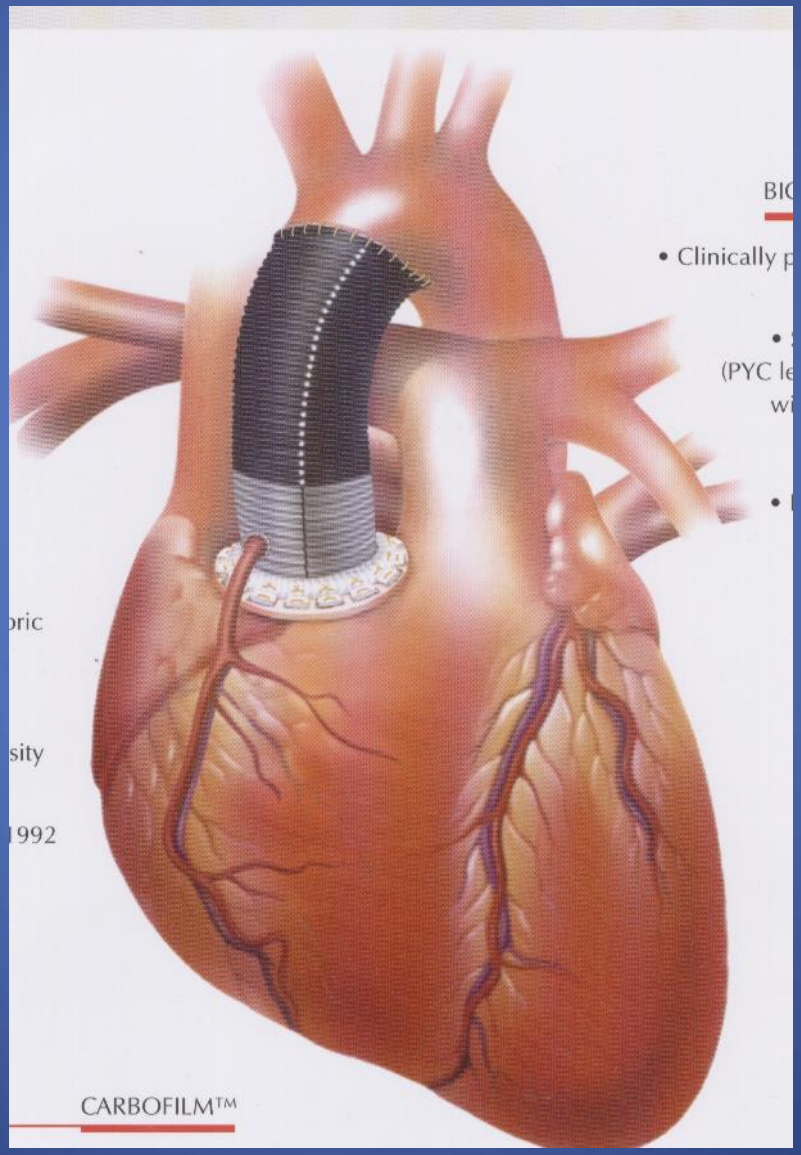


Fig 3. Freedom from reoperation of aortic root for structural valve deterioration (SVD) for the porcine bioroot (black line) and the mechanical root (gray line).

Aortic Annuloplasty

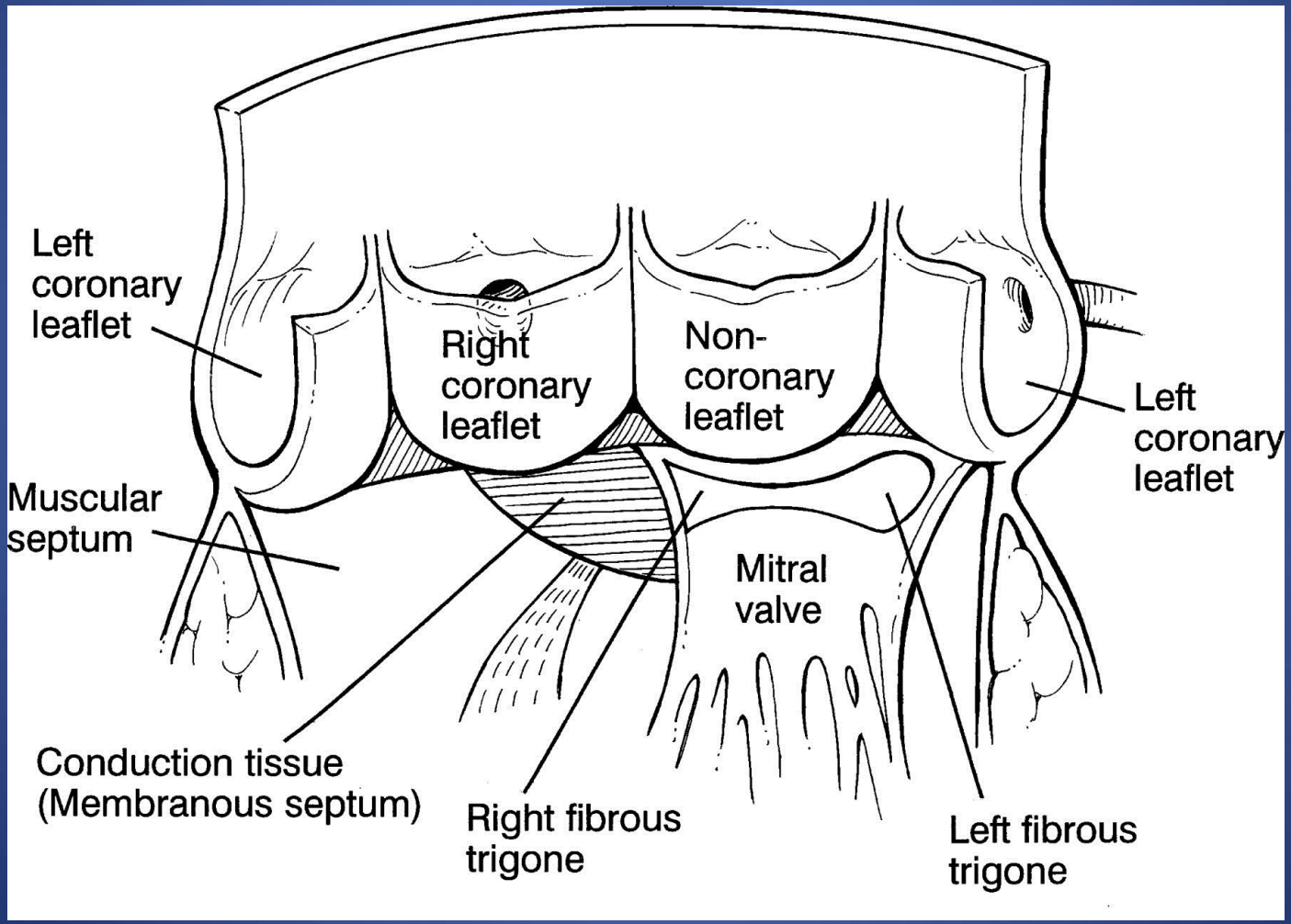


Composite AVR

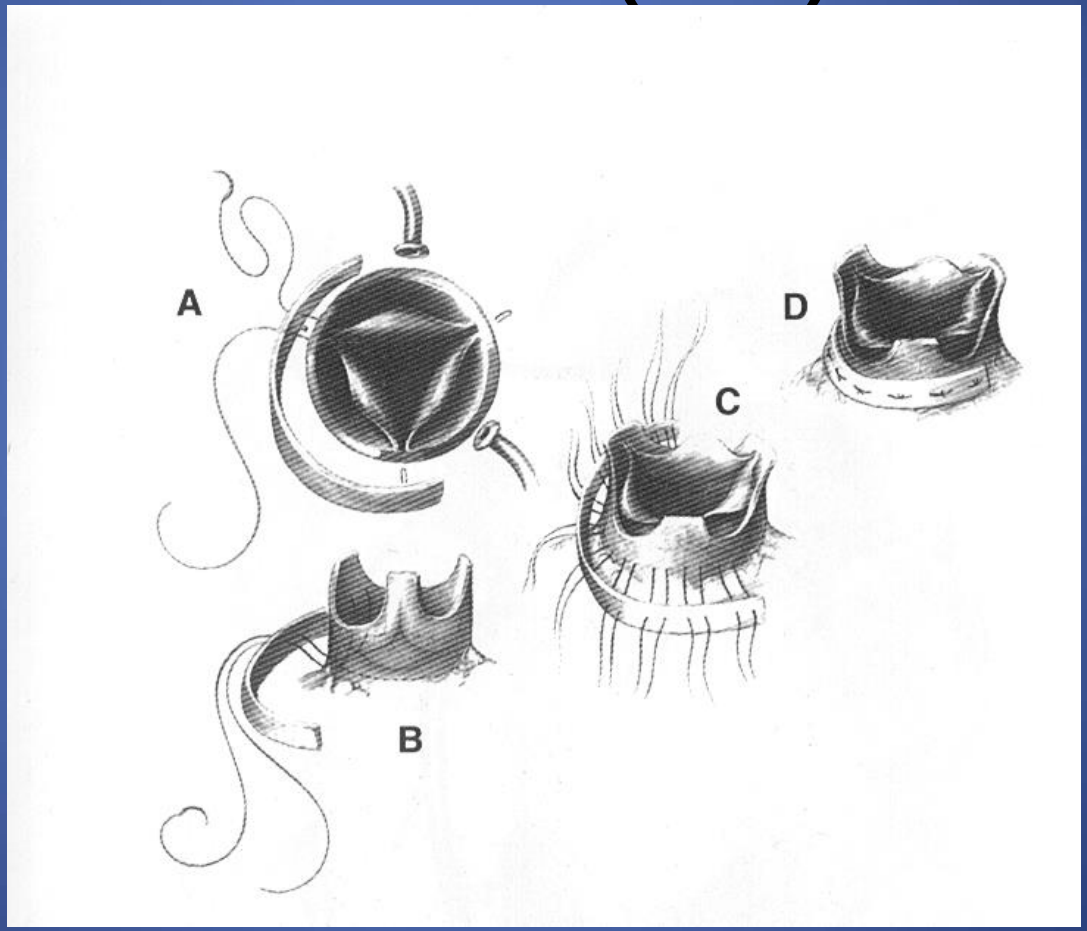


LVOT and Aortic Root Complex

Co-Location


Left coronary leaflet
Right coronary leaflet
Non-coronary leaflet
Left coronary leaflet
Muscular septum
Mitral valve
Conduction tissue (Membranous septum)
Right fibrous trigone
Left fibrous trigone

Remodeling and Correction of Dilated Annulus (D3)



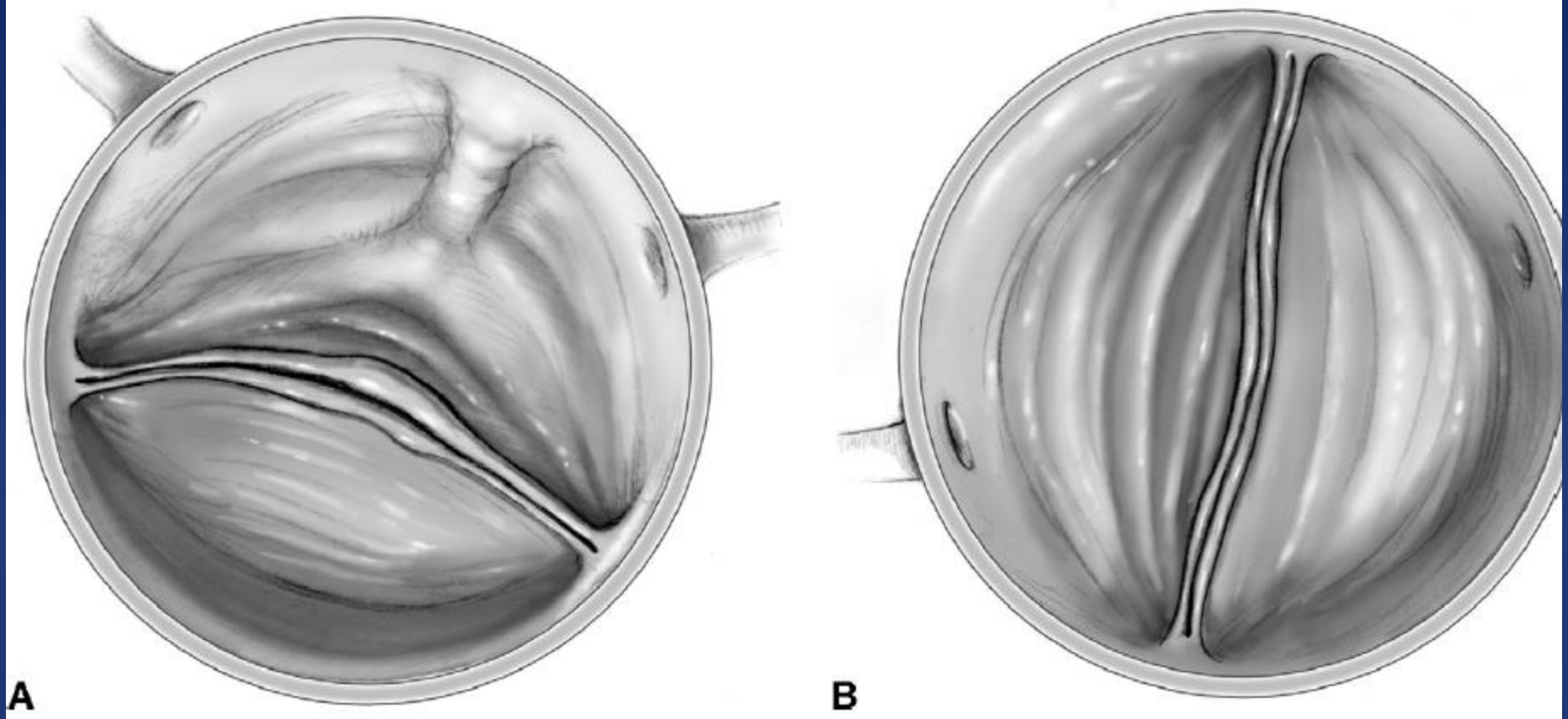
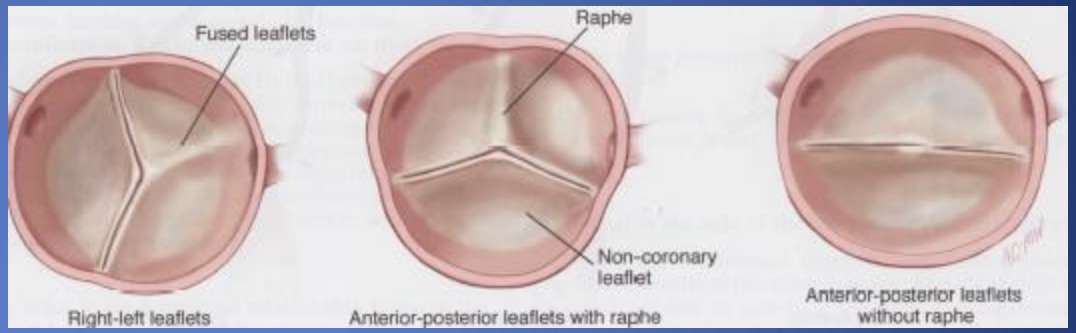
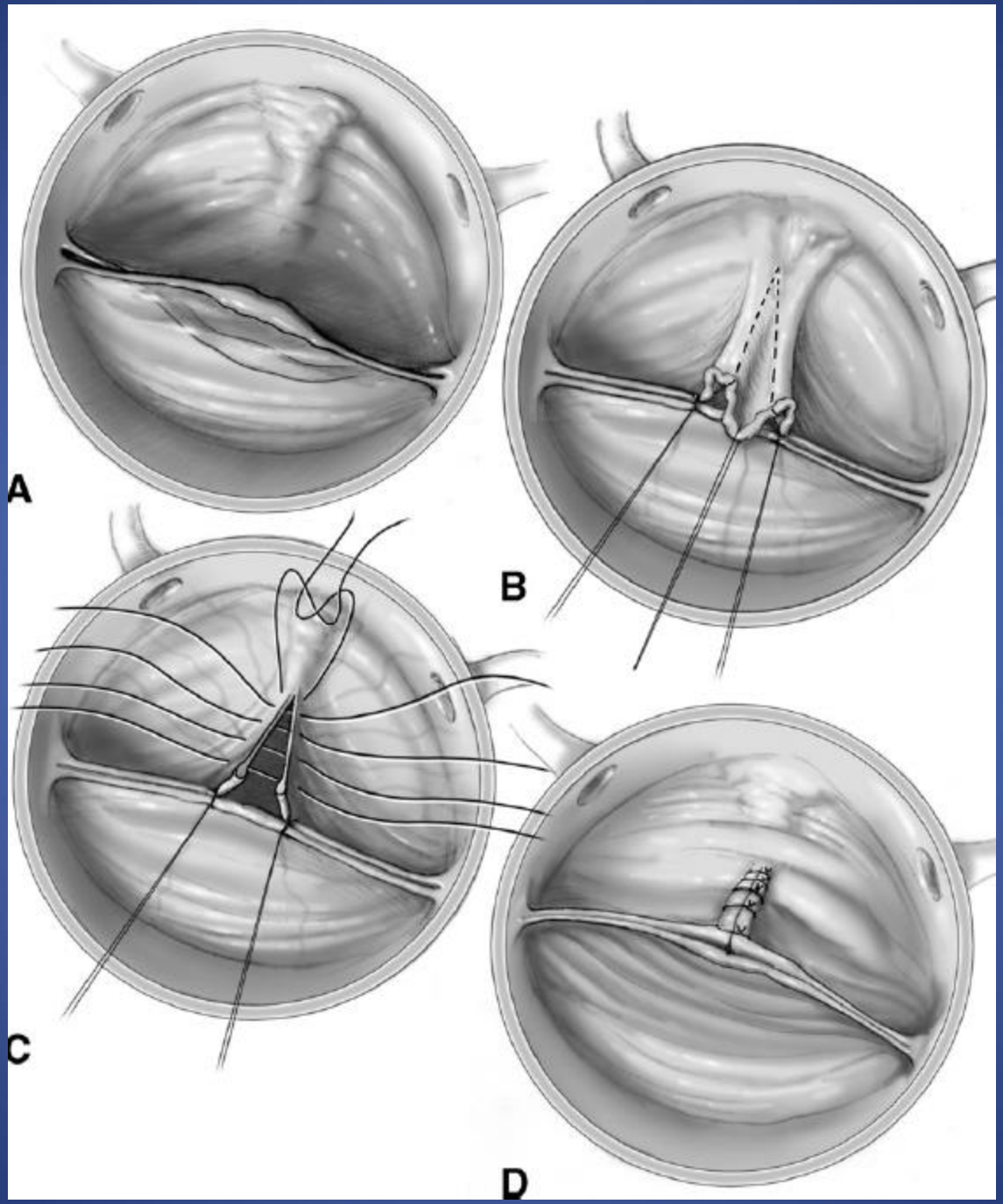
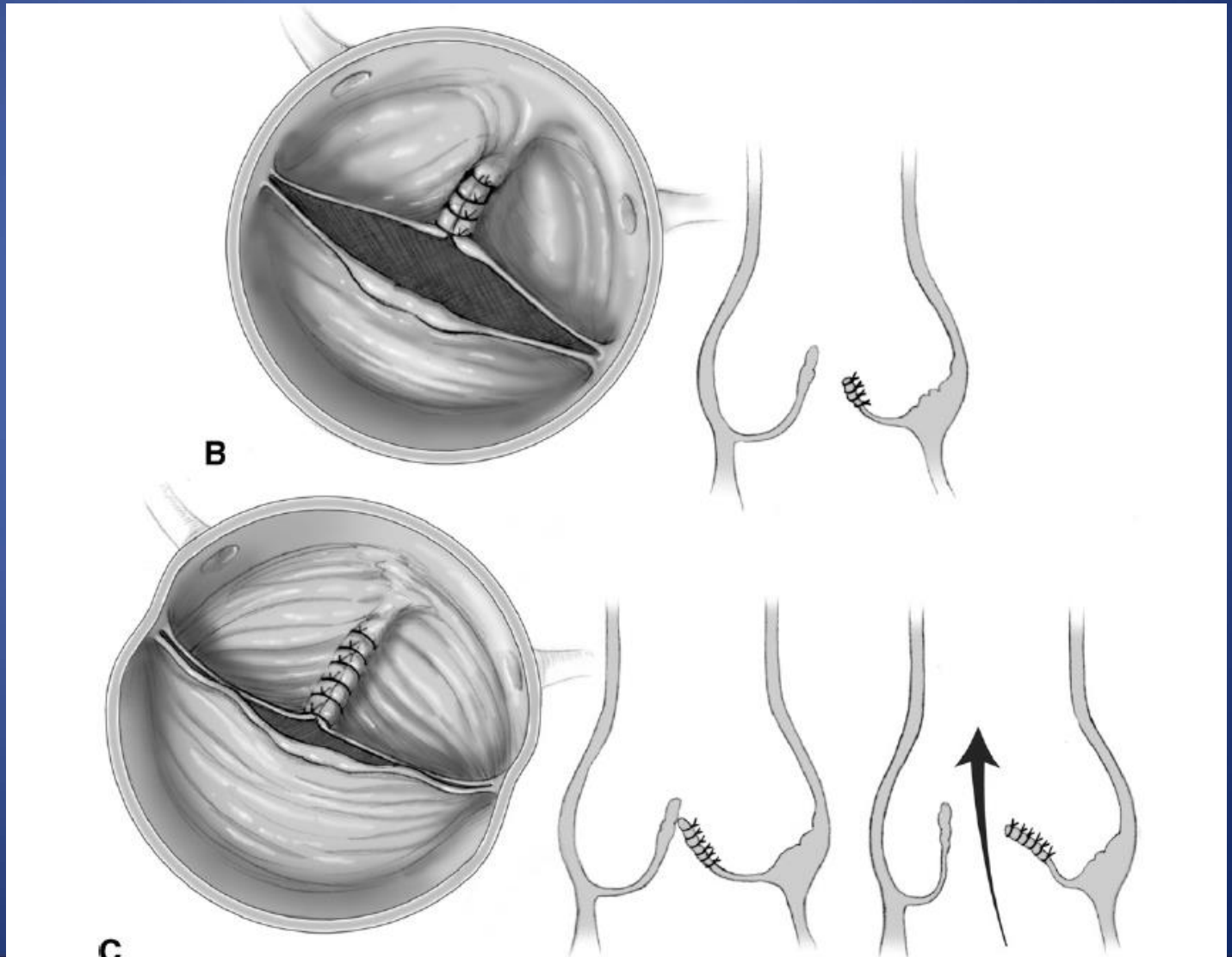
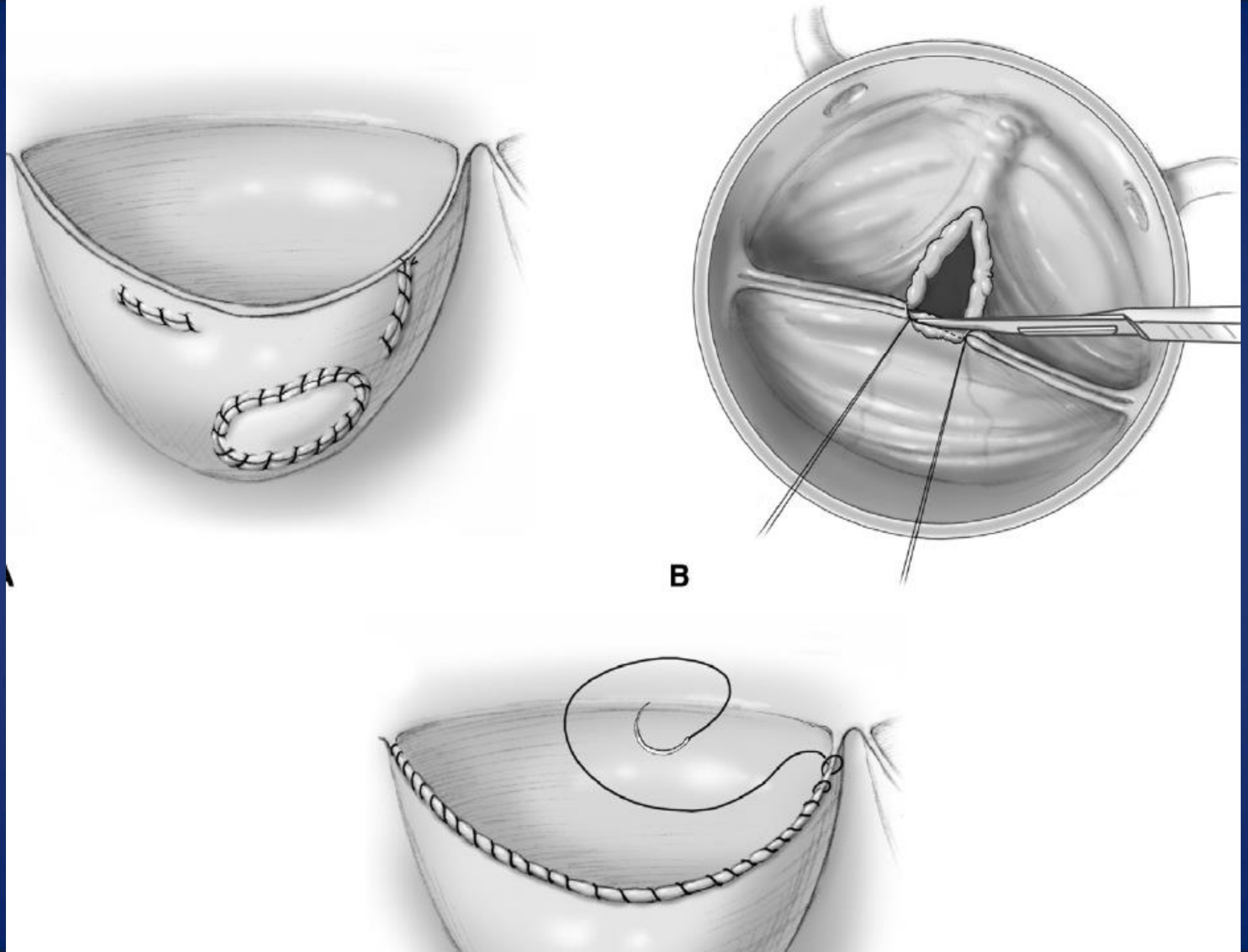


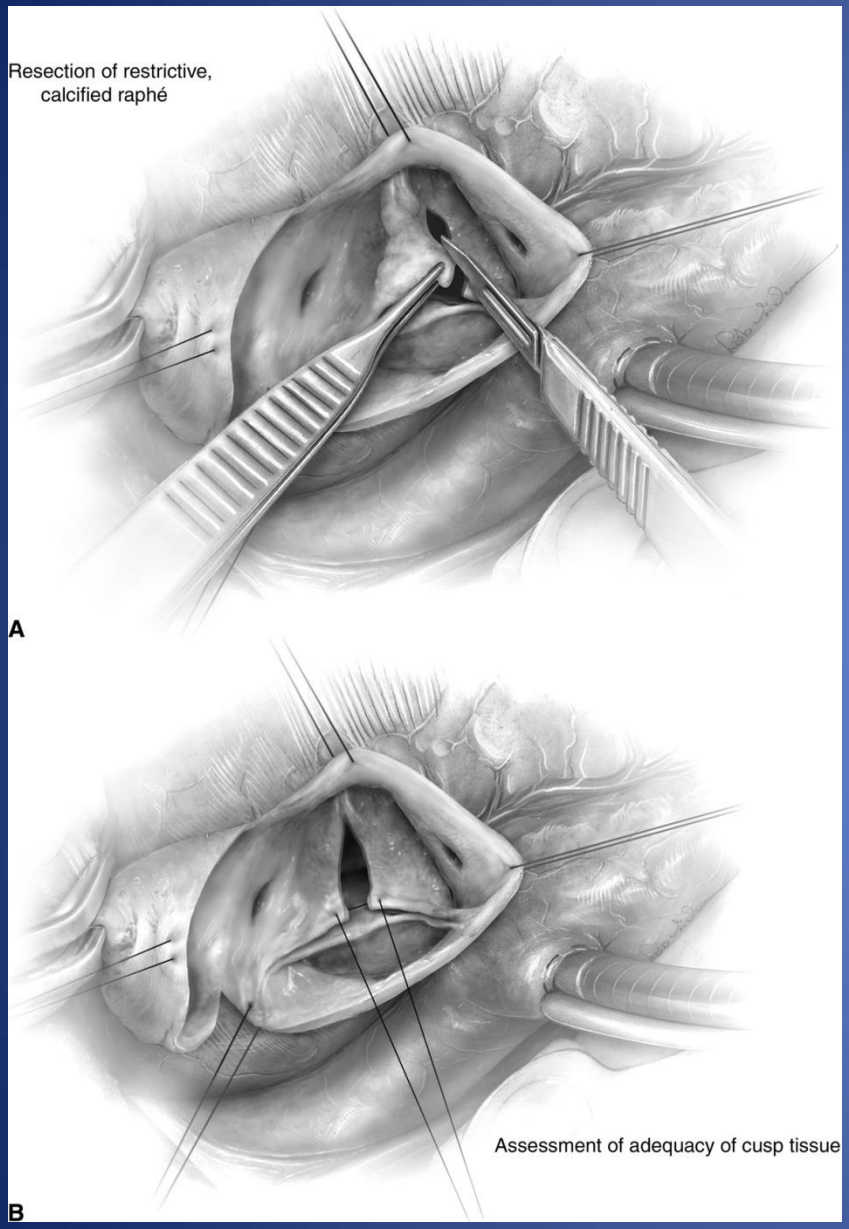
Figure 1 The leading repair principle is to transform the valve into the best possible bicommissural/bicuspid valve given the morphology and pathologic changes of the valve and root. A typical good bicuspid valve (A) is competent, displays complete fusion of the conjoint cusp, and has a raphe. The valve presents with one normal-looking cusp, called by us the reference cusp, and one larger cusp, appearing to be the result of fusion of two cusps normally encountered in the tricuspid form of aortic valve (conjoint cusp). Right and left cusp fusion remains most common, and the conjoint cusp is usually larger than the reference cusp; the ratio between the two cusps can be anywhere between 1:1 and 2:1. If the fusion is complete and the two cusps are coapting properly, one has a good functioning valve without regurgitation. In systole, it opens with a "fish-mouth" appearance; although the valve area is large, there is always some turbulence and a low gradient. This valve may remain well functioning for life or it may eventually thicken, calcify, and become stenotic, requiring surgery later in life. BAVs exhibiting two symmetrical cusps with horizontal orientation and no raphe are less common (B).

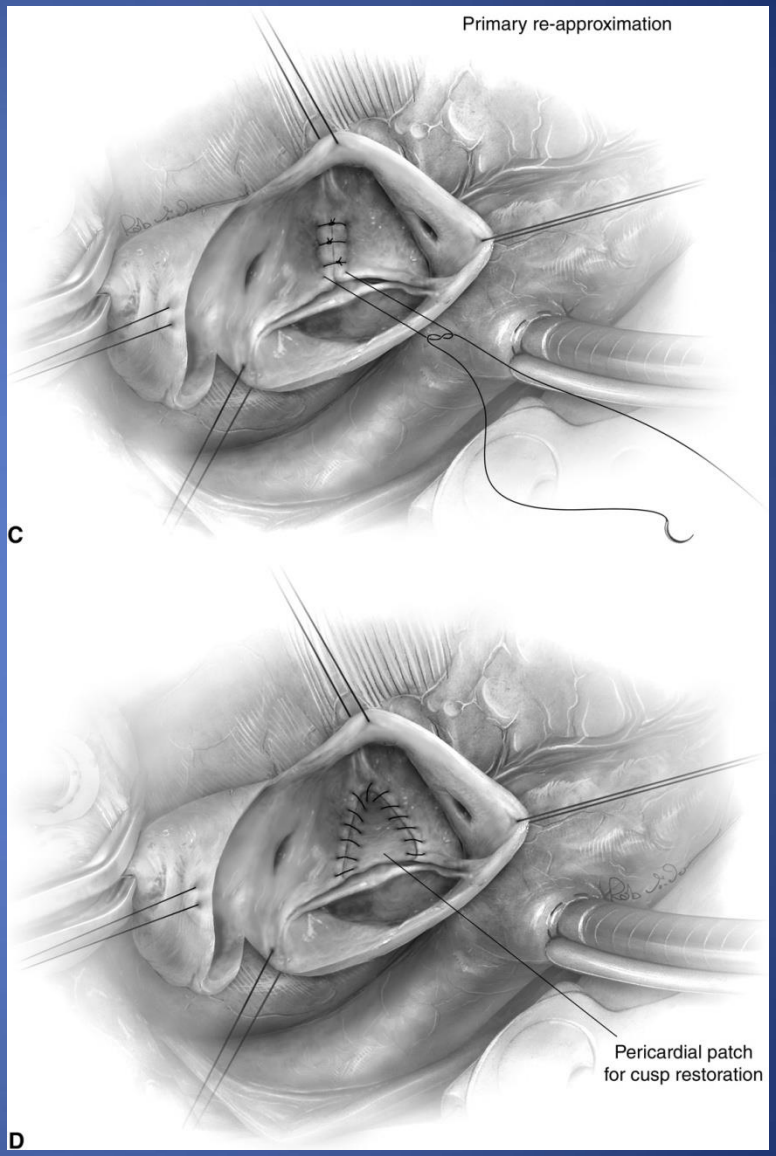

Fused leaflets
Raphe
Non-coronary leaflet
Right-left leaflets
Anterior-posterior leaflets with raphe
Anterior-posterior leaflets without raphe


A
B
C
D

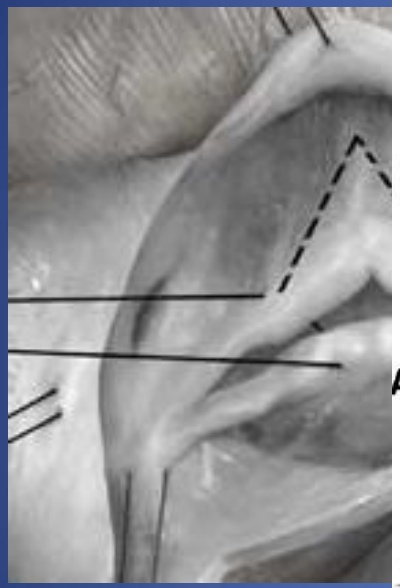

B
C

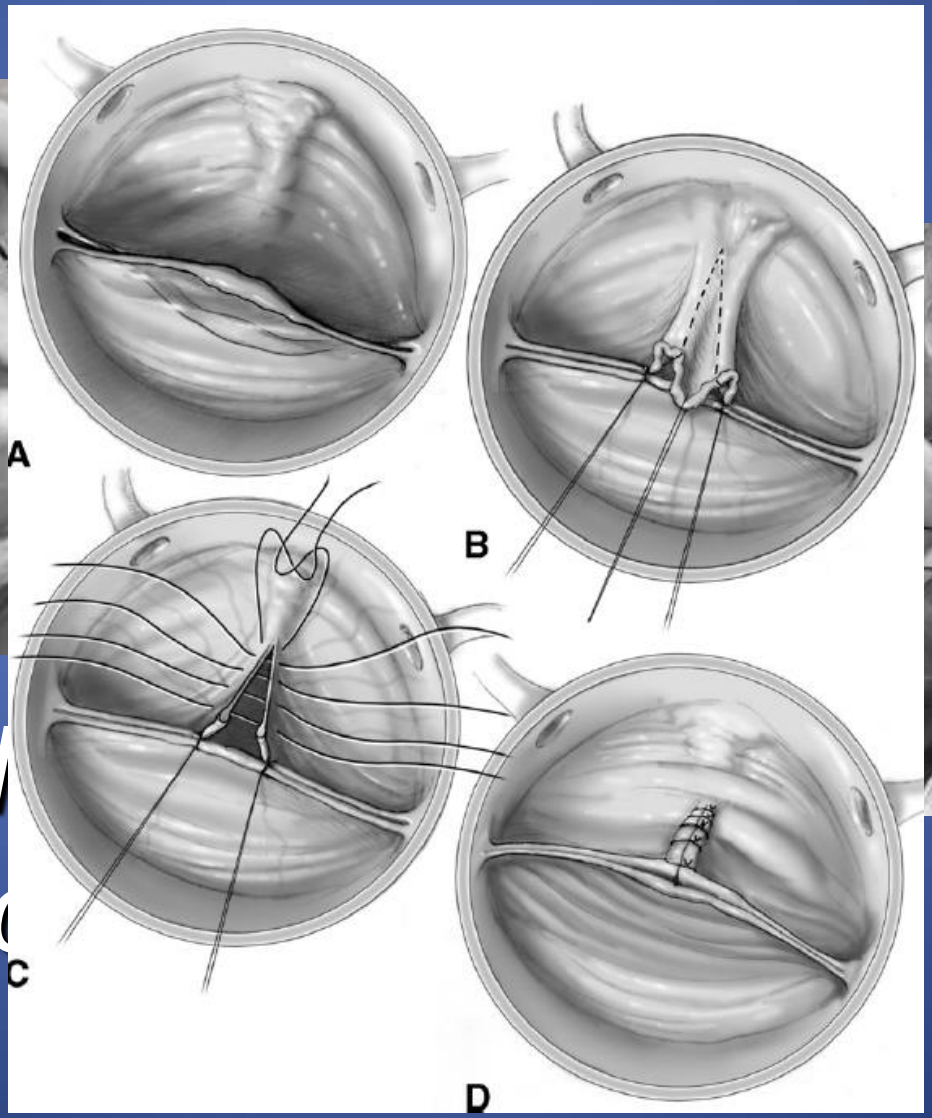

B


Resection of restrictive, calcified raphé
A
Assessment of adequacy of cusp tissue
B


Primary re-approximation
C
Pericardial patch for cusp restoration
D

Fibrotic and Redundant





Triangul

Resectio

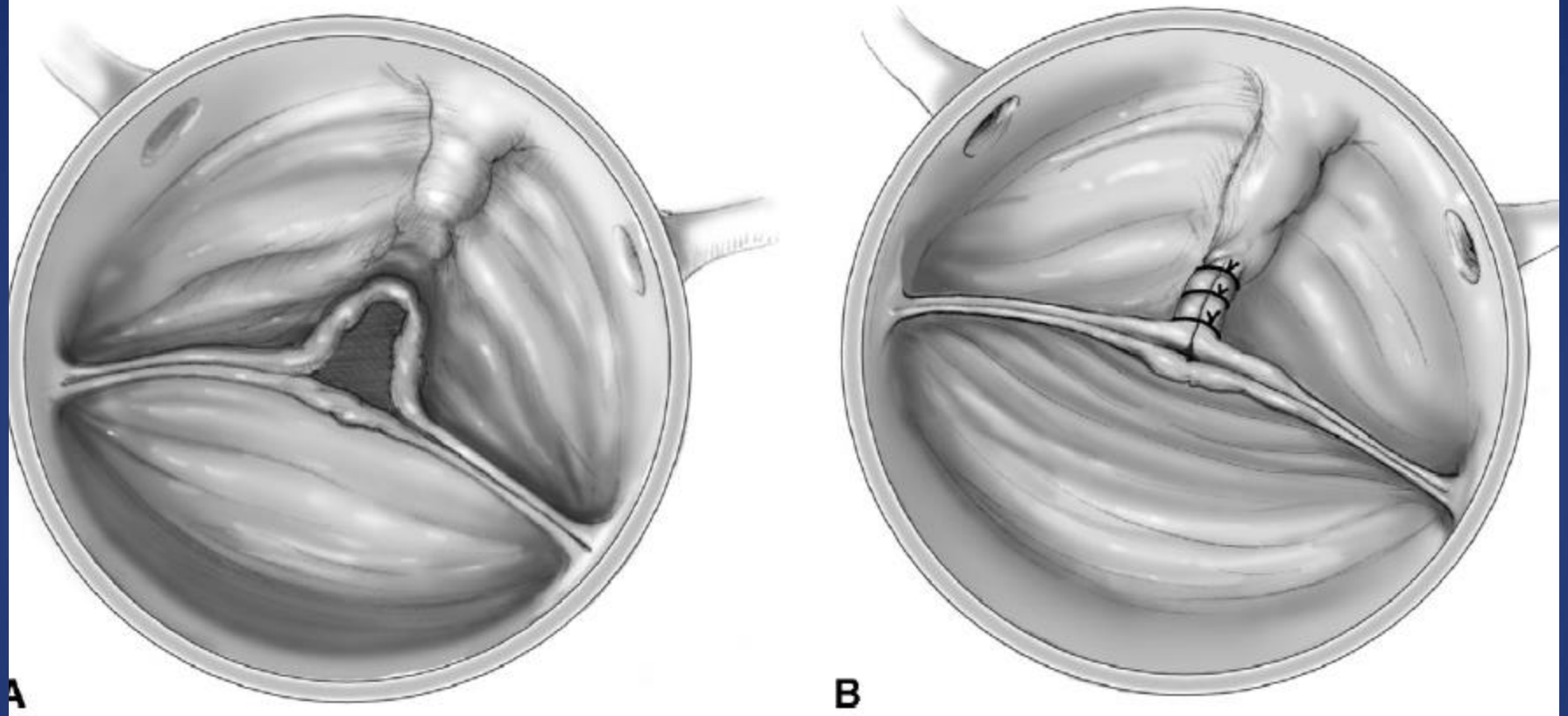


Figure 5 "Cleft" conjoint cusp with sufficient or excess tissue/size (A). The most important and deciding step of the repair is to equalize the length of the free margins of the two cusps. Most often, the two portions of the conjoint cusp have enough cusp tissue to make up for a second good cusp after completed bicuspidalization (B) by direct closure of the "cleft" with interrupted stitches. (We still refer to this kind of repair as plication, although it does not involve excess tissue.)

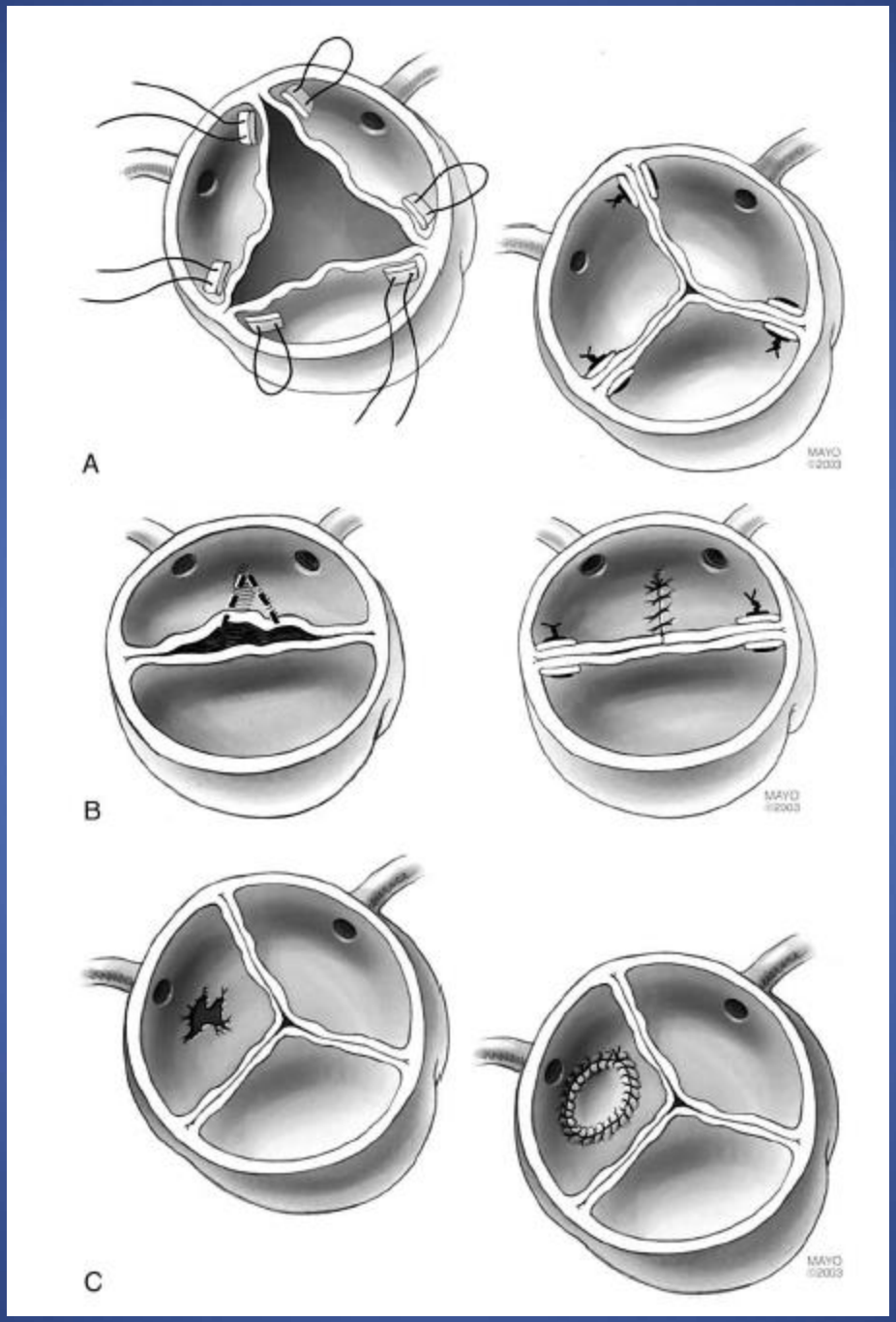
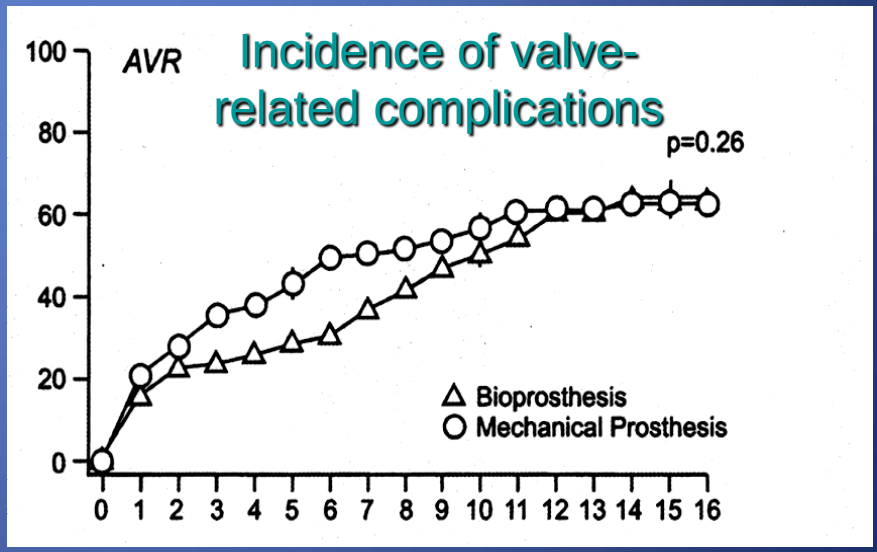

A
MAYO
©2003
B
MAYO
©2003
C
MAYO
©2003

Table 7. Results of main series comparing valve sparing with composite valve and graft replacement (CVG)

	Bassano 2001 [10]		de Oliveira 2003 [27]		Kaick 2004 [60]		Zehr 2004 [118]		Coselli 2008 [20]		Patel 2008 [89]	
	Valve sparing	CVG	Valve sparing	CVG	Valve sparing	CVG	Valve sparing	CVG	Valve sparing	CVG	Valve sparing	CVG
Number	32	37	61	44	45	74	54	149	66	33	84	56
Age (years)	53±19	58±13	35±10	34±11	28±12	35±11	51±15	54±16	31±11	40±14	29.2±12.3	38.1±14.1
Marfan	12%	3%	100%	100%	100%	100%	30%	23%	100%	100%	100%	100%
Bicuspid	–	–	–	9%	2%	4%	15%	12%	–	–	1 (1.2%)	1 (1.2%)
Type of operation	Remod.	–	Reimpl. 63.9% Remod. 36.1%	Mech. 59% Biop. 20.4%	Reimpl.	Mech.	Reimpl. 85.1% Remod. 14.8%	Mech. 89.2% Biop. 9.8%	Reimpl. 98% fs 2%	Mech. 85% Biop. 15%	Remod. 40 (47.6%) Reimpl. 44 (52.4%)	Mech. 100%
Acute dissection	0	0	9 (15%)	6 (14%)	3 (7%)	17 (23%)	12 (6%)		6 (9%)	3 (9%)	7 (12.5%)	9 (16.1%)
AC time (min)	101±24	96±25	–	–	125±29	78±26	107±30	96±28	185±76	111±48	102.6±14.7	115.2±60.4
Op. mortality	0	5.4%	0	2.3%	0	6.7%	3.7%	4%	0	0	0	0
Reexploration for bleeding	12.5%	21.6%	8.2%	9%	4.4%	10.8%	4%	4%	7.5%	15.1%	0	3.6%
Follow-up	1021 pt/m	926 pt/m	49±38m	75±54m	30m	114m	7.3± 6y		30 days	30 days	8y	8y
Freedom from reop.	87.5%	100%	5y 100% 10y 100%	5y 92±5% 10y 75±9%	5y 84±8%	92±3% 5y	63% 5y	96% 5y	Early: 1 valve reoperation	0	90.4±4.3% 8y	95.8±5.1% 8y
Freedom from TE complications							97% 5y	97% 5y			98.8%	91%
Freedom from HC	82±8% 5y	88±7% 5y	100% 5y 100% 10y	89±5% 5y 89±5% 10y	97.8%	76%	–	73% 15y		–	98.8% 97.6%	91% 96.4%
Freedom from endocarditis					100%	97.1%	99% 15y		–	–	100%	
Survival 5y 10y	100% follow-up	97.3% follow-up	96±3% 96±3%	92±5% 87±7%	96±4% –	89±4% –	93% 79%		–	–	100% 8y	90.1%± 4.8% 8y

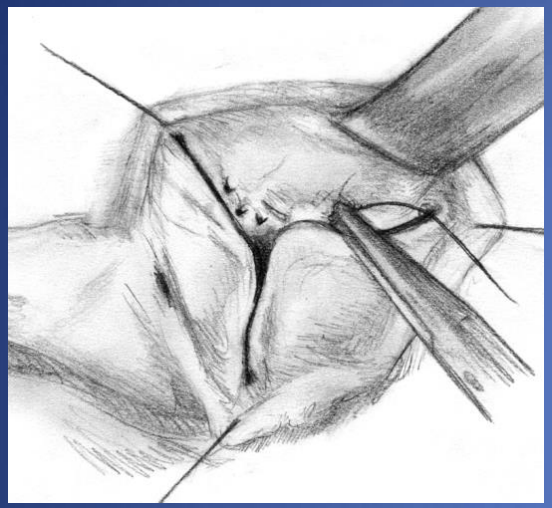
Aortic Valve Replacement

- Thromboembolism
- Anticoagulation/Hemorrhage
- Structural failure
- PV endocarditis



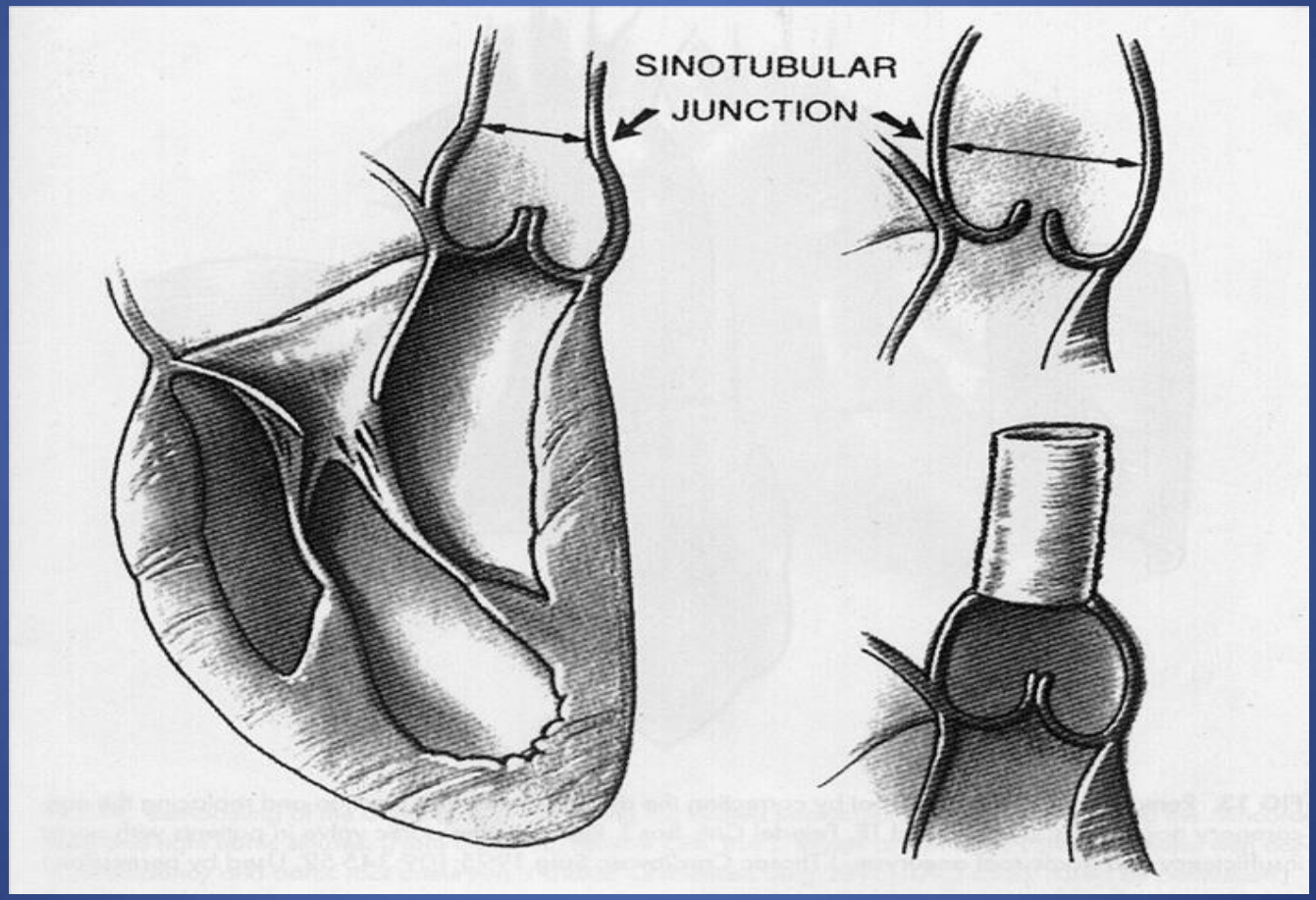
Hammermeister et al, JACC 2000

Prolapse



Plication of Cusp Margin

Dilatation of the STJ



Cusp repair in aortic valve reconstruction: Does the technique affect stability?

Diana Aicher, MD, Frank Langer, MD, Oliver Adam, MD, Dietmar Tscholl, MD, Henning Lausberg, MD, and Hans-Joachim Schäfers, MD

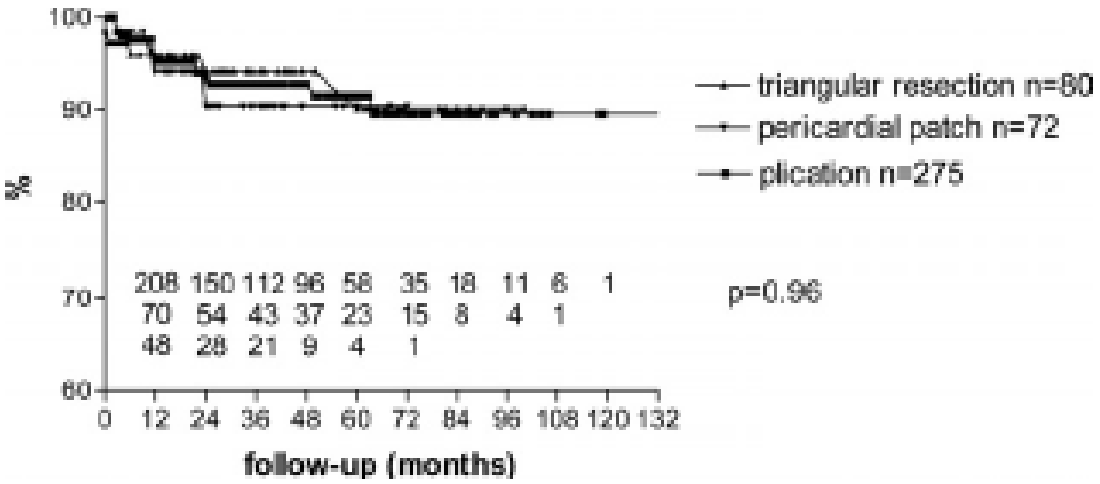
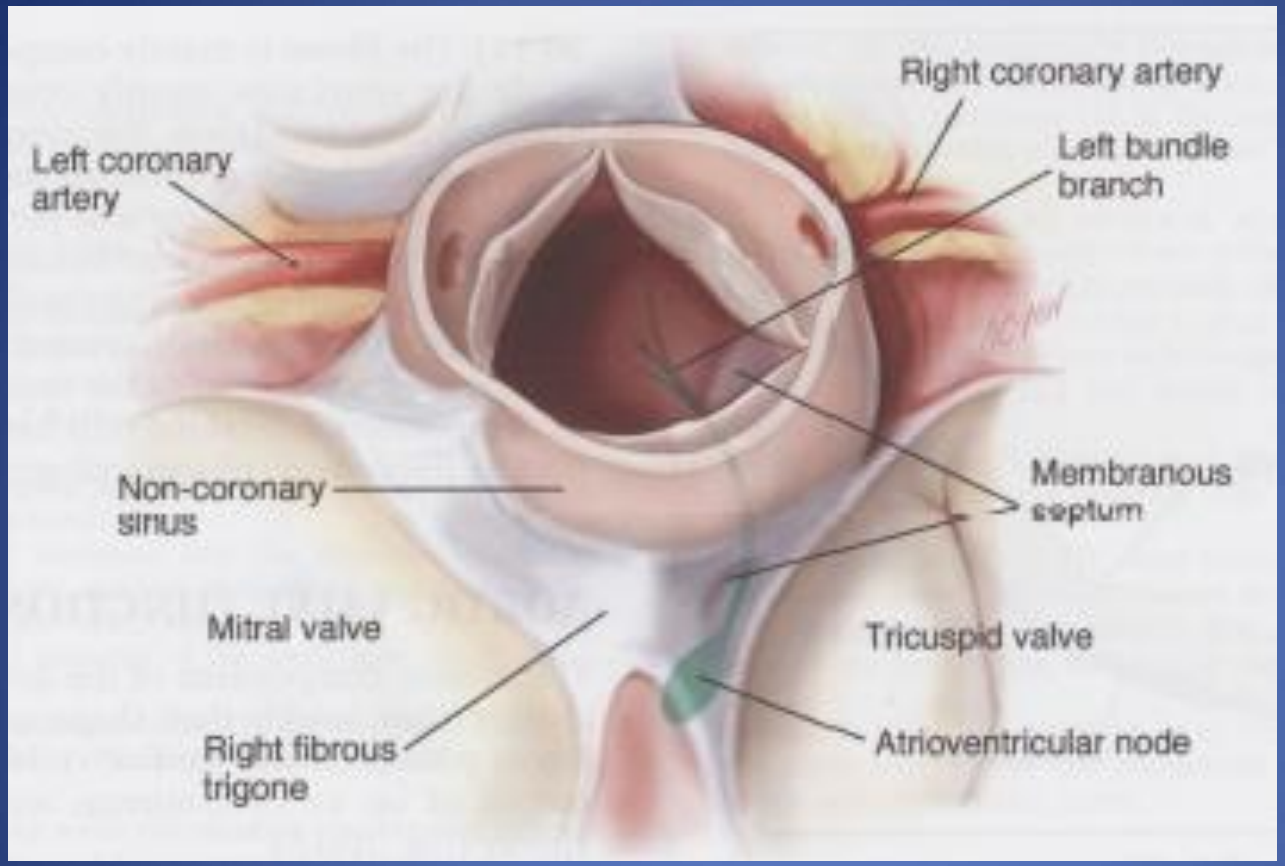


Figure 2. Freedom from aortic regurgitation of grade II or more after the three different cusp repair techniques.

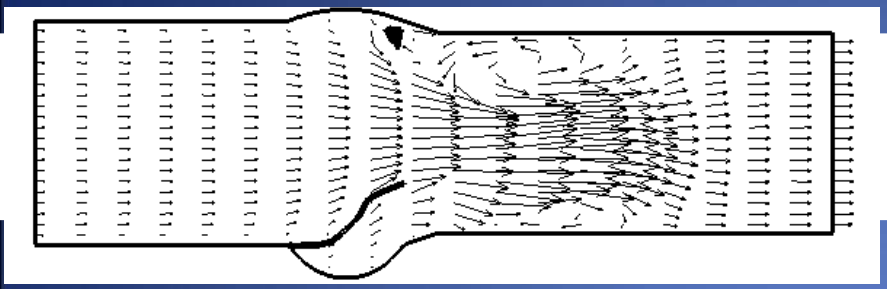
The Journal of Thoracic and Cardiovascular Surgery • December 2007

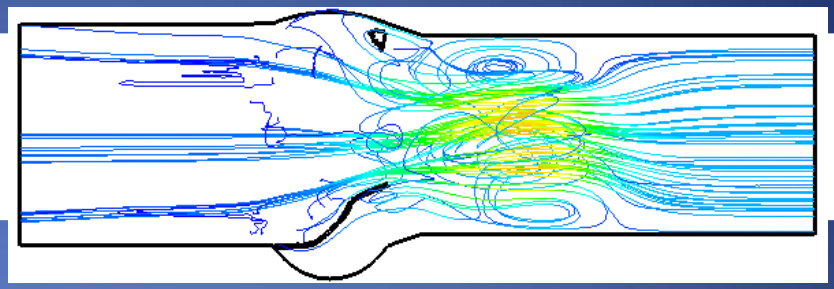


- Position of His bundle
- Position of RCA Ostia

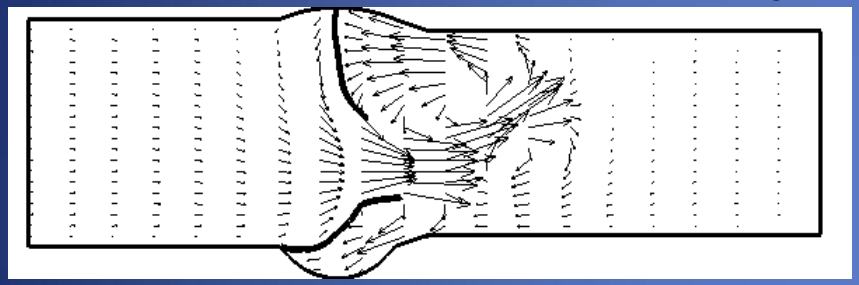
Velocity vectors and streamlines

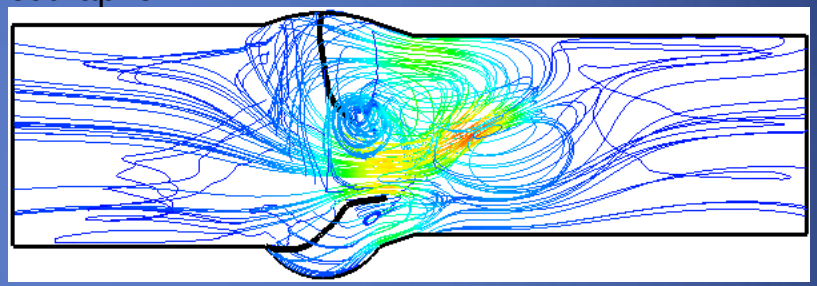
TAV



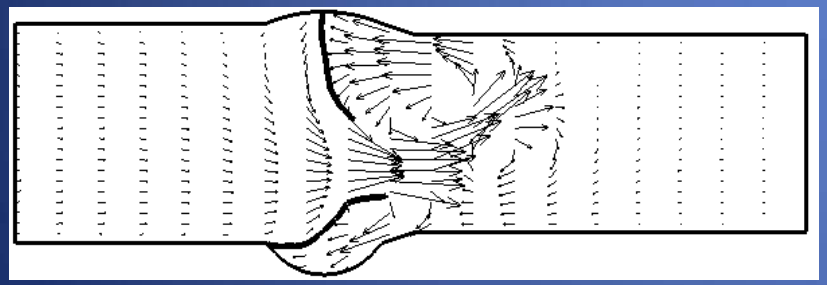


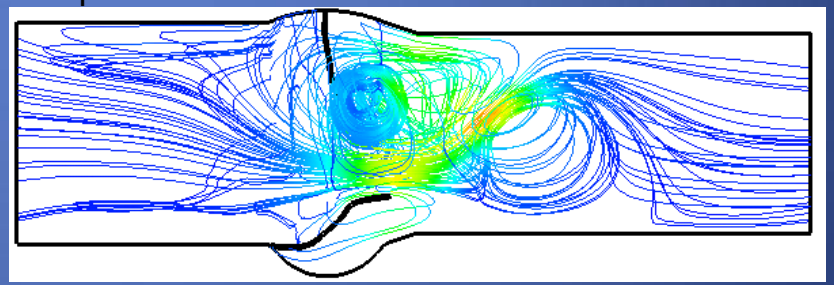
BAV no. 1 without raphe



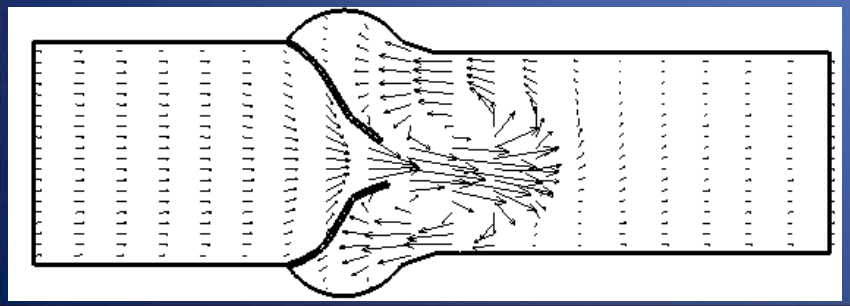


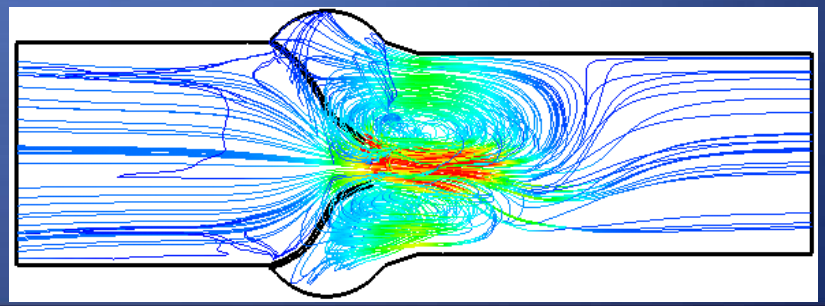
BAV no. 1 with raphe





BAV no. 2





Flow velocity magnitude [m/s]

Valve-sparing aortic root replacement in bicuspid aortic valves: A reasonable option?

Diana Aicher, MD[a]
Frank Langer, MD[a]
Anke Kissinger[a]
Henning Lausberg, MD[a]
Roland Fries, MD[b]
Hans-Joachim Schäfers, MD[a]

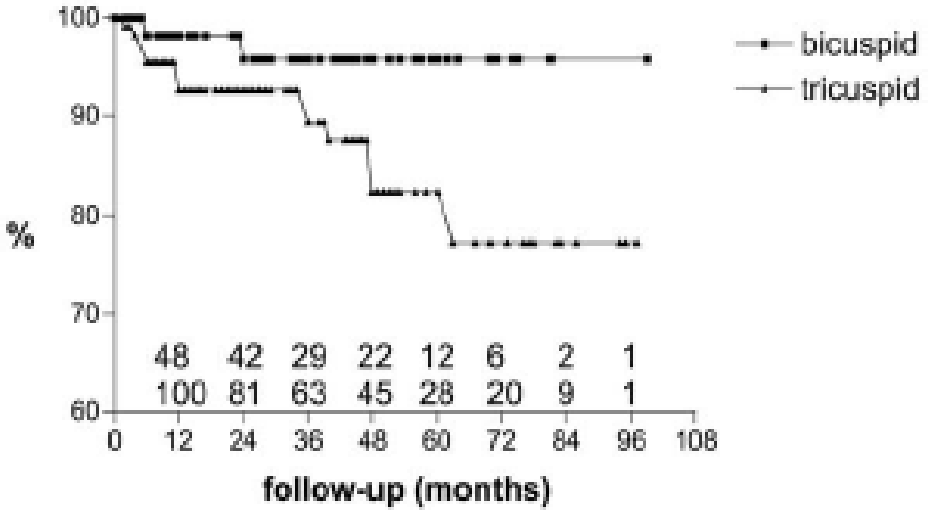


Figure 1. Actuarial freedom from aortic regurgitation of II or greater after root remodeling in the presence of bicuspid or tricuspid aortic valve anatomy.

The Journal of Thoracic and Cardiovascular Surgery • November 2004