Reconstruction of the Aortic Valve and Root: A Practical Approach

September 13th-15th, 2017, Homburg/Saar, Germany

The Role Of Ross Operation In Aortic Insufficiency

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UCL Université catholique de Louvain

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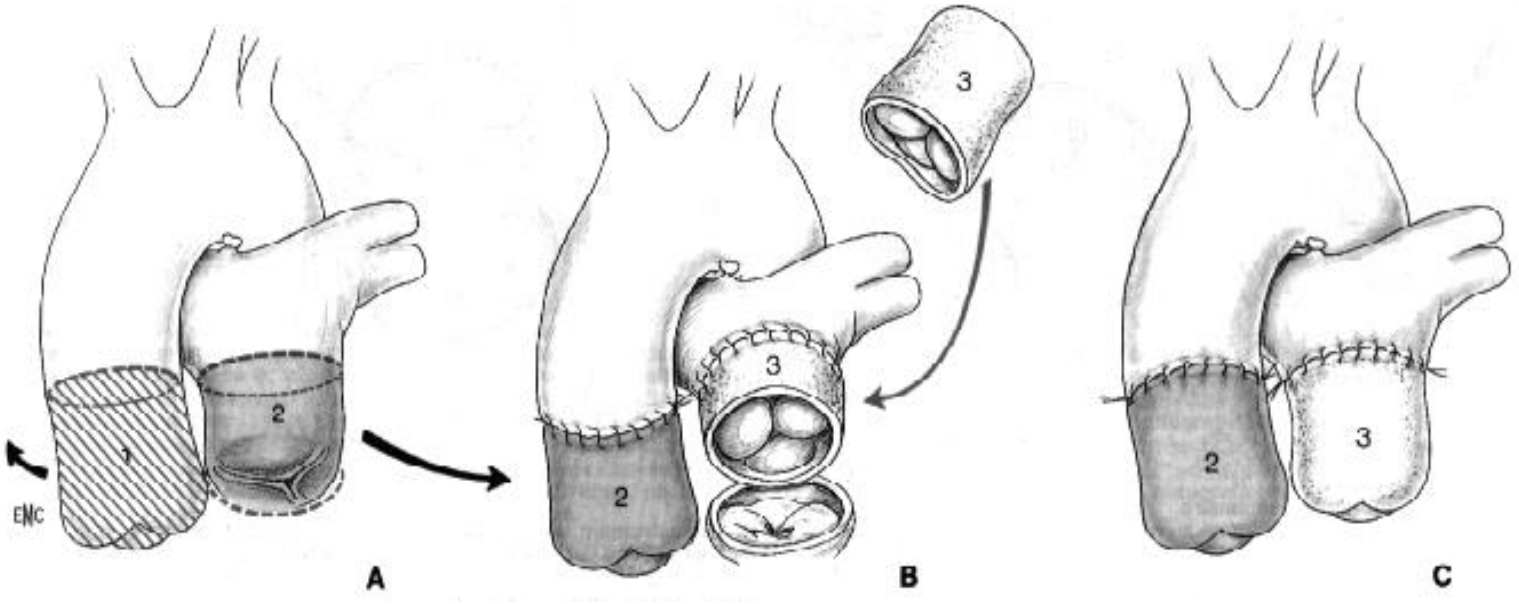
SCORE: 1234

Replacement of Aortic and Mitral Valves with a Pulmonary Autograft

Ross DN *Lancet 1967 Nov 4;2(7523):956-8*

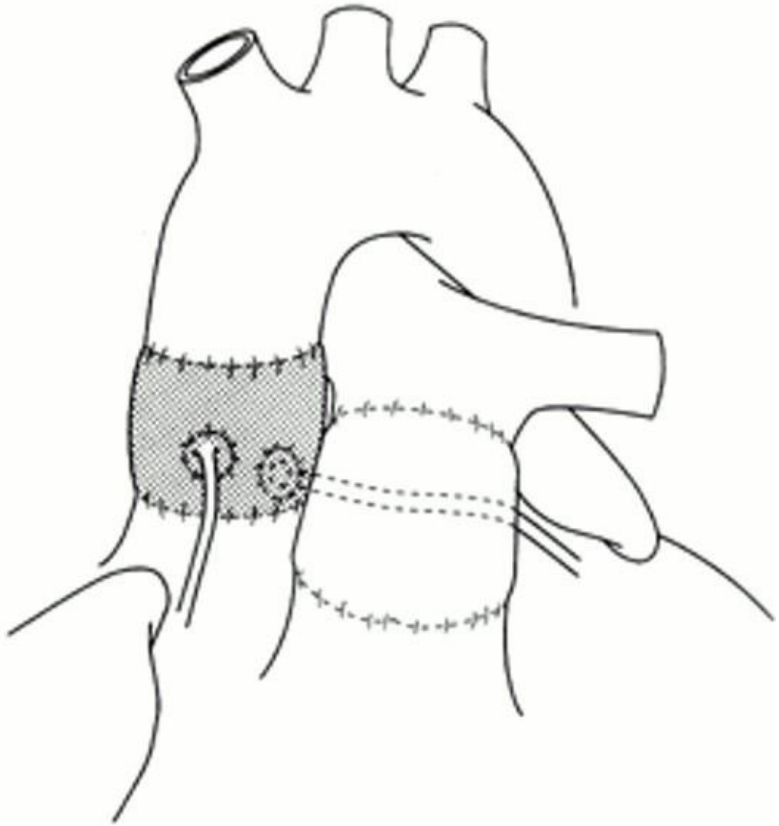


- Indicated in pediatric and young adult population (≤ 55 years) suffering from AS and/or AI
- No anticoagulation, growth potential
- Excellent exercise tolerance

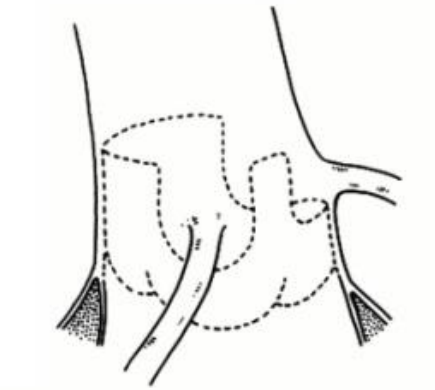
Doty et al. Asian Cardiovasc Thorac Ann 1999
Porter et al. JHVD 1999

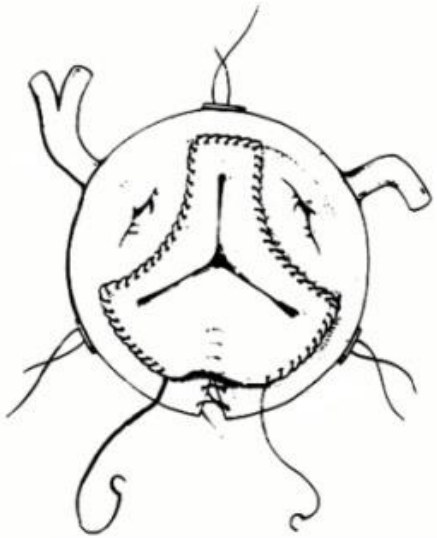
Ross operation in AI: Ross techniques

Freestanding Root

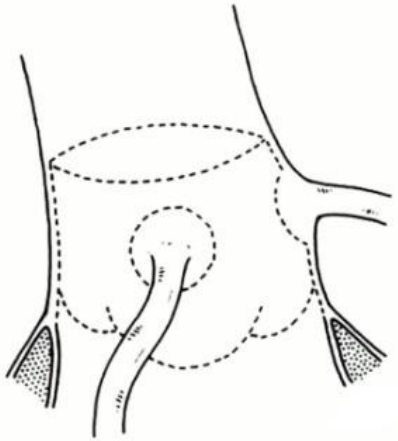


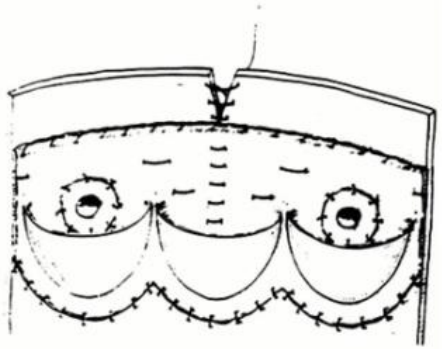
Subcoronary





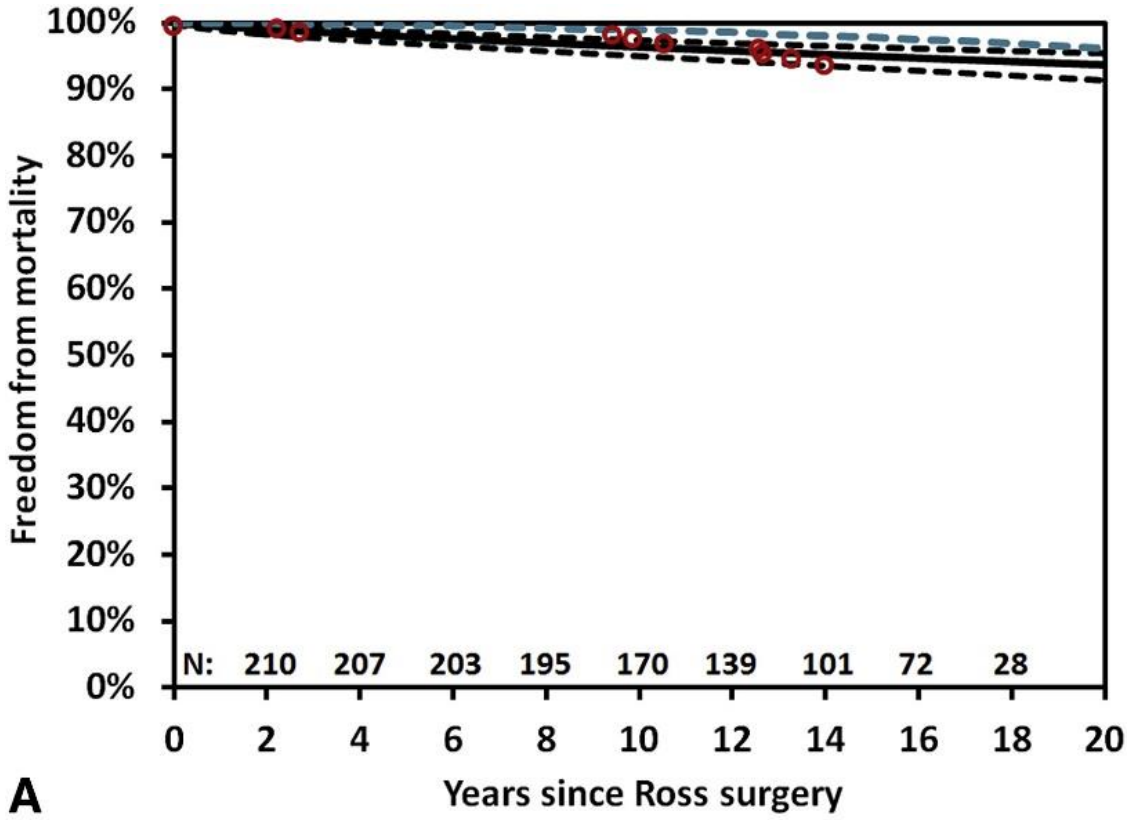
Inclusion cylinder



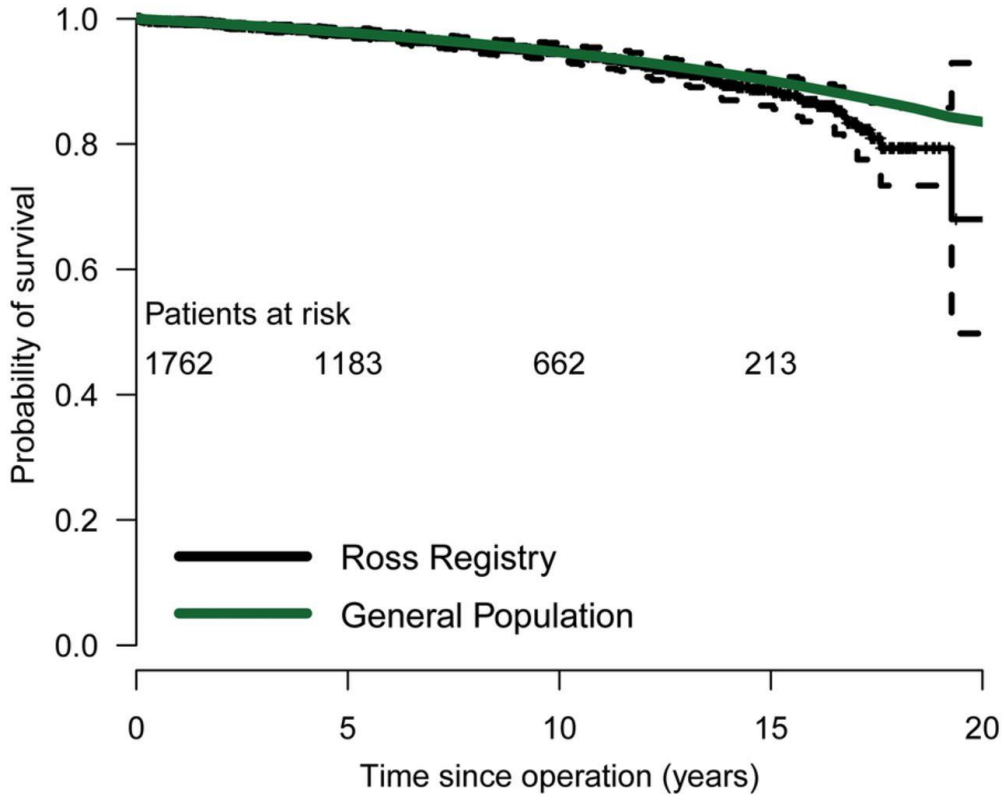


Ross operation in AI: Why perform a Ross

- Low operative mortality (≤1%)
- Excellent survival up to 20 y = to general population matched for age and sex



T. David et al. J Thor Cardiovasc Surg 2014



H-H. Sievers et al. Eur J Cardiothorac Surg 2015

Ross operation in AI: Why perform a Ross

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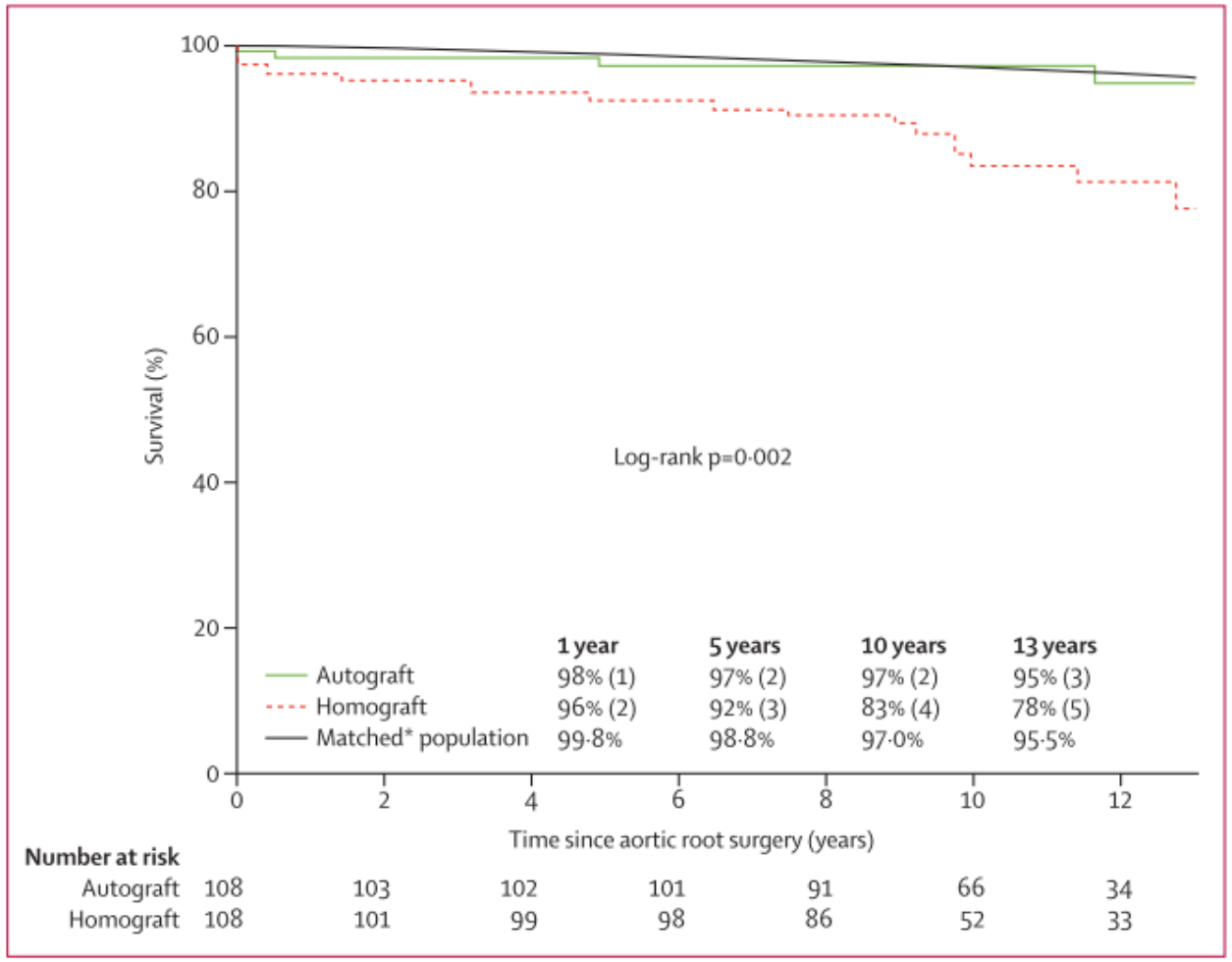
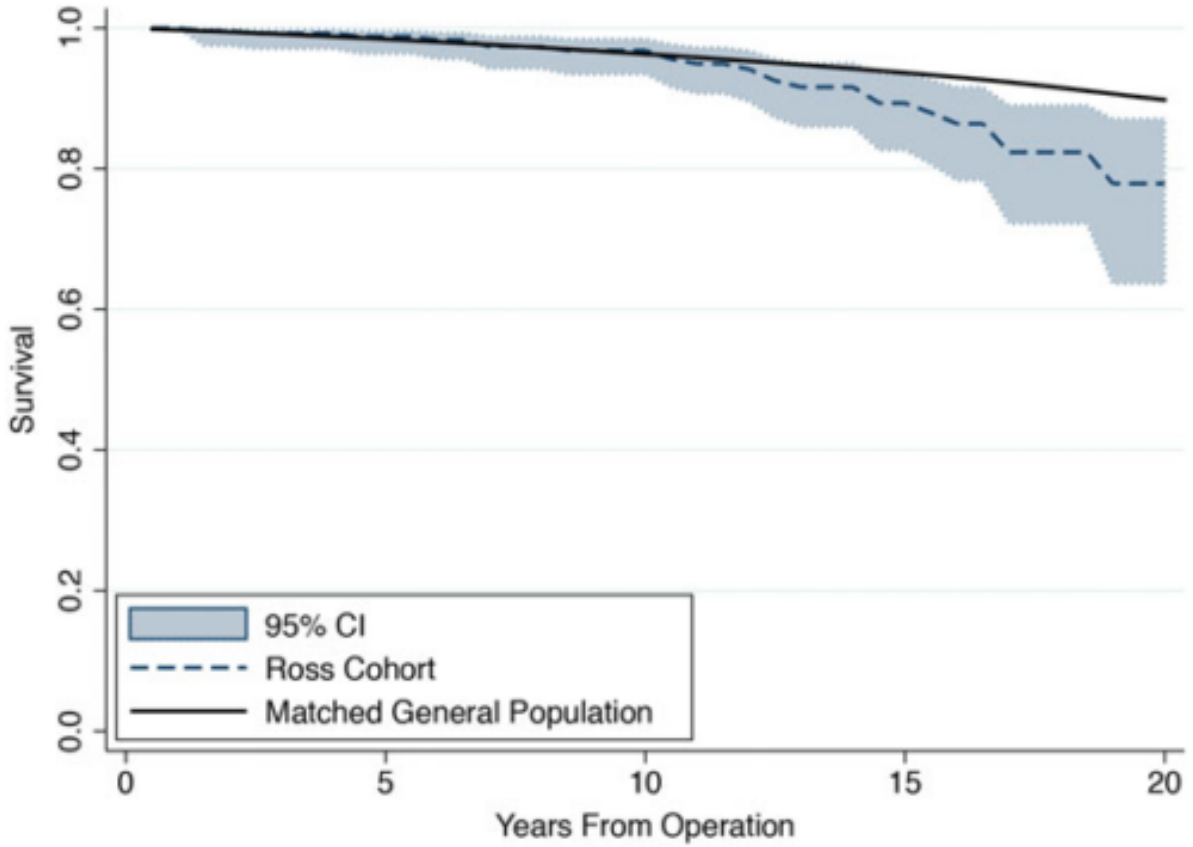


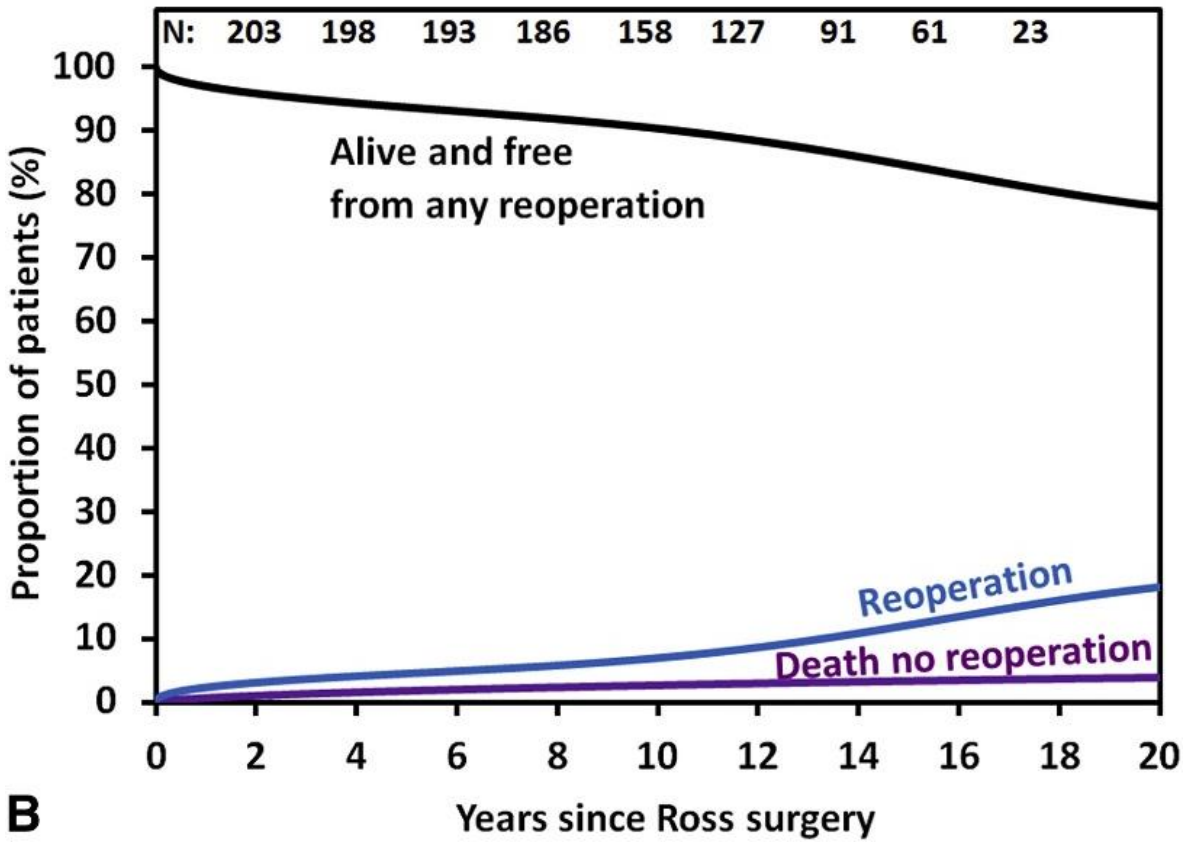
Ismail El-hamamsy et al. Lancet 2010

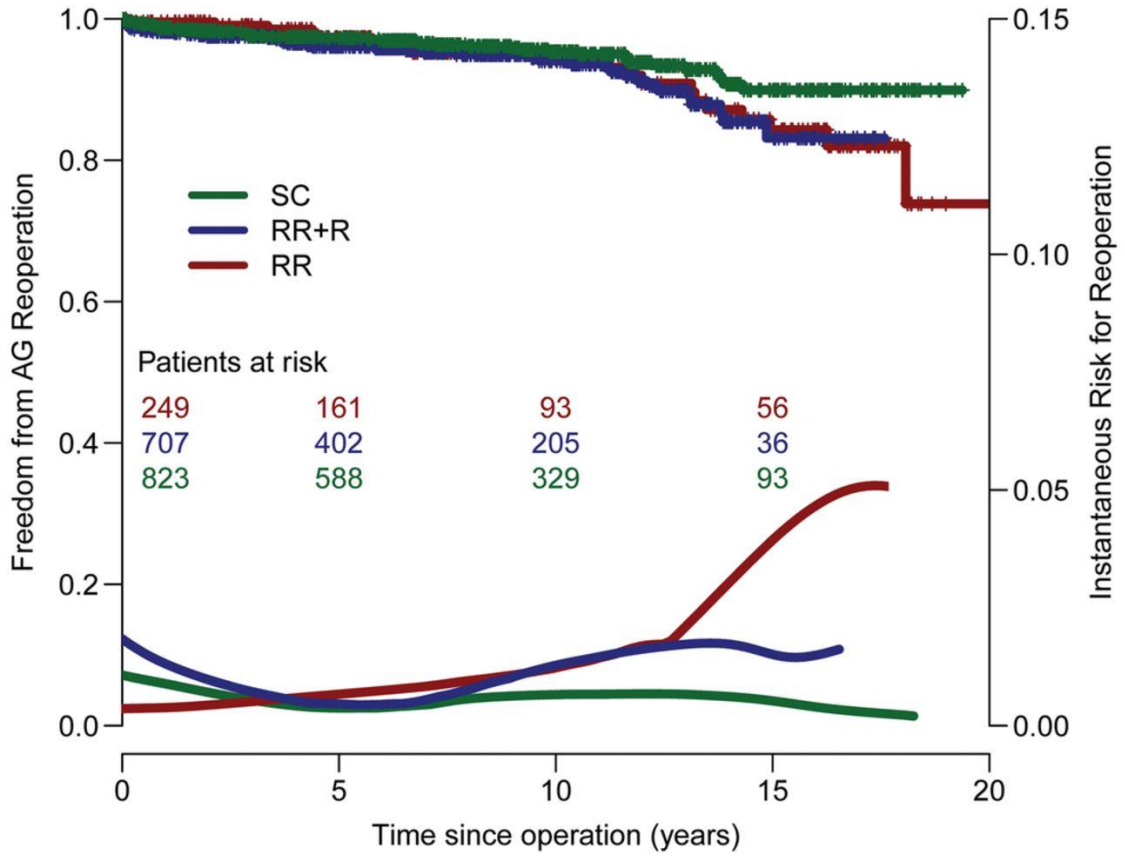


S. Mastrobuoni et al. EJCTS 2015

Ross operation in AI: Why perform a Ross

- Durability of PA: 80-90% freedom from reoperation at 20 years.



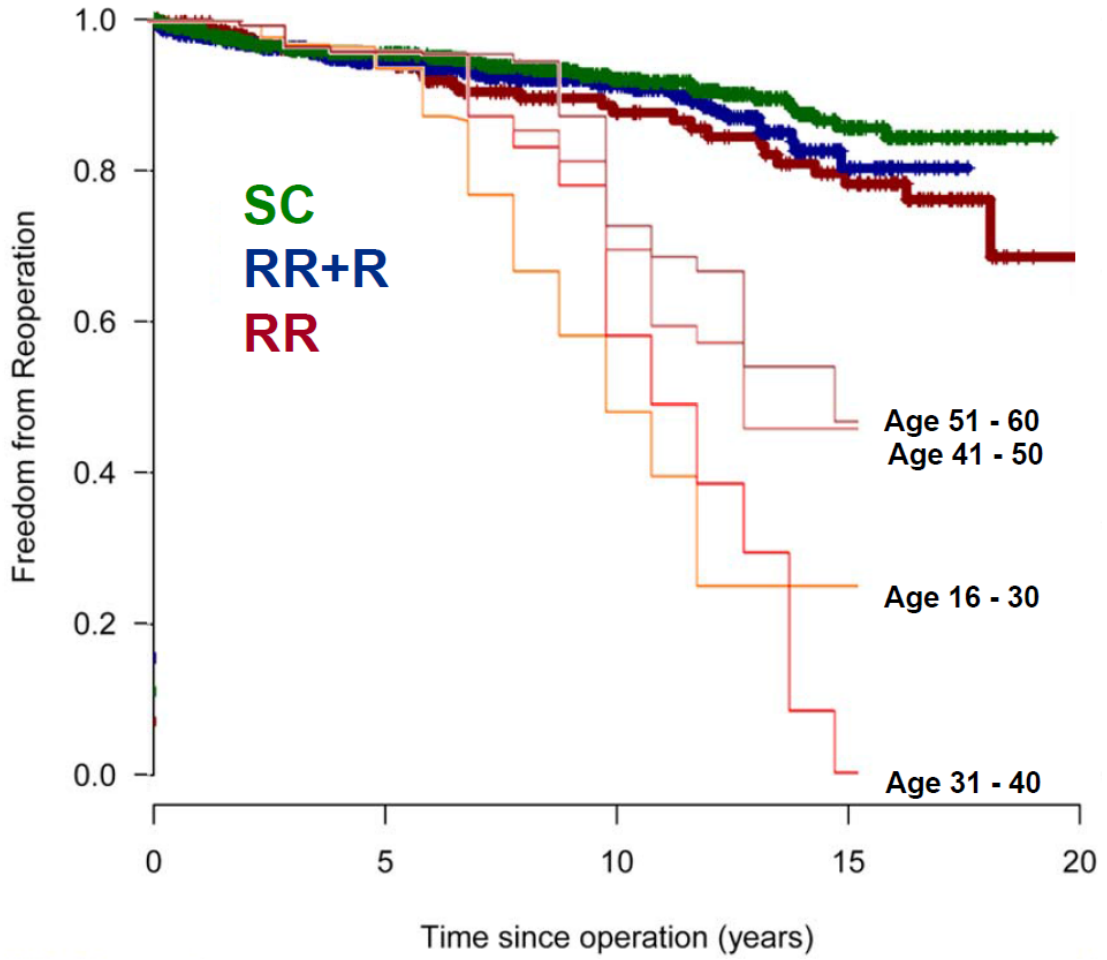


T. David et al. J Thor Cardiovasc Surg 2014;147 (1): 85-94

H-H. Sievers et al. Eur J Cardiothorac Surg 2015;ejcts.ezv001

Ross operation in AI: When Compared to Alternatives

- Lower reoperation rates compared to bioprosthesis in young adults



Age (years):

Ross

45.1 ± 11.2 (SC)

45.7 ± 11.3 (RR-R)

40.3 ± 12.8 (RR)

LOR: ~ 1% / ptyear

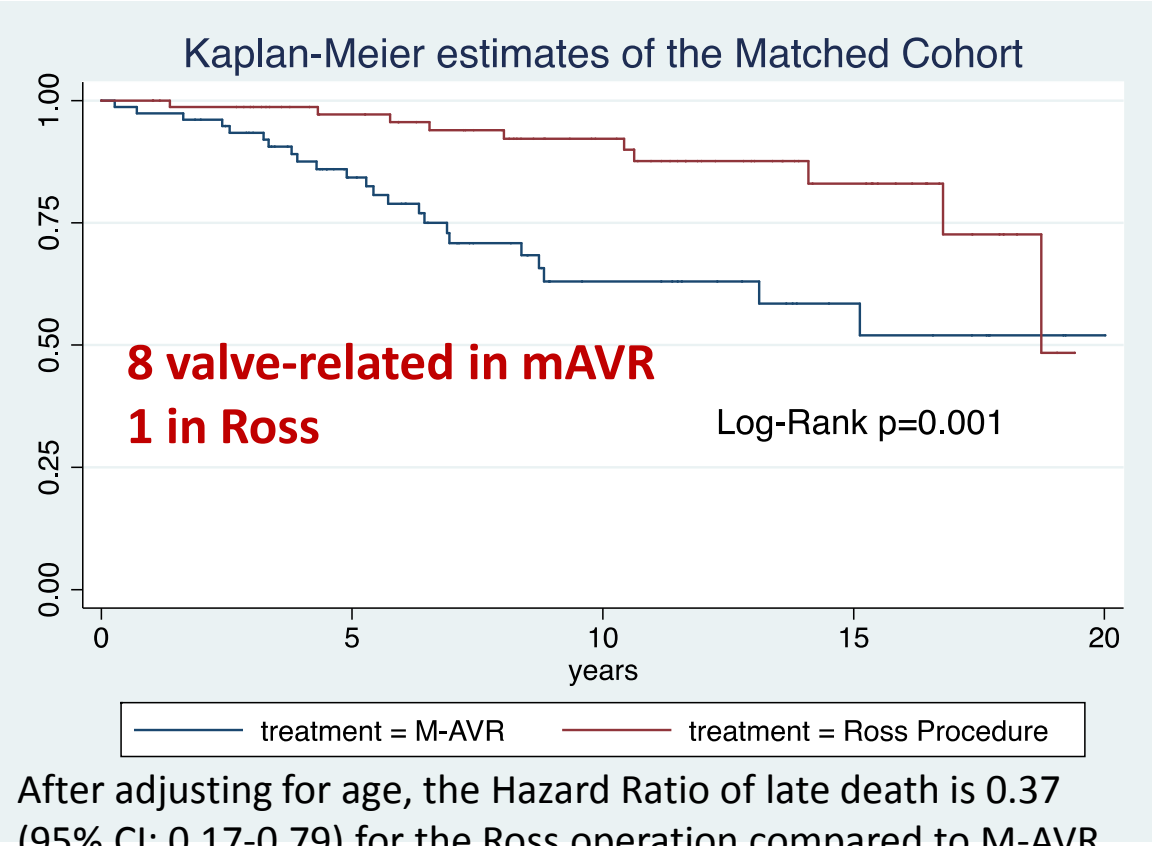
Xenograft

Fann et al. Curr Opin Cardiol.2001;16:126-135.

1 Sievers HH et al. Eur J Cardiothorac Surg. 2016.49:212-8.

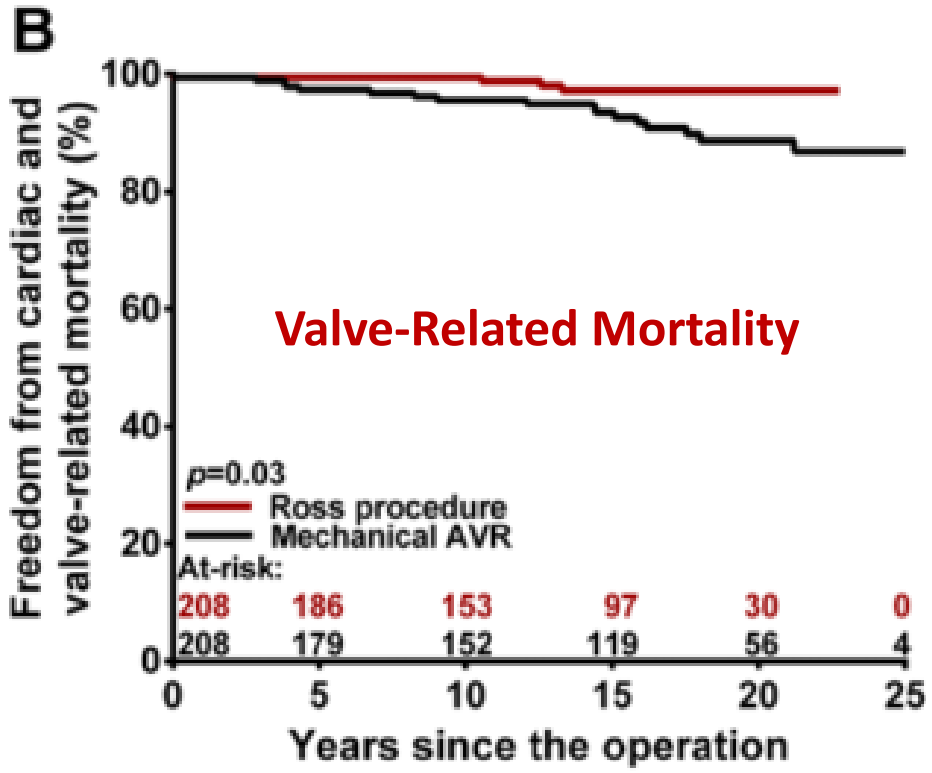
Ross operation in AI: When Compared to Alternatives

- Compared to Mechanical Valve Replacement (mAVR) – Matched Cohorts:
  - Better overall survival



After adjusting for age, the Hazard Ratio of late death is 0.37 (95% CI: 0.17-0.79) for the Ross operation compared to M-AVR

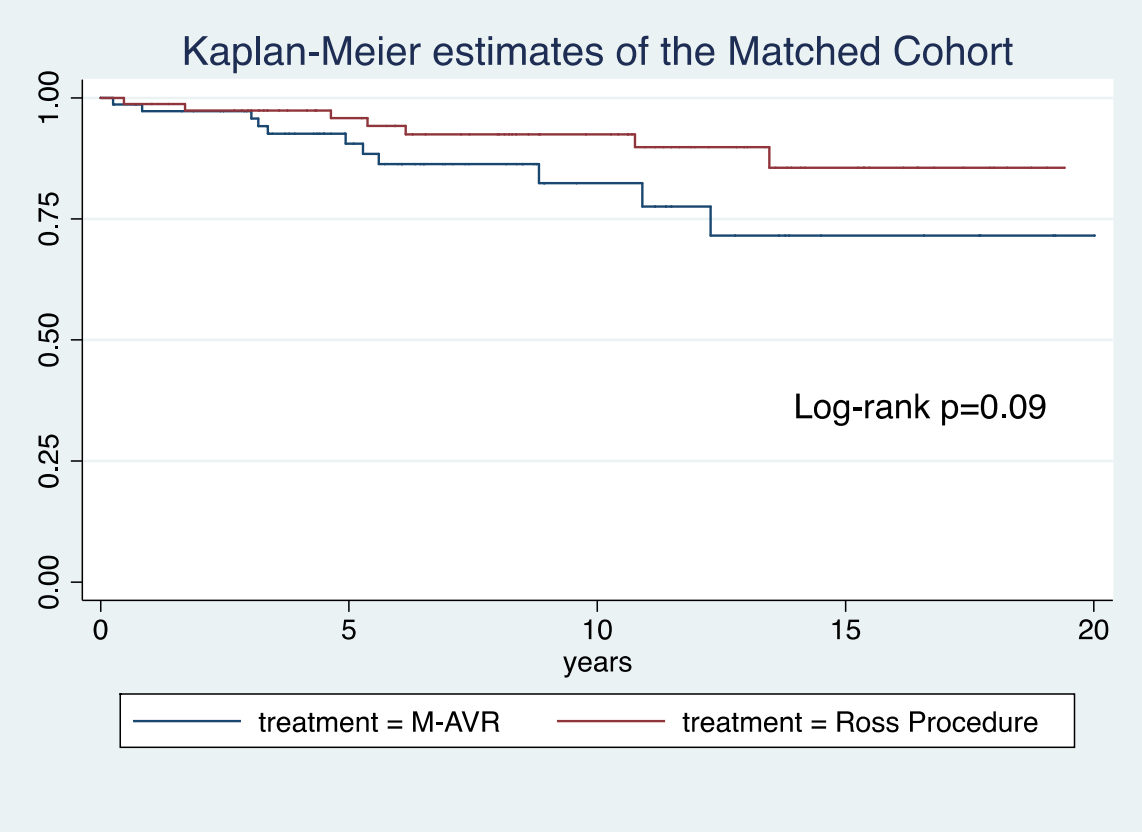
S. Mastrobuoni – Presented at HVS Meeting 2014



Mazine A et al. Circulation. 2016

Ross operation in AI: When Compared to Alternatives

- Compared to mAVR:
  - Higher hemorrhagic and thromboembolic in mAVR

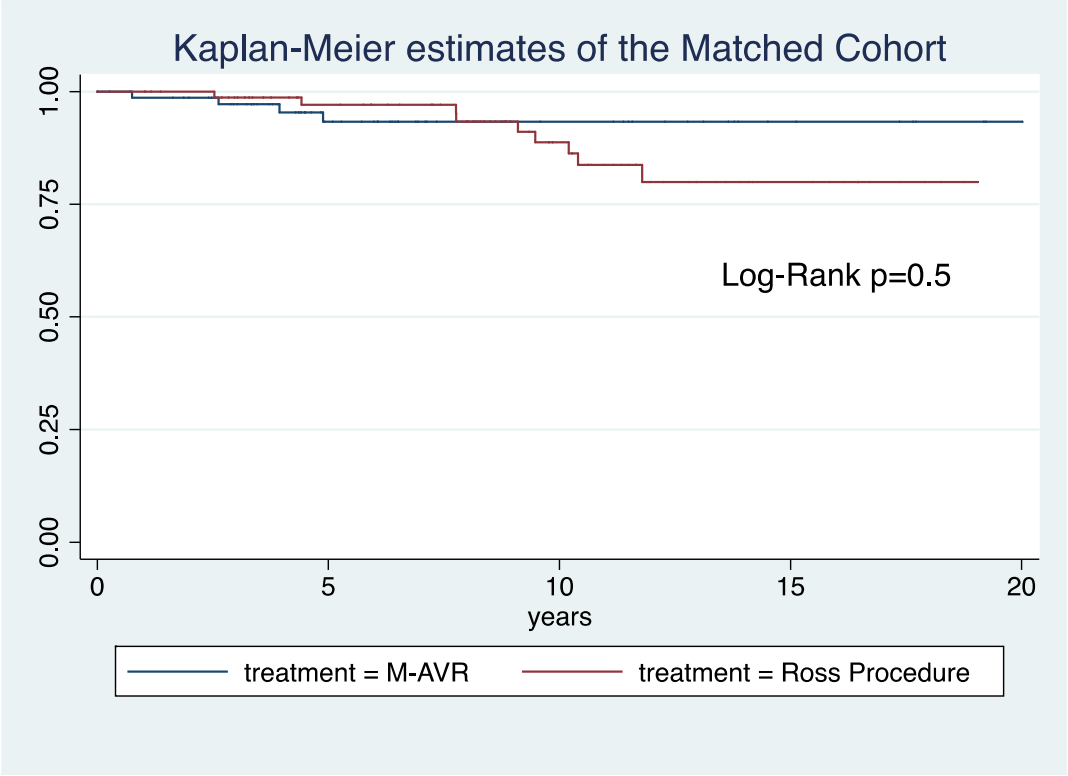


S. Mastrobuoni – Presented at HVS Meeting 2014

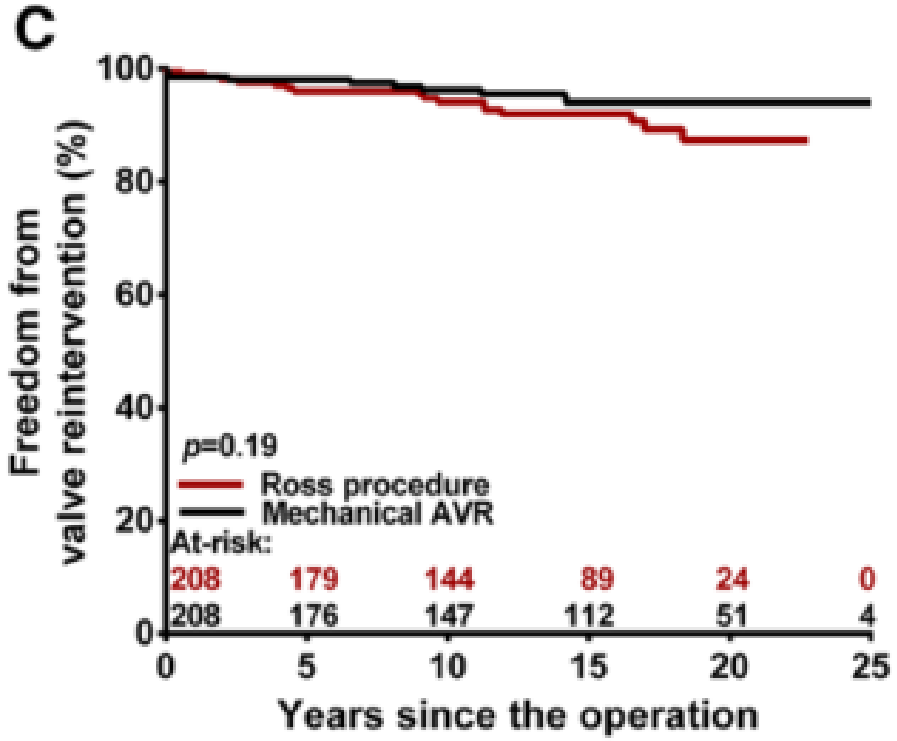
Mazine A et al. Circulation. 2016

Ross operation in AI: When Compared to Alternatives

- Compared to Mechanical Valve Replacement (mAVR) – Matched Cohorts:
  - Non-significant in term of reoperation



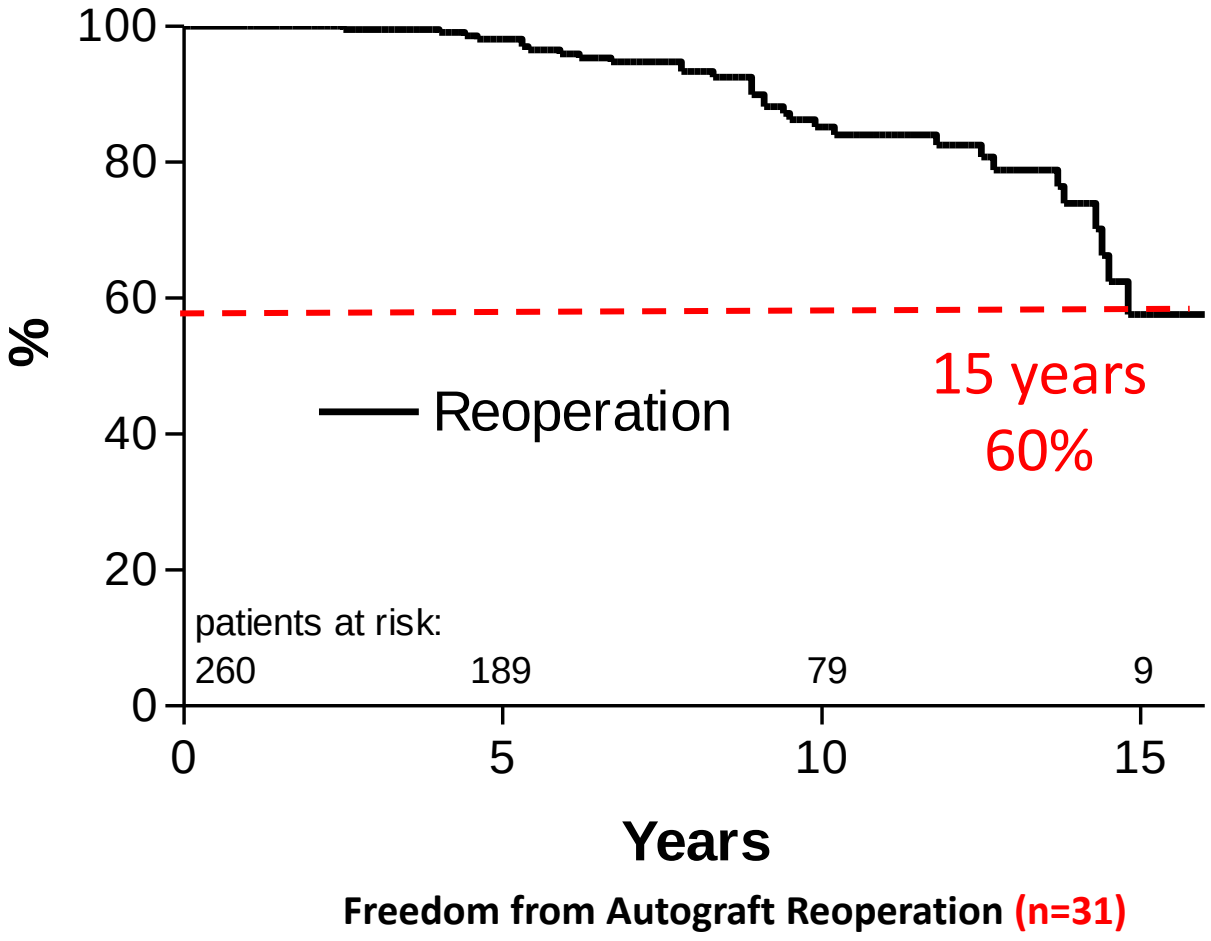
S. Mastrobuoni – Presented at HVS Meeting 2014



Mazine A et al. Circulation. 2016

Ross operation in AI: When the Ross fails…

Brussels Experience: Reoperations



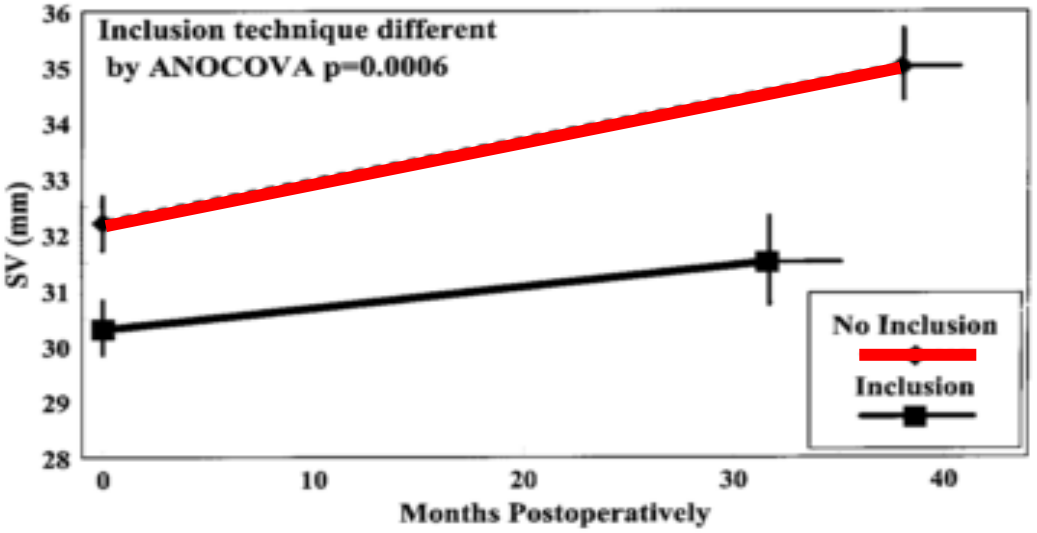
Freedom from Autograft Reoperation (n=31)

• Sievers	87%	15y
• David	82%	20y
• **Chambers**	**88%**	**10y**
• **Kouchoukos**	**75%**	**10y**
• **Klieverik**	**69%**	**13y**

Ross operation in AI: When the Ross fails…

Brussels Experience: Reoperations, mechanisms of failure

Sinus Valsalva diameter



David T., JTCVS. 2000

Mechanisms	n=31	Root Technique n=24 (%)	Inclusion Technique n=7 (%)
Proximal aorta dilatation (±AI)	24 (77)	21 (88)	3 (43)
Autograft Insufficiency	7 (23)	3 (12)	4 (57)

de Kerchove L, Ann Thorac Surg 2009

Ross operation in AI: When the Ross fails…

Risk Factors of Failure (autograft dilatationAI)

- Preoperative AI
- Dilated Annulus, Root or Asc Ao preop *(= suppleness of proximal support)*
- BAV (because large annulus/root/asc aorta!!!)
- Root Technique (++ long autograft)
- Older age
- Male Gender
- Postoperative Hypertension *(unproven)*

Takkenberg J, J Heart Valve Dis 2006

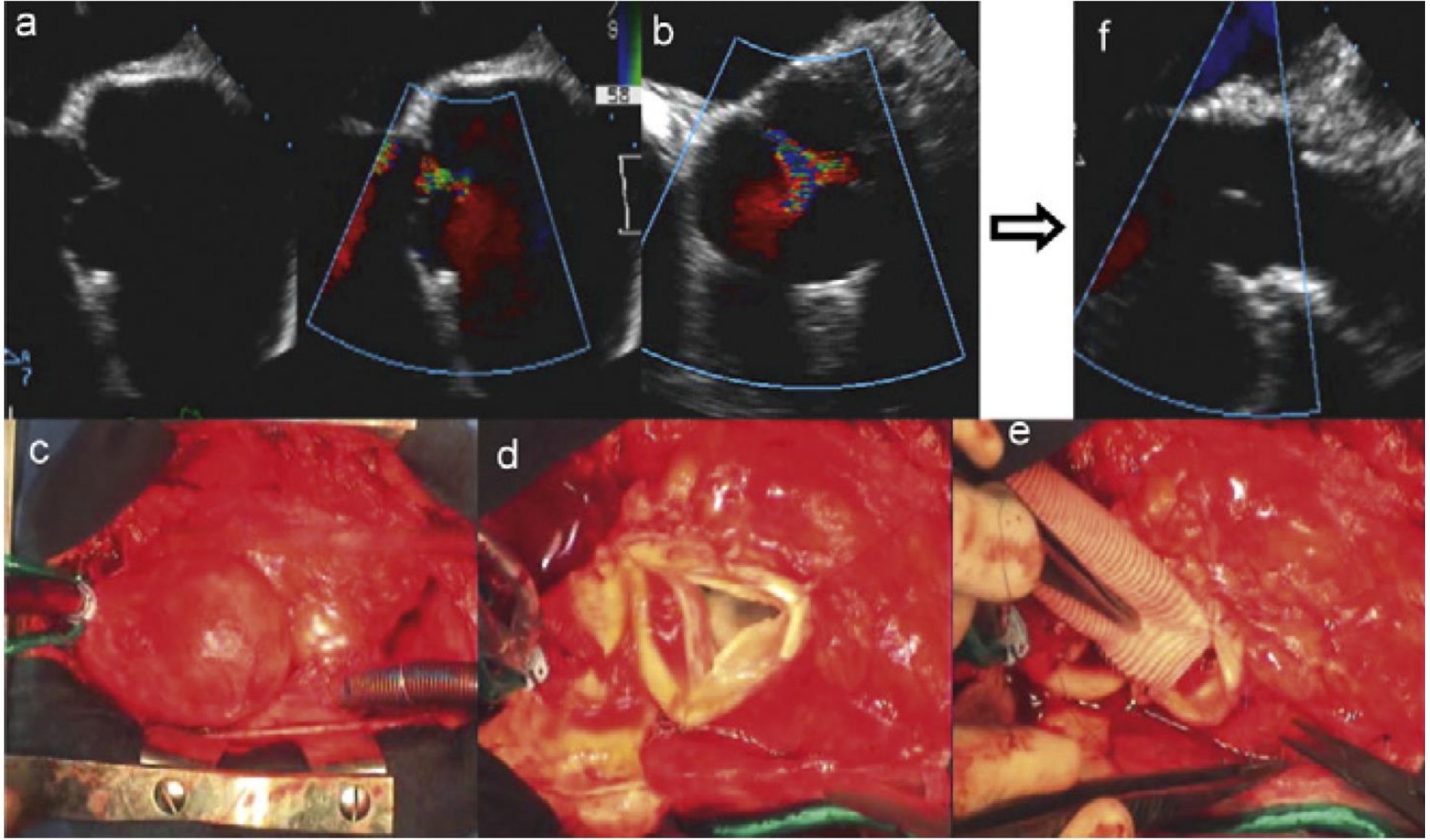
Hanke T. Circulation 2007

de Kerchove L, Ann Thorac Surg 2009

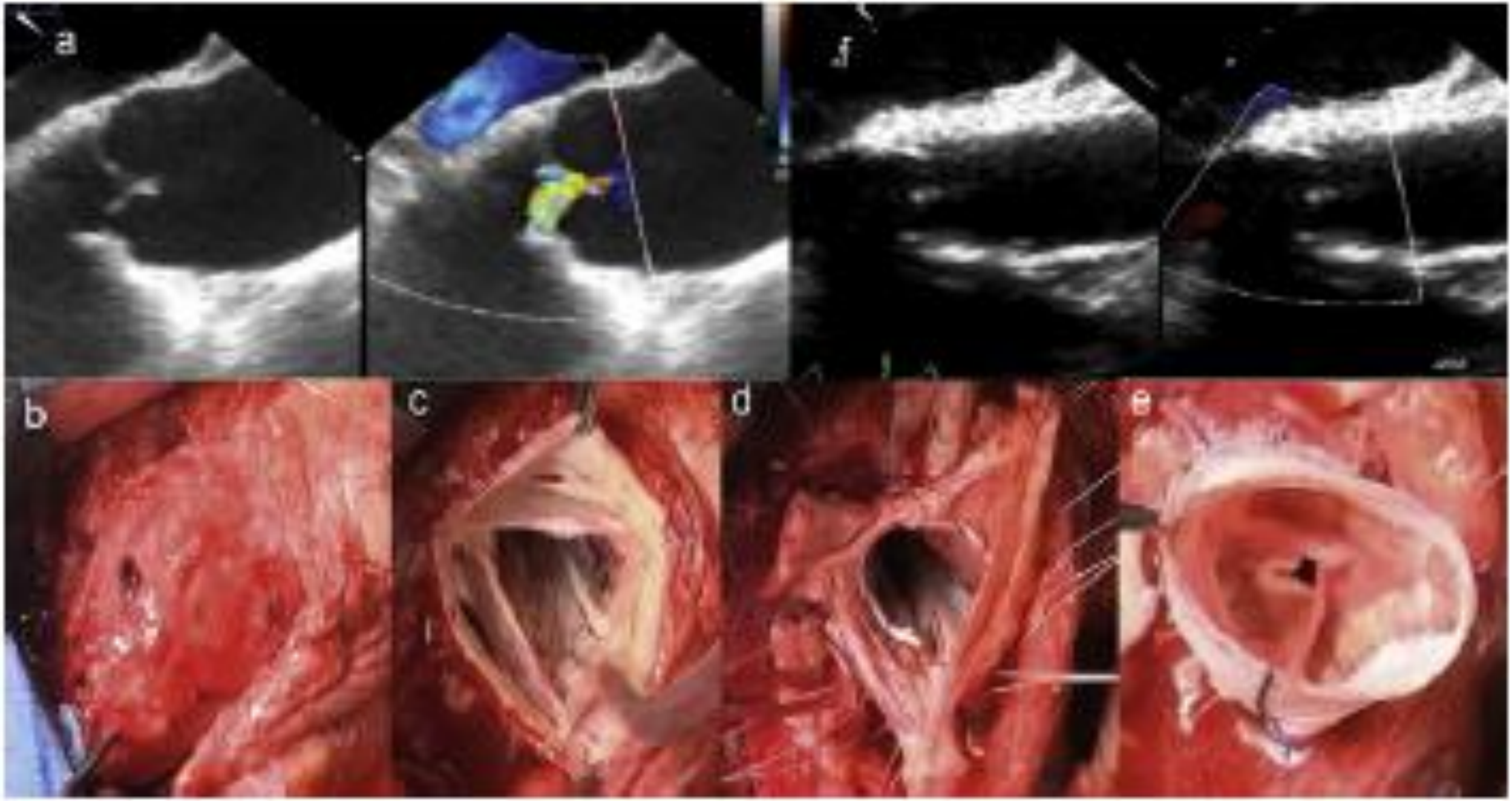
Takkenberg J. Circulation 2009

David TE. J Thorac Cardiovasc Surg 2014

Skillington P. JTCVS 2015



de Kerchove L., EJCTS 2010; 38:326-332



de Kerchove L., EJCTS 2010; 38:326-332

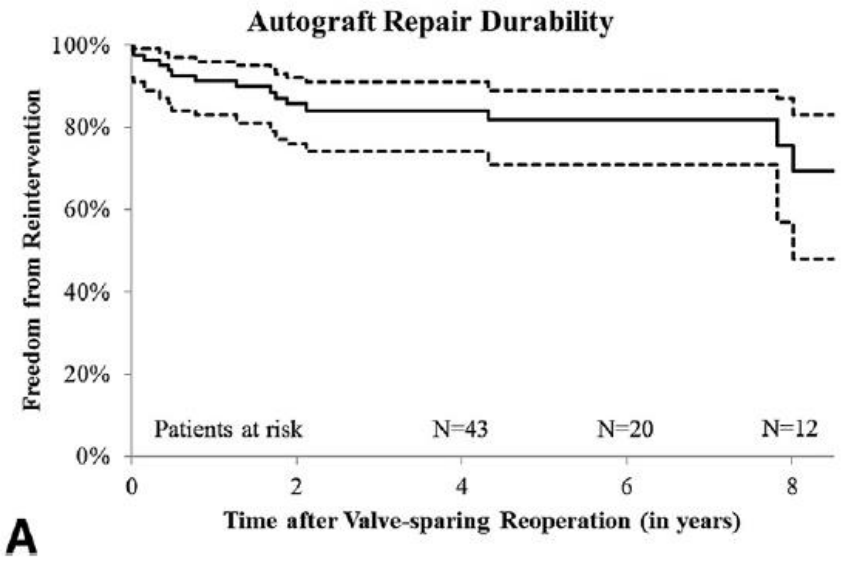
Ross operation in AI: When the Ross fails…

Repair options and results

European multicenter experience with valve-sparing reoperations after the Ross procedure

Aart Mookhoek, MD,[a] Laurent de Kerchove, MD,[b] Gebrine El Khoury, MD,[b] Timo Weimar, MD,[c] Giovanni Battista Luciani, MD,[d] Alessandro Mazzucco, MD,[d] Ad J. J. C. Bogers, MD, PhD,[a] Diana Aicher, MD,[e] Hans-Joachim Schäfers, MD, PhD,[e] Efstratios I. Charitos, MD, PhD,[f] Ulrich Stierle, MD,[f] and Johanna J. M. Takkenberg, MD, PhD[a]

- 86 pts, 6 centers
- 1% hosp. mortality



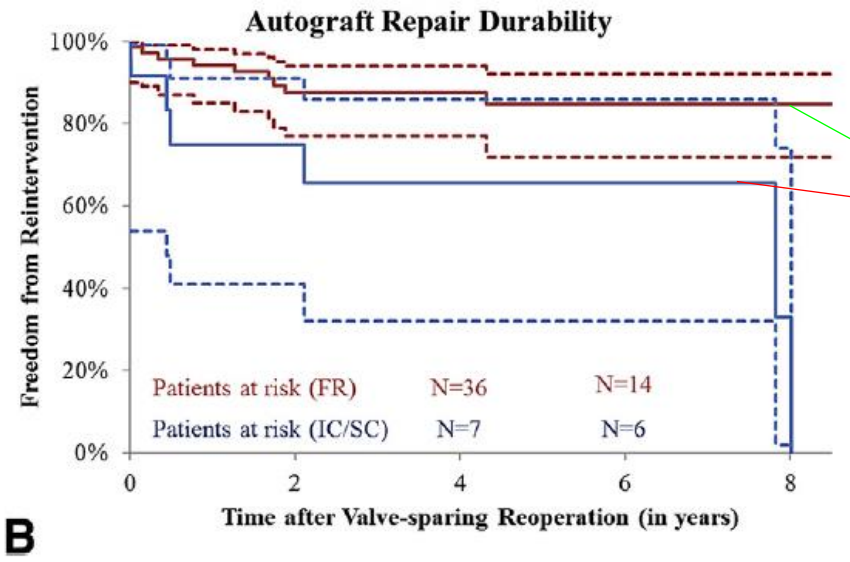


TABLE 4. Univariable analysis of the hazard of reintervention after valve-sparing reoperation

Variable	Hazard ratio (95% CI)	*P* value
Ross technique		
Full root	1.000	
Inclusion cylinder	4.358 (1.454-13.064)	.009
Subcoronary	4.005 (0.497-32.286)	.193
Age	0.944 (0.906-0.985)	.007
Isolated aortic regurgitation (as repair indication)	5.021 (1.721-14.649)	.003
Severe aortic regurgitation (grade ≥3)*	3.736 (1.165-11.978)	.027
Isolated autograft valve repair	5.041 (1.677-15.154)	.004
Valve-sparing autograft root replacement	0.199 (0.070-0.565)	.002

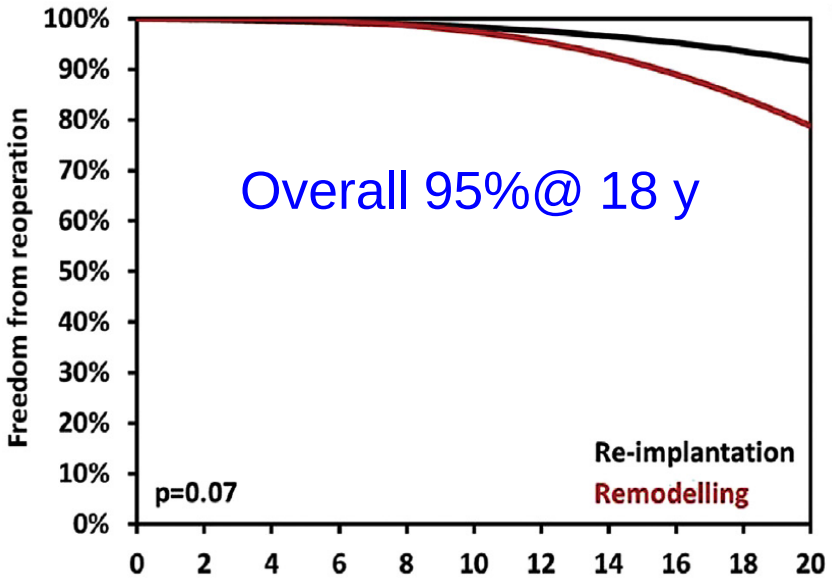
CI, Confidence interval. *At the time of valve-sparing reoperation after Ross procedure.

Mookhoek A., JTCVS 2015; 150:1132-7

Ross operation in AI: Root dilat + AI is best Repaired …

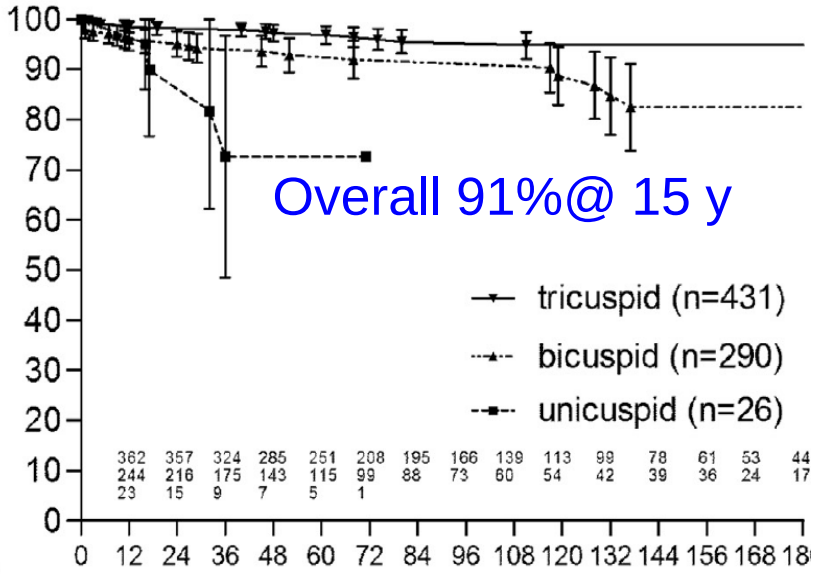
Freedom from Reoperation

Reimpl. & Remod.



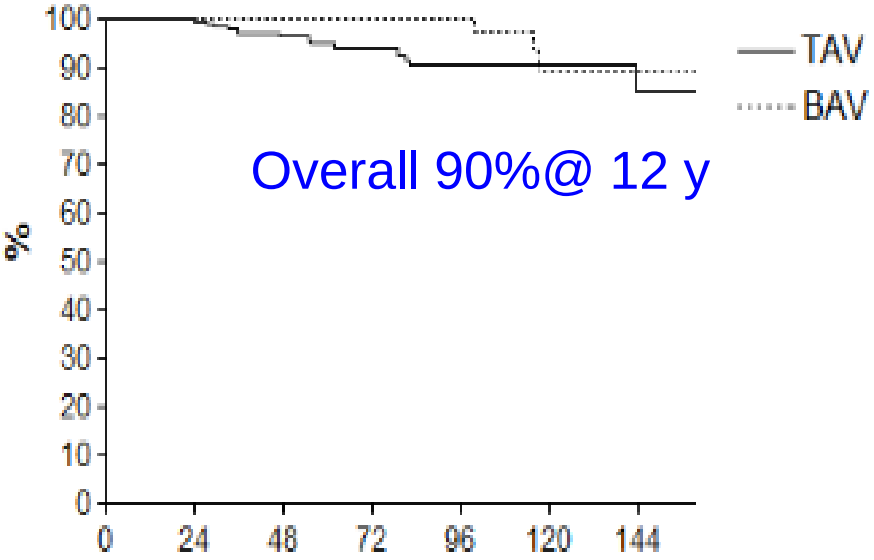
T. David JTCVS 2014

Remodeling



H-J Schafers EJCTS 2015

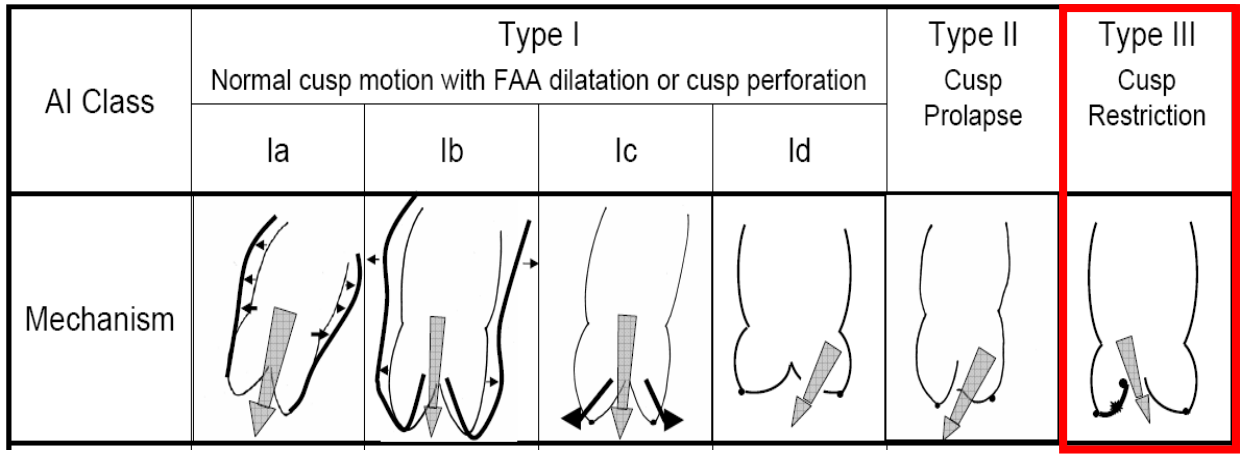
Reimplantation



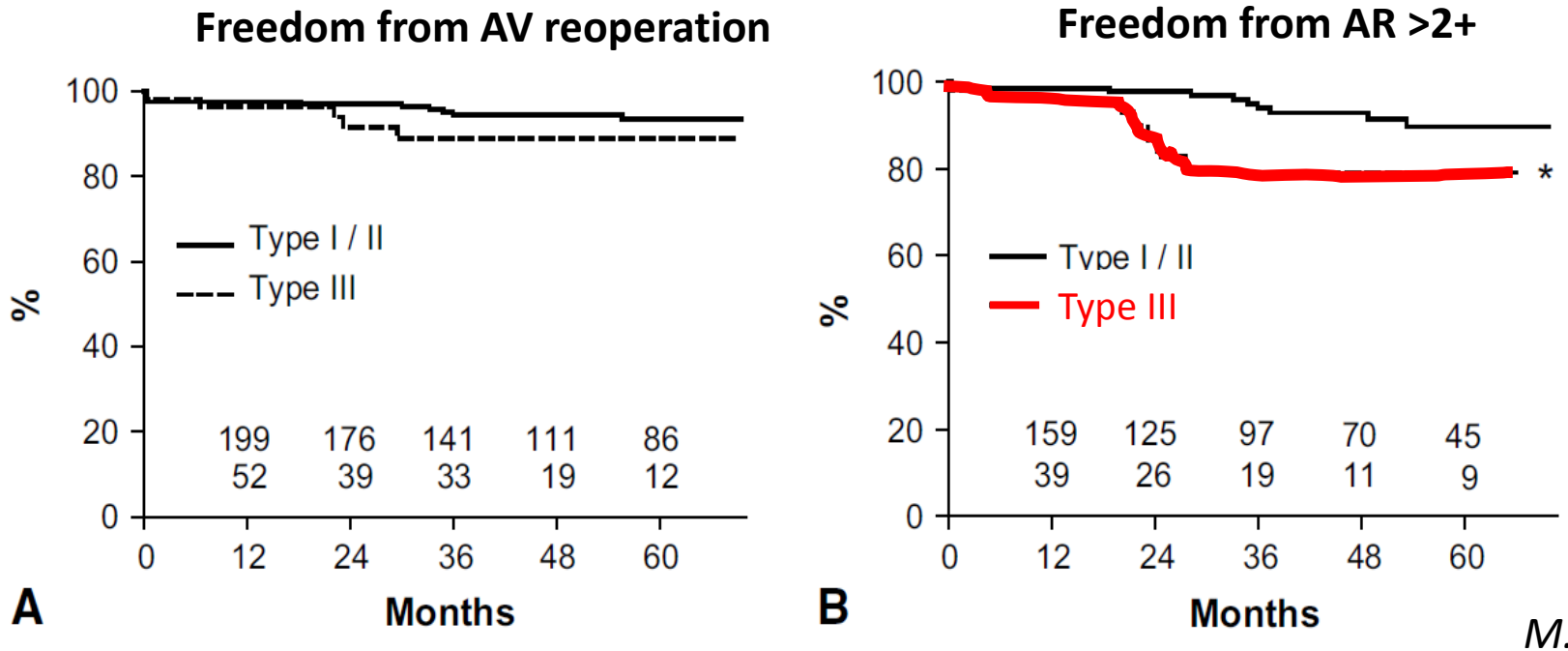
Brussels group updated 2017

Durable !

Ross operation in AI: AI is best repaired … But



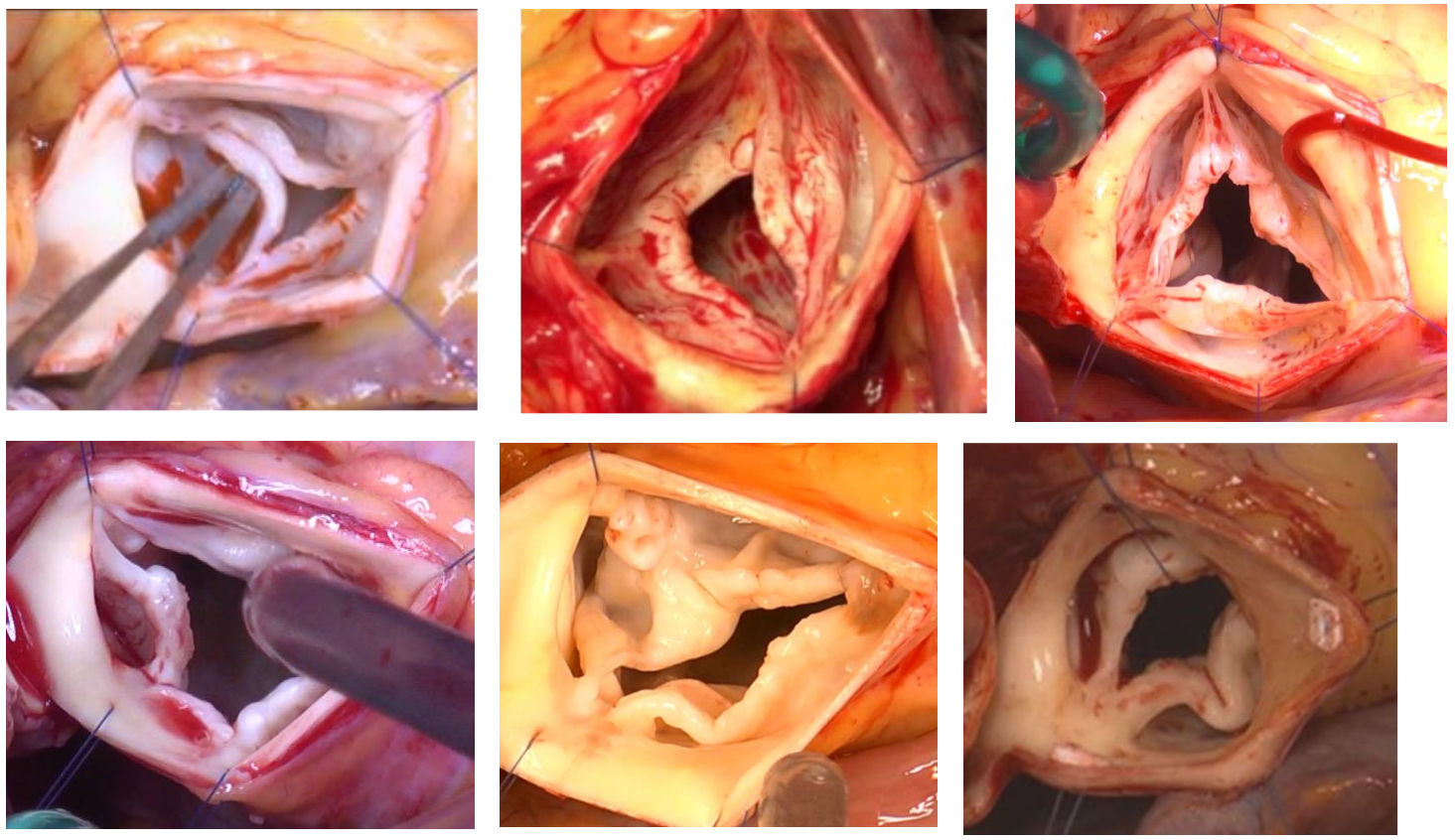
Mitigated results in retracted valves (Type III AI following el Khoury Classification)



M. Boodhwani, JTCVS 2009

Ross operation in AI: Retracted Valve Type III Etiologies

- Retracted Valve Etiologies
  - ✓ Rheumatic
  - ✓ Degenerative calcification
  - ✓ Bicuspid
  - ✓ Quadricuspid
  - ✓ Unicuspid
  - ✓ Dysmorphic



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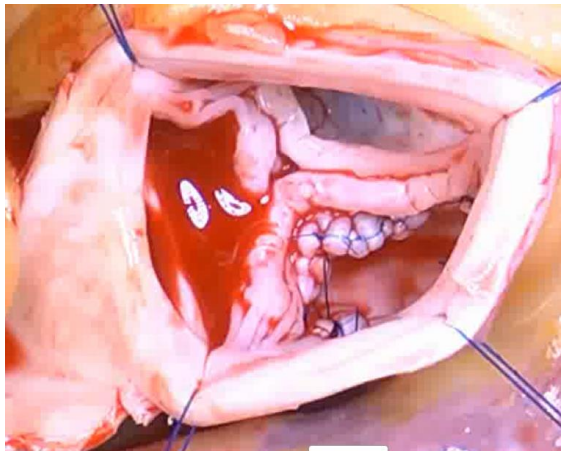
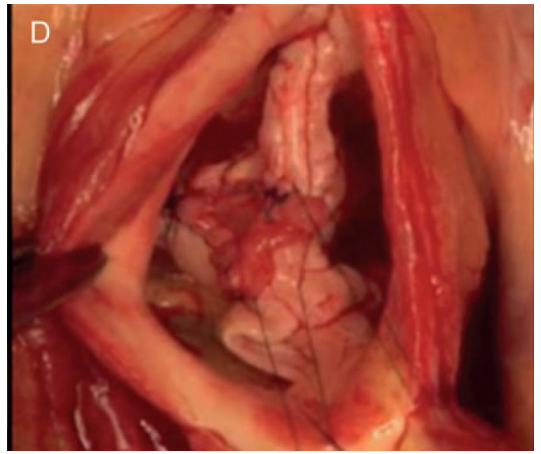
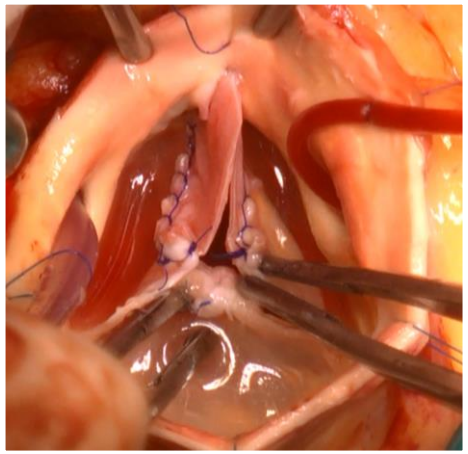
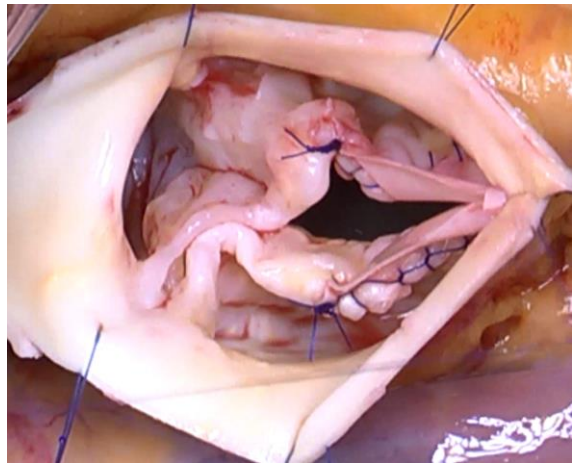
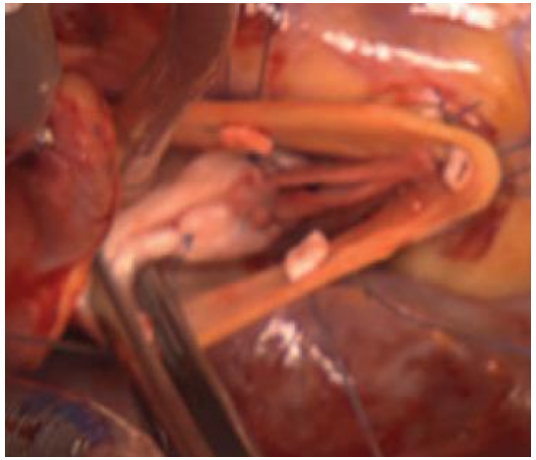
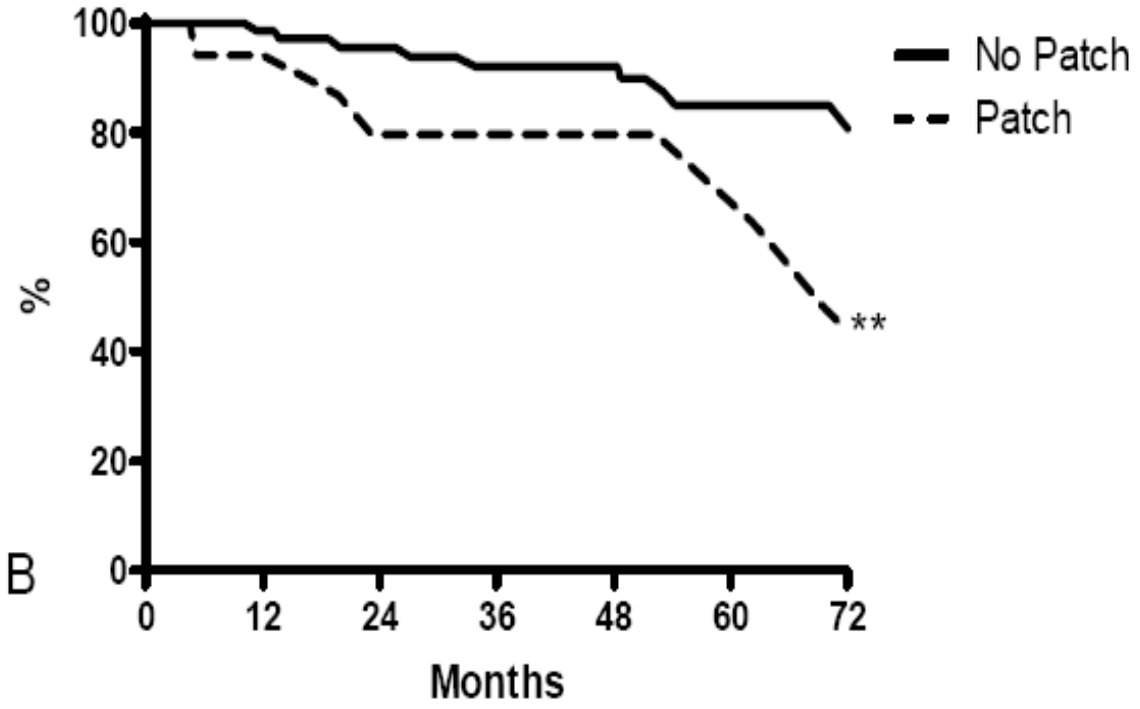
Often Repaired with Patch

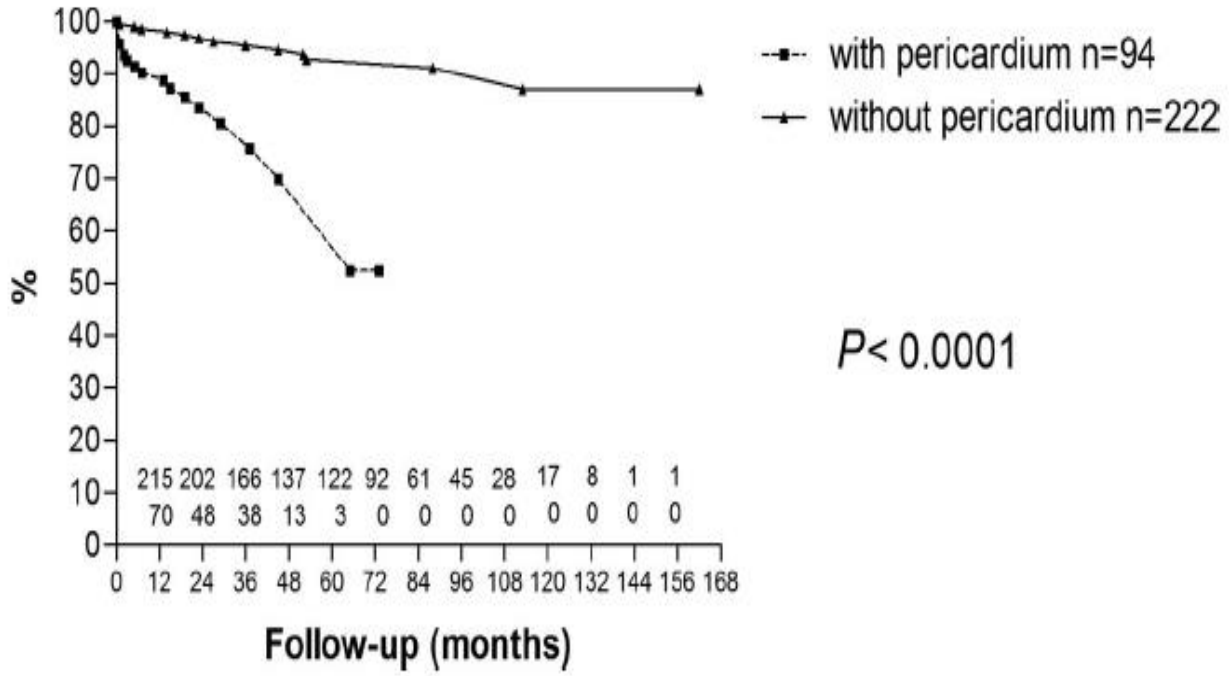





Ross operation in AI: Retracted Valve Type III Etiologies



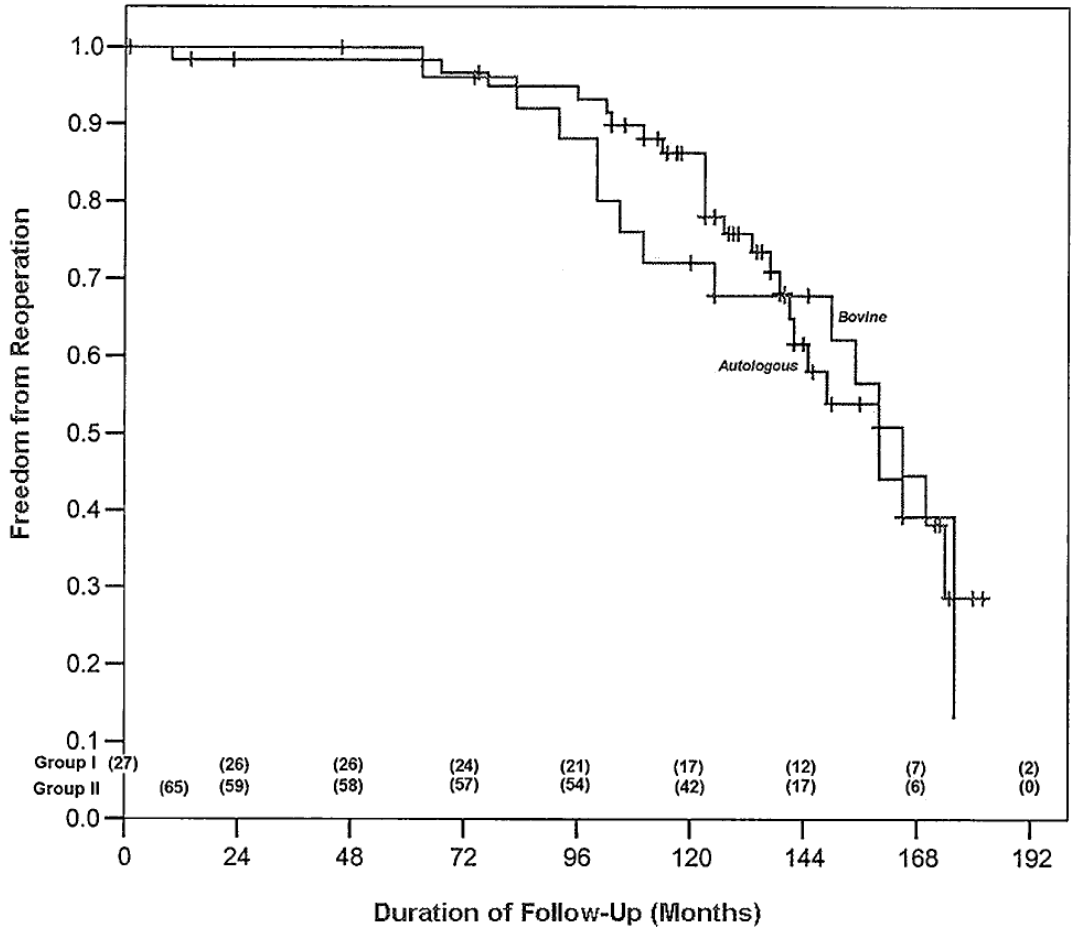
Boodhwani M. JTCVS 2010

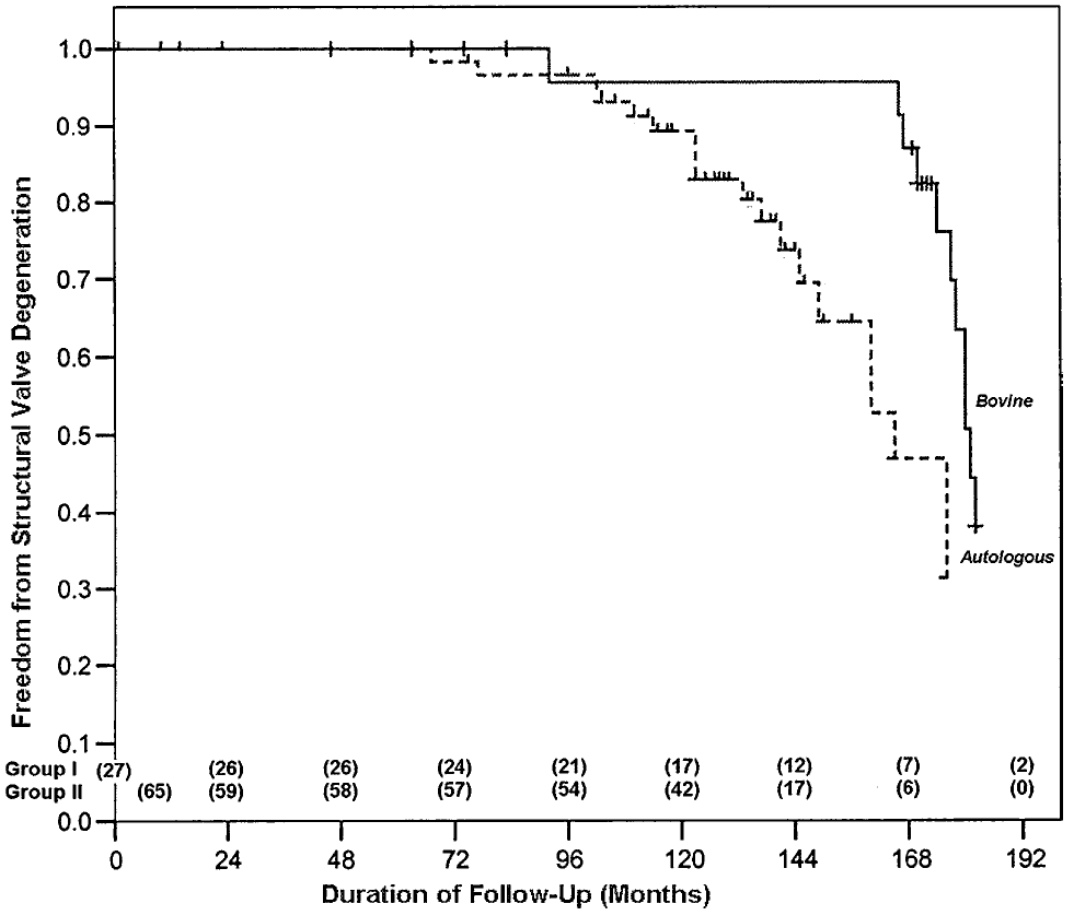


Aicher D. Circ. 2011

Ross operation in AI: Retracted Valve Type III Etiologies

- 1988-1995: 94 pts, mean age 30y, 84% rheumatic etiology





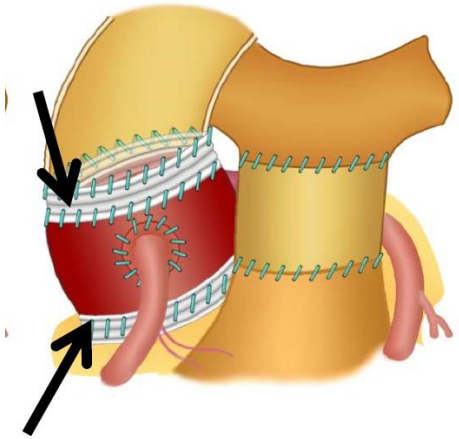
Z. Al Halees et al. Eur J Cardiothorac Surg 2005

Ross operation in AI: Need for Reinforcement

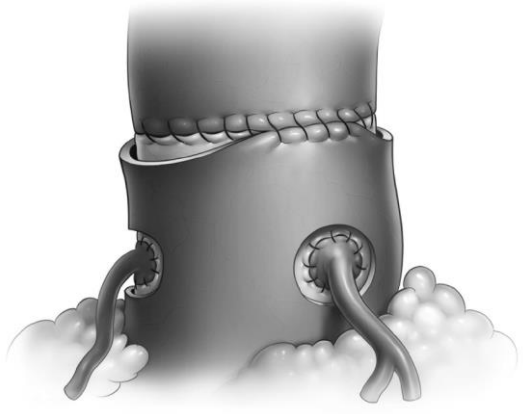
In Retracted valve Type III AI or any other AI judged non reparable, the Ross procedure is an option.

But

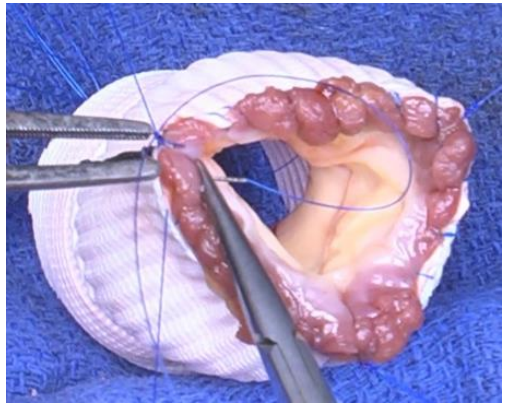
Autograft need to be reinforced in those cases



H. Sievers, 2nd North American Aortic Valve repair Symposium, 2016

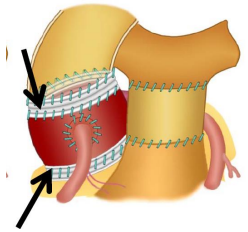


Skillington et al., JTCVS 2015

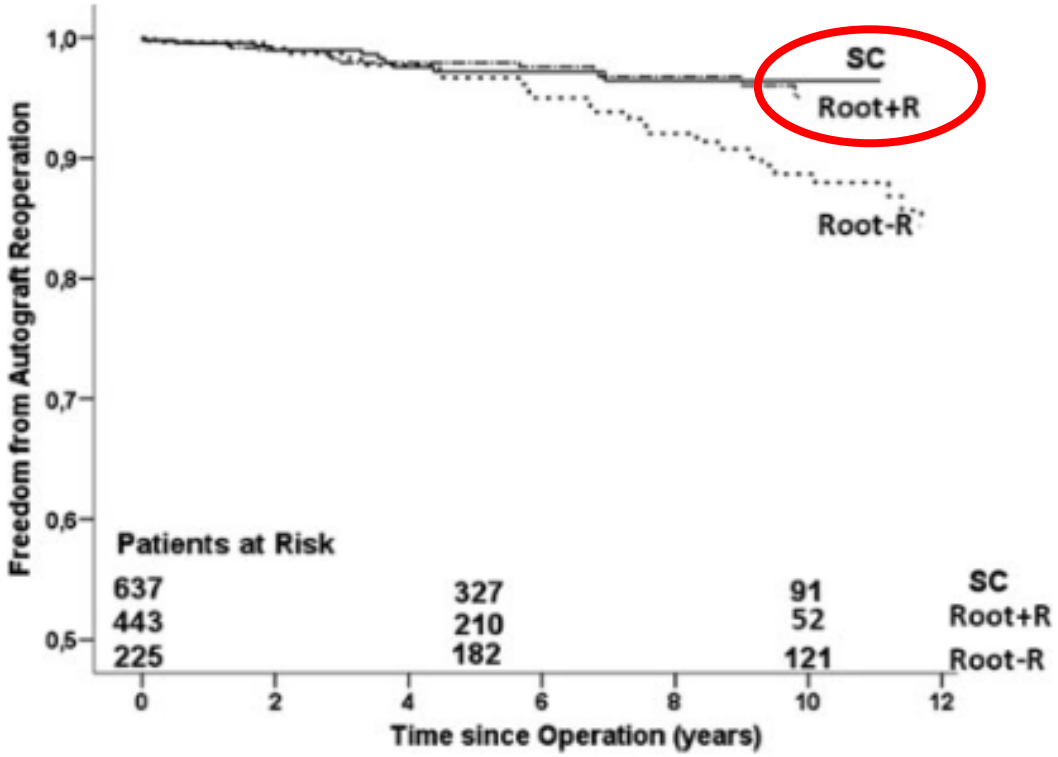


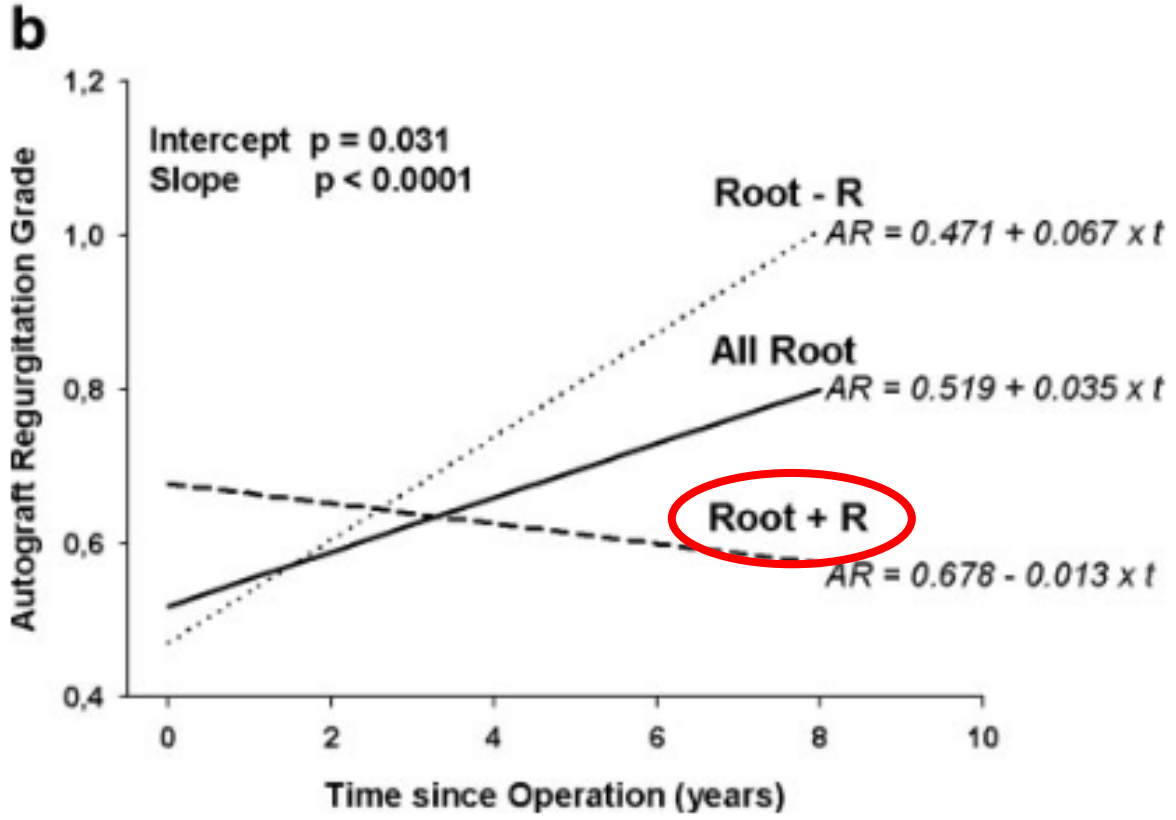
Carrel et al., JTCVS 2008
El Khoury et al., Presented at HVS 2017

Ross operation in AI: Need for Reinforcement



Root Reinforcement: German-Dutch Ross Registry





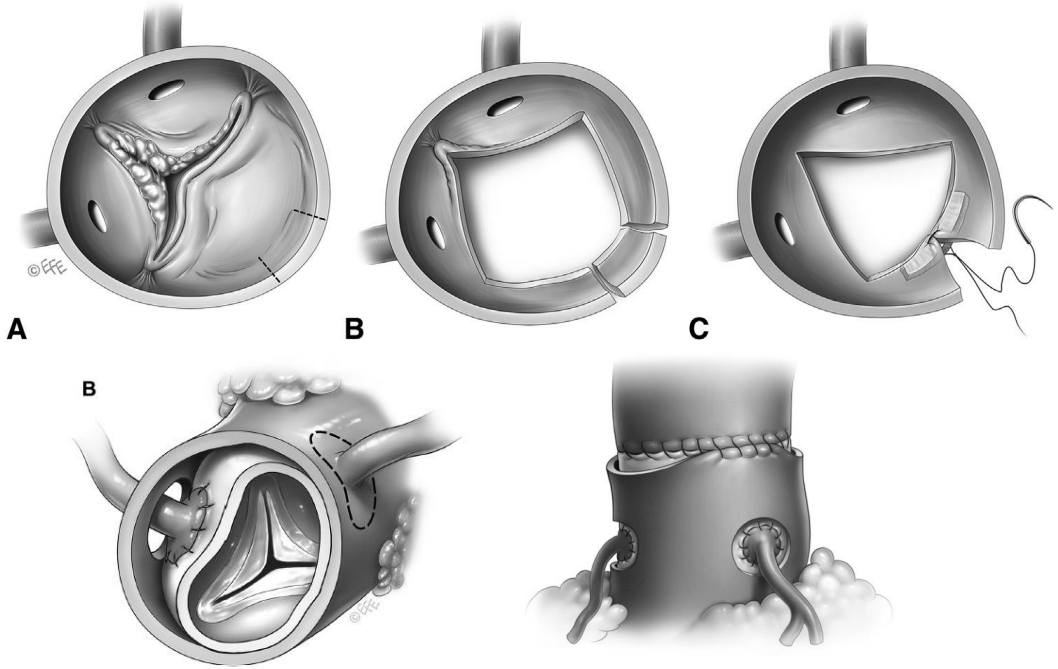
Charitos et al. Circulation 2009

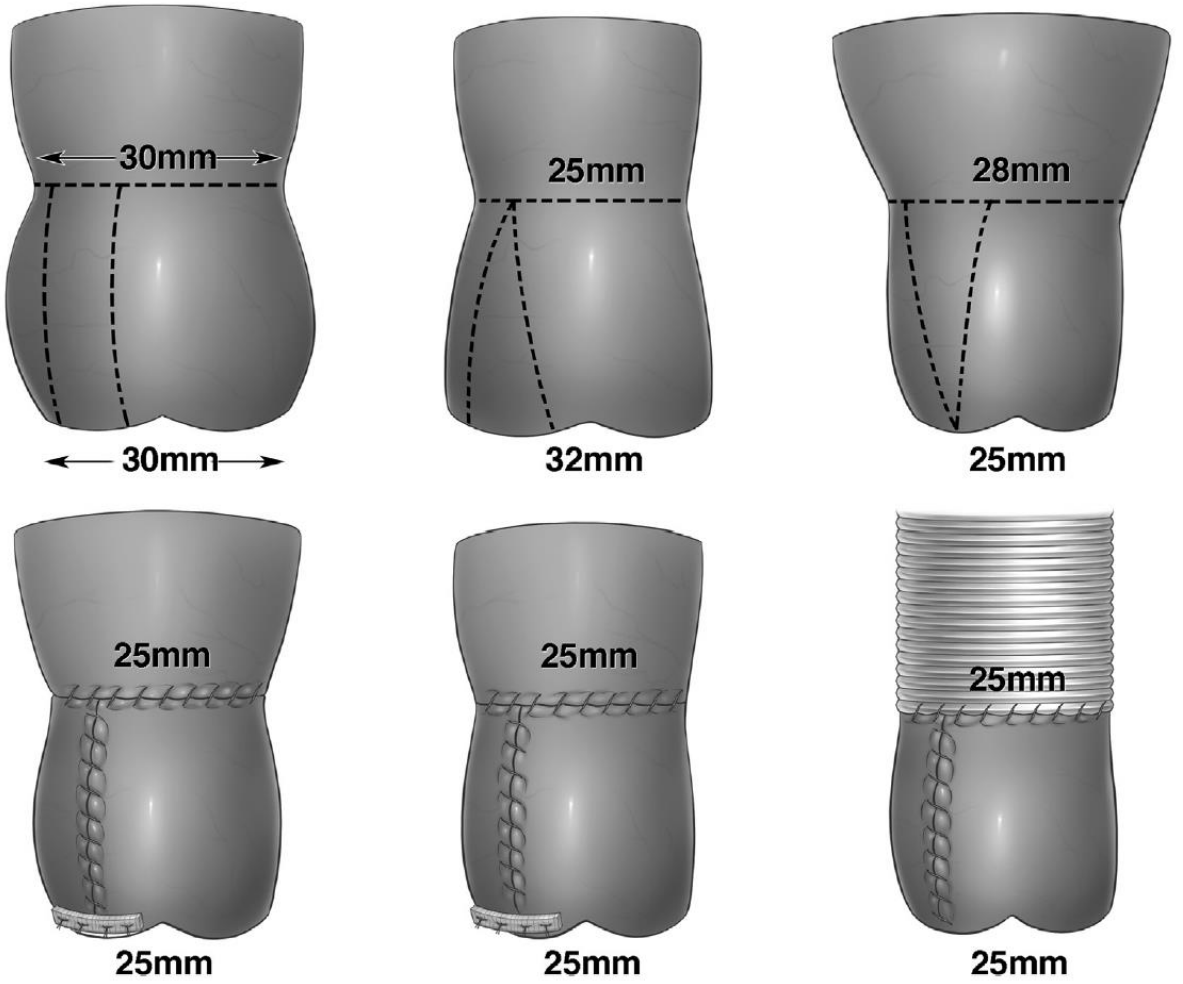
Ross operation in AI: Need for Reinforcement

Autologous Root Reinforcement: Melbourne Experience

20 yr experience (1992-2012):

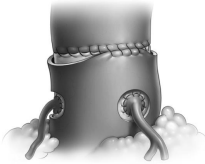
- 310 patients, 1/3 AI, 1/2 AS, 1/5 AI+AS,
- 92% BAV
- Modified Inclusion technique
- ± annulus/root/Asc Ao reduction



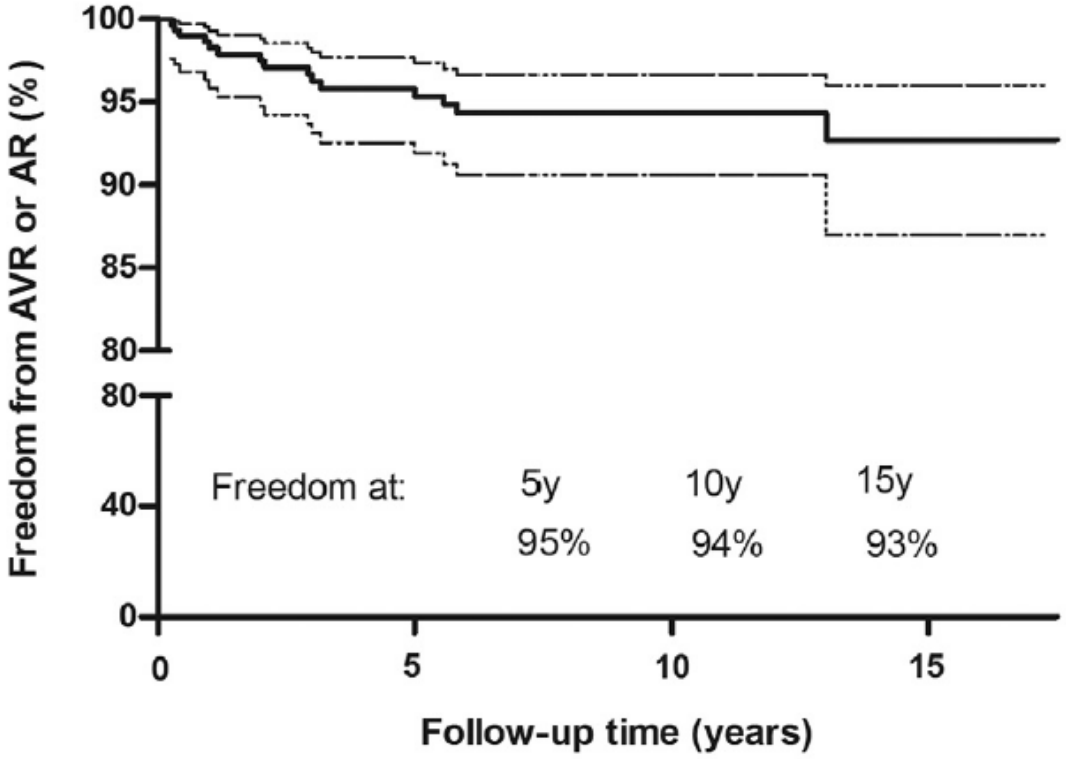


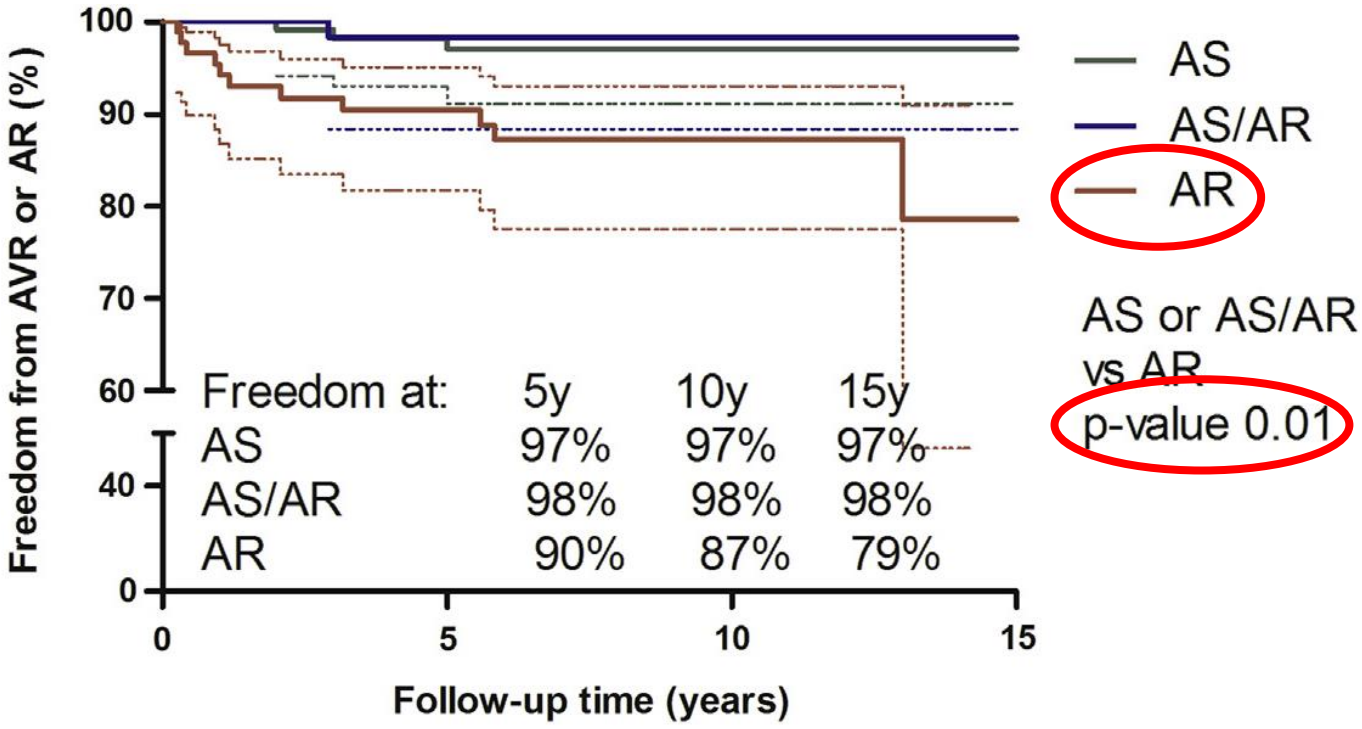
Skillington et al., JTCVS 2015

Ross operation in AI: Need for Reinforcement



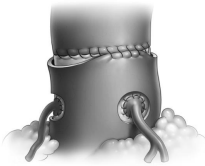
Autologous Root Reinforcement: Melbourne Experience





Skillington et al., Annals of Thoracic Surgery 2013

Ross operation in AI: Need for Reinforcement



Autologous Root Reinforcement: Melbourne Experience

322 Ross: **- 96% Freedom from reoperation @ 18 Yrs**

- AI remains a risk factor for recurrent AR or AVR ! (n=11 only)

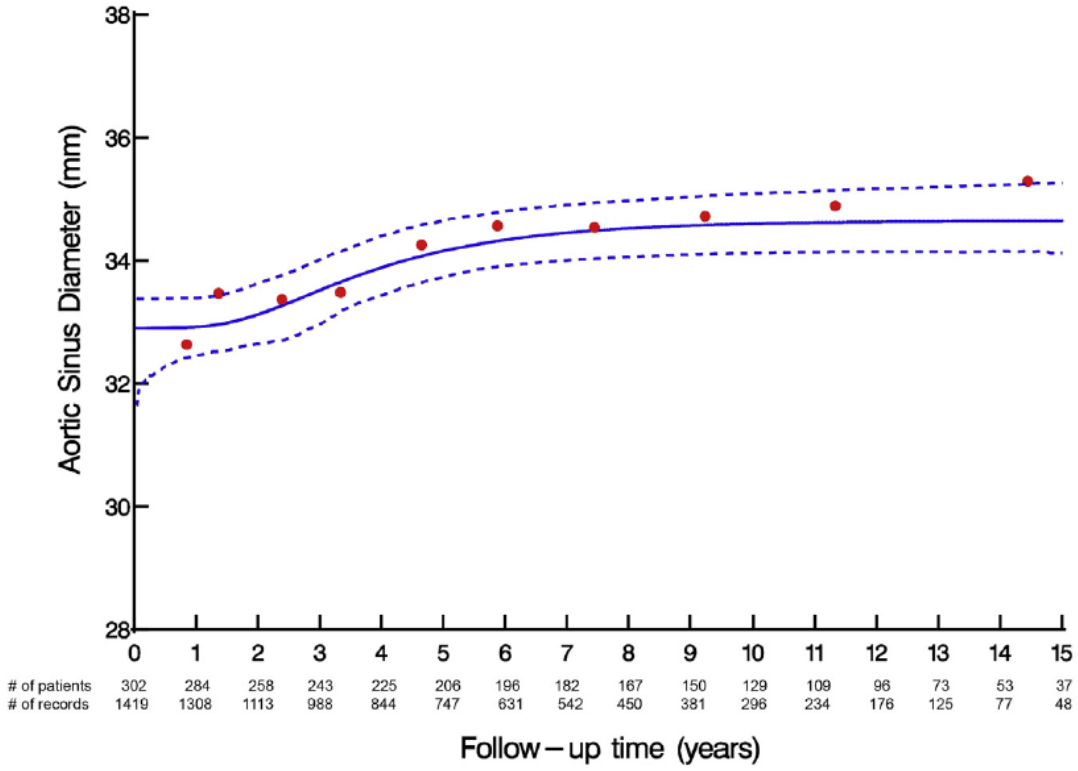


TABLE 2. Risk factors associated with aortic sinus diameter during follow-up

Factor	Estimate ± SE	*P*	Reliability
Preoperative aortic sinus diameter	0.005195 ± 0.001405	<.001	86%
Male (vs female)	0.03776 ± 0.01415	.008	20%
Autograft diameter	0.01848 ± 0.004579	<.001	100%
Enlargement of sinotubular diameter at the time of surgery	0.04055 ± 0.02006	.044	89%
Aortic annulus diameter	0.006023 ± 0.002162	.006	100%
AS (vs AR and AR/AS)	−0.02847 ± 0.01099	.010	91%

AR, Aortic regurgitation; *AS*, aortic stenosis; *SE*, standard error.

Skillington et al. – JTCVS 2015

Ross operation in AI: Need for Reinforcement

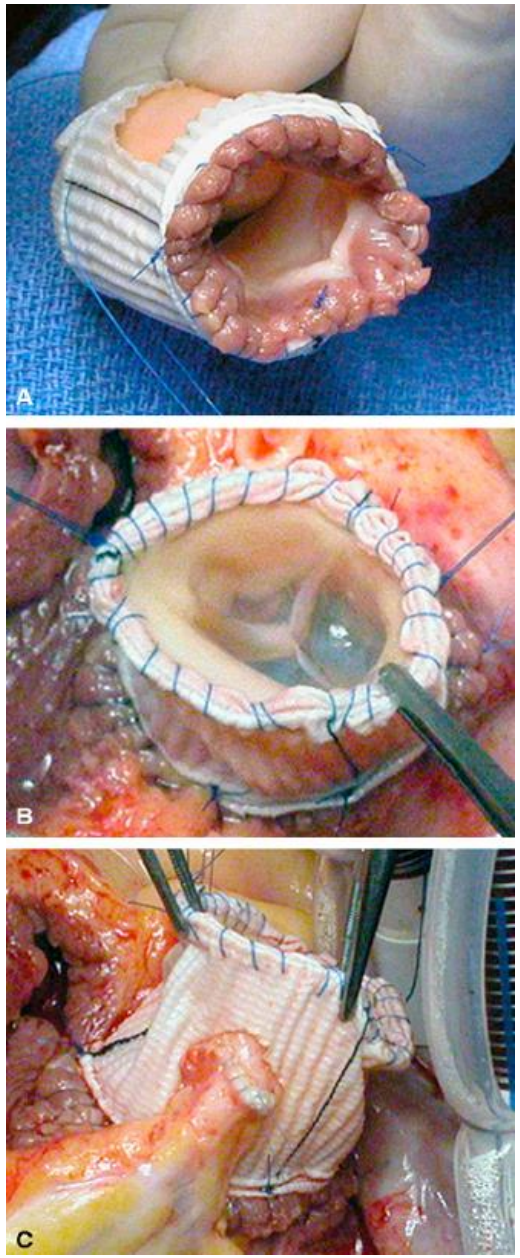
Dacron Graft Reinforcement: Lille Experience

12 pts (2003 - 2007):

- All BAV
- No mortality
- 1 reoperation (false aneurysm proximal suture line)
- FU No Grade 2+ AI

TABLE 2. Echocardiographic autograft diameter

Measurement level	Discharge (mm)	Last control (mm)	*P*
Annulus	23.3 ± 2.6	24.0 ± 1.9	.32
Neosinuses	32.6 ± 3.3	33.6 ± 3.3	.08
Sinotubular junction	28.9 ± 4.5	29.5 ± 3.6	.25



Juthier et al. – JTCVS 2010

Ross operation in AI: Need for Reinforcement

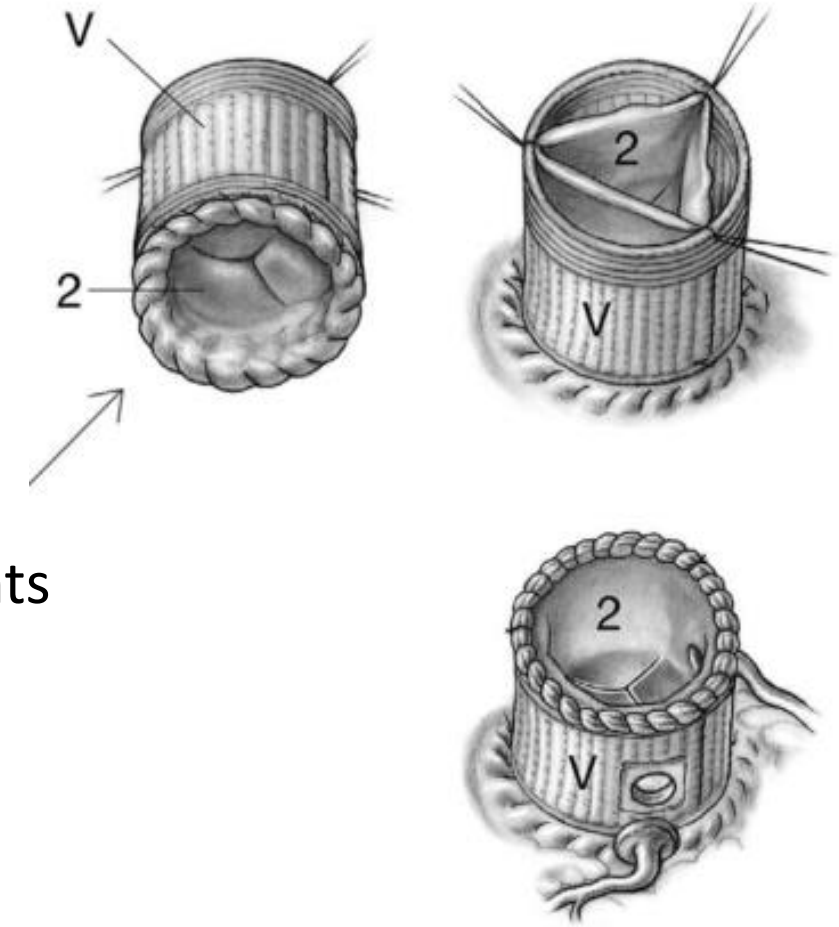
Dacron Graft Reinforcement: Bern Experience

22pts (2006 - 2016):

- No mortality
- 1 reoperation

➔ 4.5% at 10 years

- No Neo-aortic dilatation
- No AI in 15 patients and stable AI Grade I in 6 patients



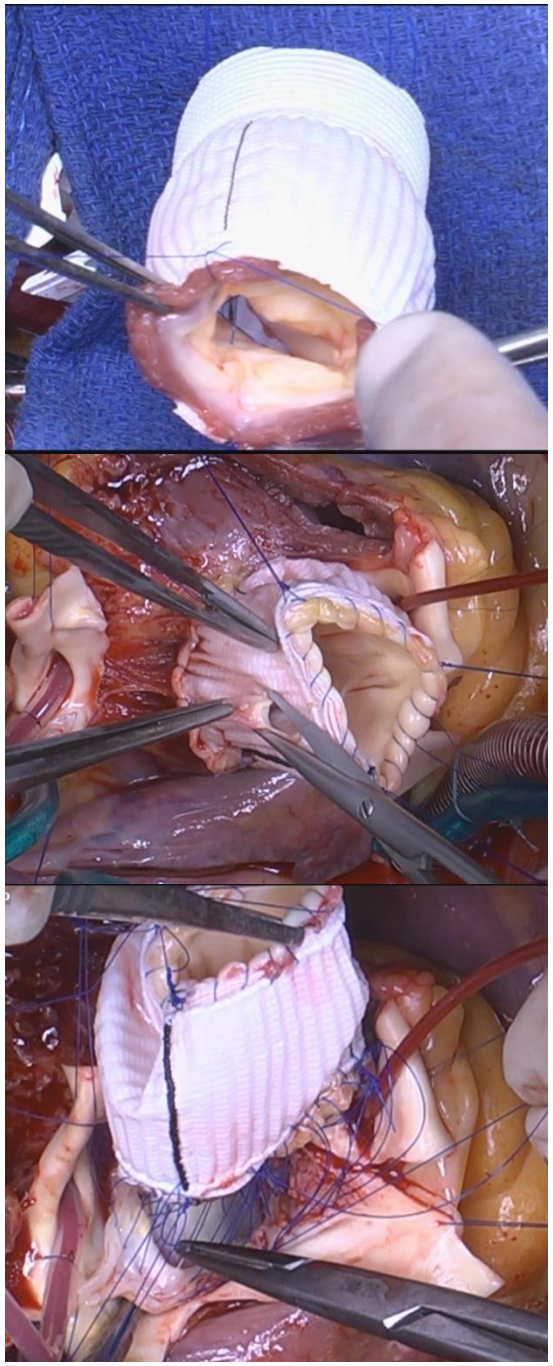
Carrel et al. – Seminars in Thor and Cardiovasc Surg 2016

Ross operation in AI: Need for Reinforcement

Dacron Graft Reinforcement: Brussels Experience

76 pts (2011 - 2016):

- Indication: large aortic annulus (31±5 mm) /aorta
- Inclusion in Valsalva® or Cardioroot® graft
- Graft size 28 – 30 mostly
- No mortality
- Autograft reoperations 4 pts (5%)
- FU AI grade 2+ 5 pts (6%)



Tamer S. et al. – Presented at HVS 2017

Ross operation in AR: Conclusions

- Ross operation bring survival and event-free survival advantages compared to mechanical and bioprosthesis in selected young patients

- In AI or mixed AI/AS etiologies (unsuitable for AV repair), Ross technique can be used but must be adapted to the anatomical characteristics of AI consisting in the presence of a large annulus/Root/asc Ao) otherwise the risk of failure increase significantly in those indications. Adaptation consist in the reinforcement of the autograft with stabilization and eventually reduction annuloplasty of the AVJ and the STJ.

Thank you

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Ross operation in AI: Why perform a Ross

"The pulmonary autograft is autologous, living and has a similar development, anatomy and histology of the aortic valve giving reason to use the pulmonary valve for aortic valve replacement – The Ross operation"

But there are some special issues to be considered:

a) The autograft has no fibrous annulus. manageable (intra-annular implantation)
b) The pulmonary valve is transplanted from low pressure circulation to systemic pressure. adaptation seems possible
b) The pulmonary valve is surgically manipulated.
c) Necessitates the replacement of the pulmonary valve with a homograft converting a one valve disease to a potential two valve problem.

H. Sievers, 2nd North American Aortic Valve repair Symposium, 2016

5

Proteolytic enzyme expression in pulmonary autografts compared with that seen in normal valves.

Rabkin-Aikawa E et al. J Thorac Cardiovasc Surg. 2004;128:552-61.

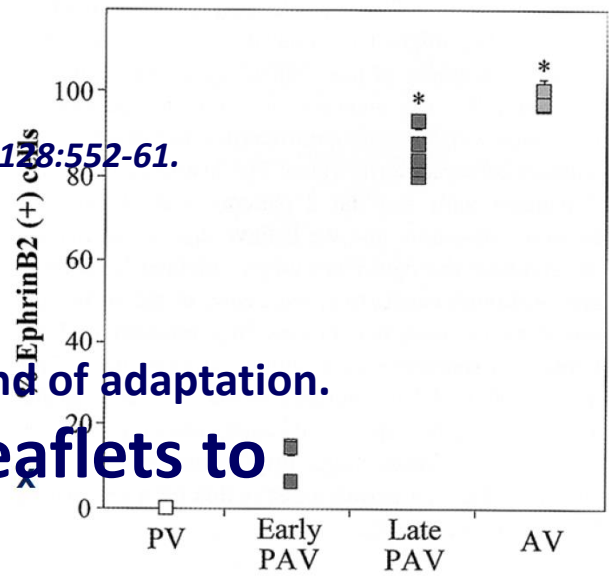
Immunophenotype of endothelial cells of normal valves and autograft explants.

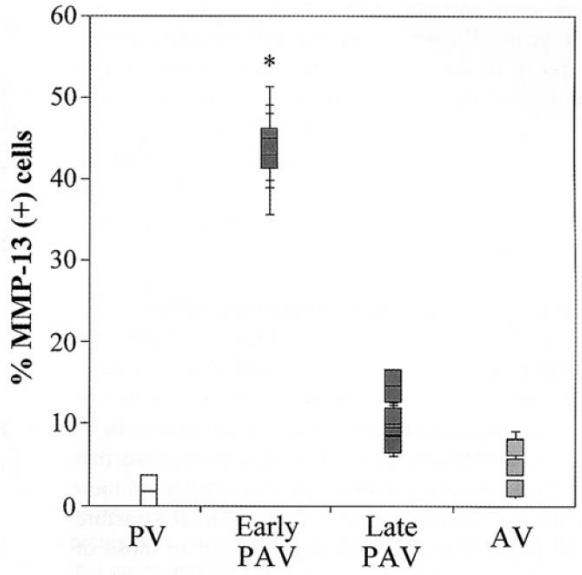
x: *Arterial endothelial cell marker*

For the leaflets there seems to be some kind of adaptation.

Adaptation of pulmonary leaflets to systemic pressure

x





Ross operation in AI: When the Ross fails…

- Predictor Factors of Failure

Table 3. Univariate and Multivariate Analyses

Variable	Odds Ratio	95% CI	*p* Value
Predictors of proximal aorta dilatation (≥45 mm)			
Univariate			
Male sex	2.9	1–8.7	0.04
Preoperative AV regurgitation	2.9	1.4–6.2	0.003
Preoperative AV disease	0.4	0.2–1	0.04
Root technique	4.7	1.6–14	0.003
Follow-up length (month)[a]	—	—	0.001
Multivariate			
Preoperative AV regurgitation	3.8	1.9–7.9	0.004
Root technique	7	2.7–18.3	0.003
Follow-up length (month)[a]	1.02	1.01–1.03	0.003
Predictors of moderate or greater autograft regurgitation			
Univariate			
Male sex	3.6	1.2–10.7	0.01
Preoperative AV regurgitation	2.1	1–4.3	0.04
Proximal aorta dilatation (≥45 mm) at follow-up	4.2	1.9–9.1	0.0002
Multivariate			
Male sex	3.1	1.0–9.3	0.045
Proximal aorta dilatation (≥45 mm) at follow-up	3.7	1.7–8.3	0.0007

Ross operation in AI: When the Ross fails…

- Predictor Factors of Failure

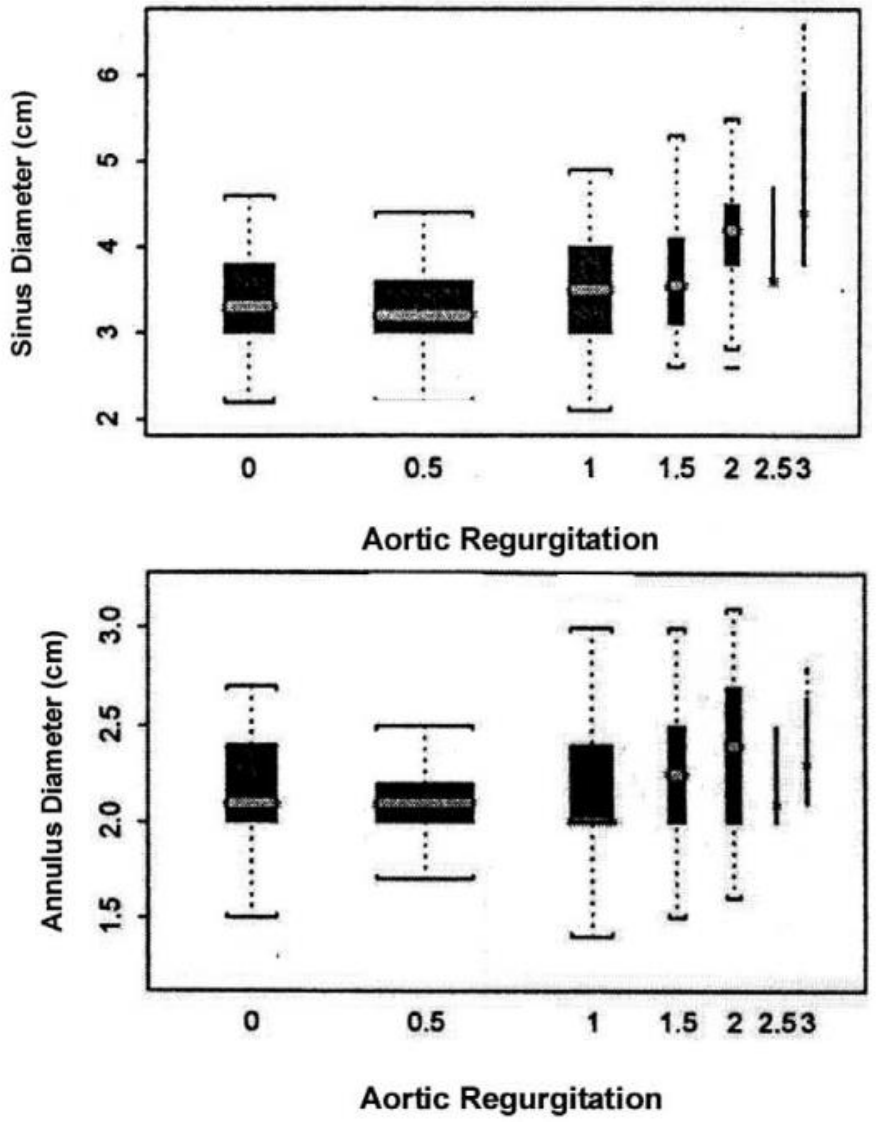
TABLE 3. Risk Factors for Autograft Dilatation

Cox proportional hazard	Beta factor	Standard Error	*P*
Age	−0.07	0.04	0.05
Preoperative sinus Valsalva diameter	0.24	0.12	0.02
Root replacement technique	2.80	1.27	0.03
Pericardial strip buttressing	−2.61	1.33	0.04

TABLE 4. Risk Factors for Autograft Dysfunction

Cox proportional hazard	Beta Factor	Standard Error	*P*
Sex (female)	3.51	1.14	0.002
Preoperative Sinus Valsalva diameter	0.34	0.16	0.04
Follow-up Sinus Valsalva diameter	0.63	0.21	0.003
Follow-up sinotubular junction diameter	0.77	0.32	0.02

Luciano et al. Circ 2003



Kouchoukos et al. ATS 2004

Ross operation in AI: When the Ross fails…

- Brussels Experience: Multivariate Predictors

Aortic Insufficiency

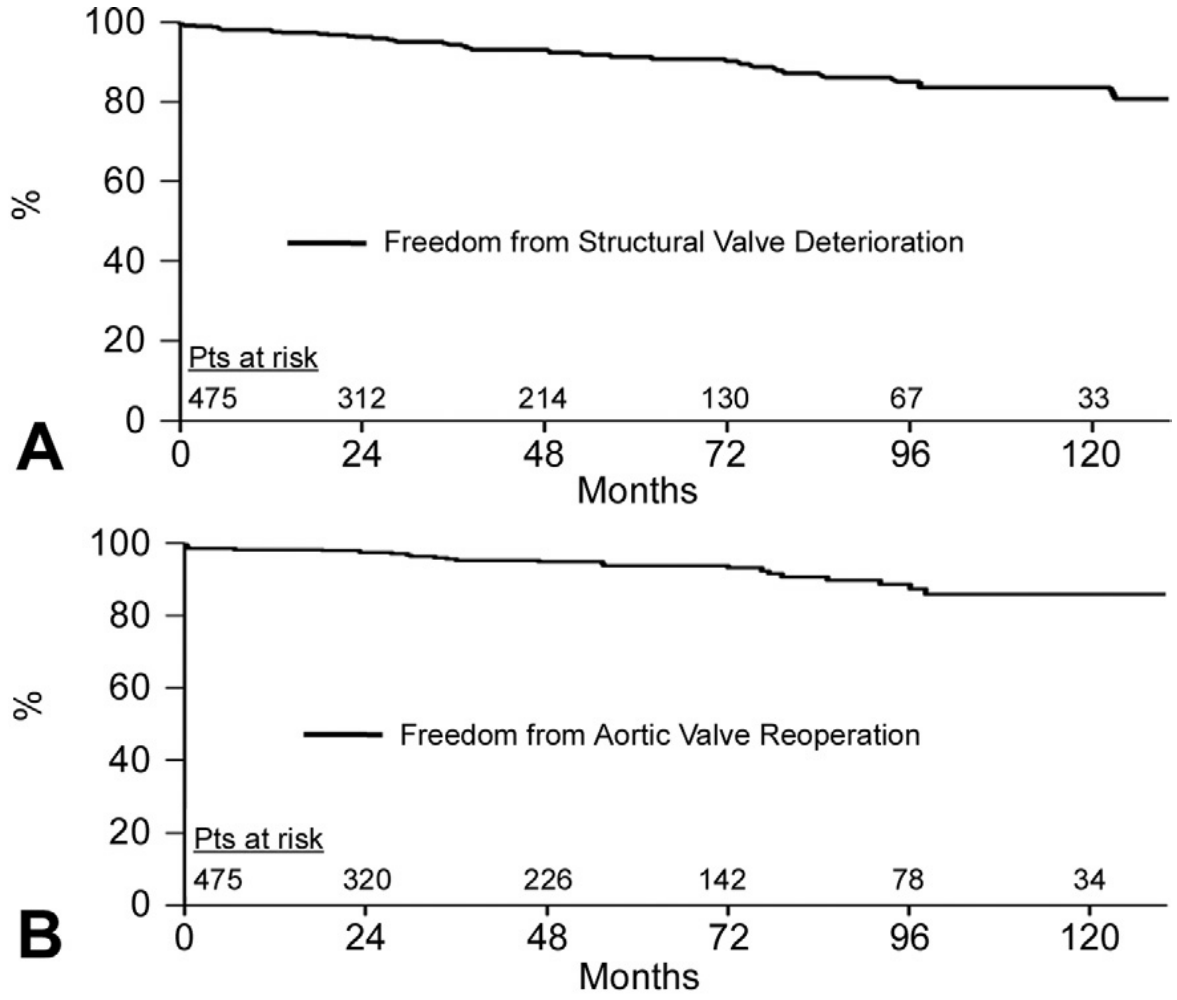
Predictors	P value	Hazard ratio (95% CI)
Age	0.001	1.04 (1-1.06)
Preoperative aortic valve insufficiency	0.001	3 (1.6-5.7)
Preoperative ascending aorta dilatation	0.02	2.8 (1.1 - 6.7)

Proximal Aorta Dilatation

Predictors	Multivariate P-value	Hazard ration (95% CI)
Root replacement technique	0.001	5.7 (2-16.5)
Preoperative aortic valve insufficiency	0.001	2.8 (1.5 - 5.1)
Preoperative ascending aorta dilatation	0.002	4.3 (1.7 – 10.6)
Age	0.007	1.03 (1 – 1.06)
Male gender	0.04	2.5 (1 - 6)

Ross operation in AI: AI is best repaired …

Freedom from Reoperation after AV Repair



J. Price ATS 2013

Ross operation in AI: Retracted Valve Type III Etiologies

Patch and AV Reoperation

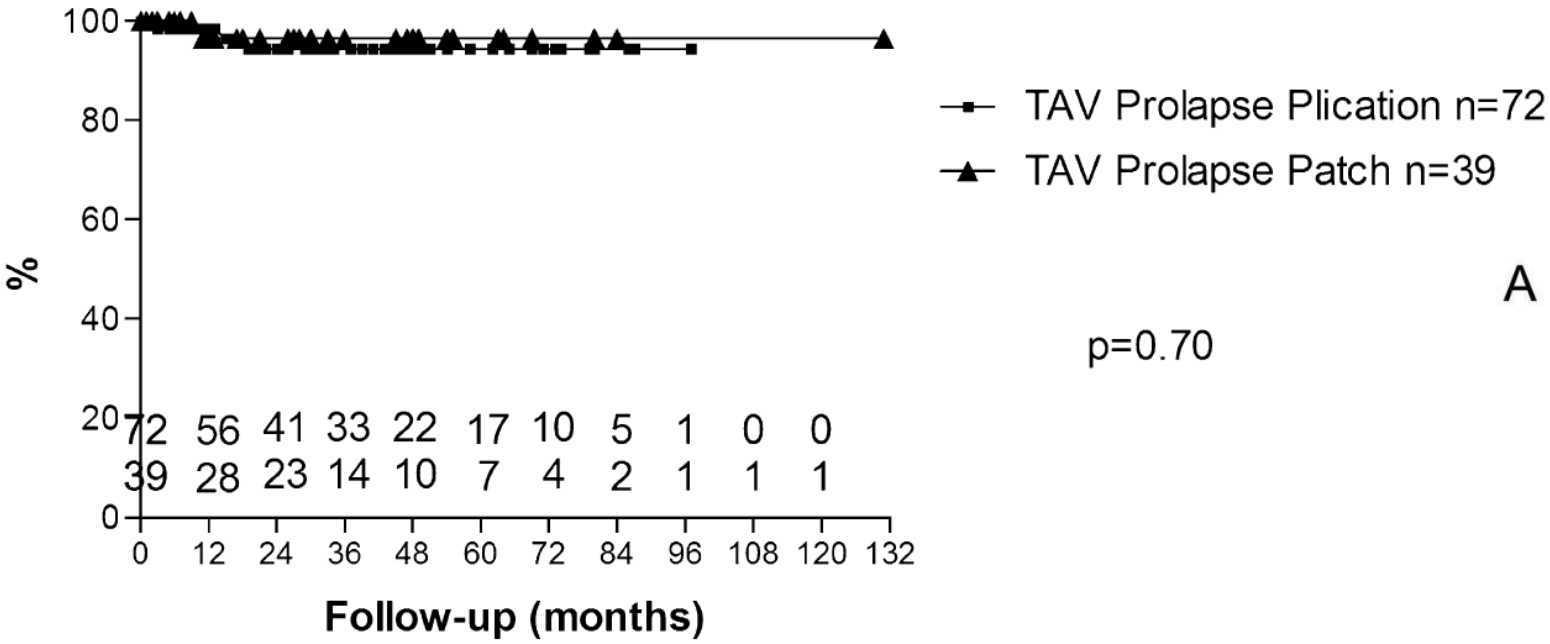
TABLE 2. Risk factors by multivariate Cox regression analysis (−2 log-likelihood function = 161.87, chi-square = 72.79, $P < .001$)

Variable	*P* value	HR	95% CI
Diameter of AV junction (mm)	<.001	1.43	1.21-1.69
Use of annuloplasty	.01	1.28	1.89-66.26
Myocardial ischemia (min)	.04	0.96	0.93-1.00
Effective height	<.001	0.58	0.43-0.79
Use of pericardial patch	<.001	6.24	2.30-16.90

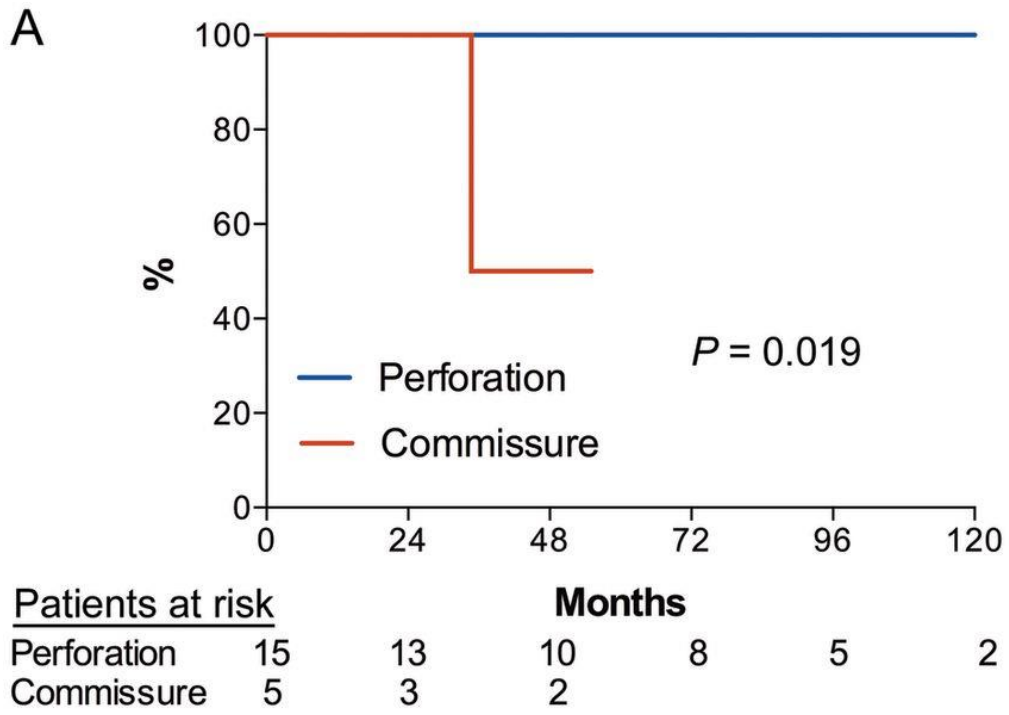
AV, Aortoventricular; *CI*, confidence interval; *HR*, hazard ratio.

H.J. Schäfers et al. J Thorac Cardiovasc Surg 2015

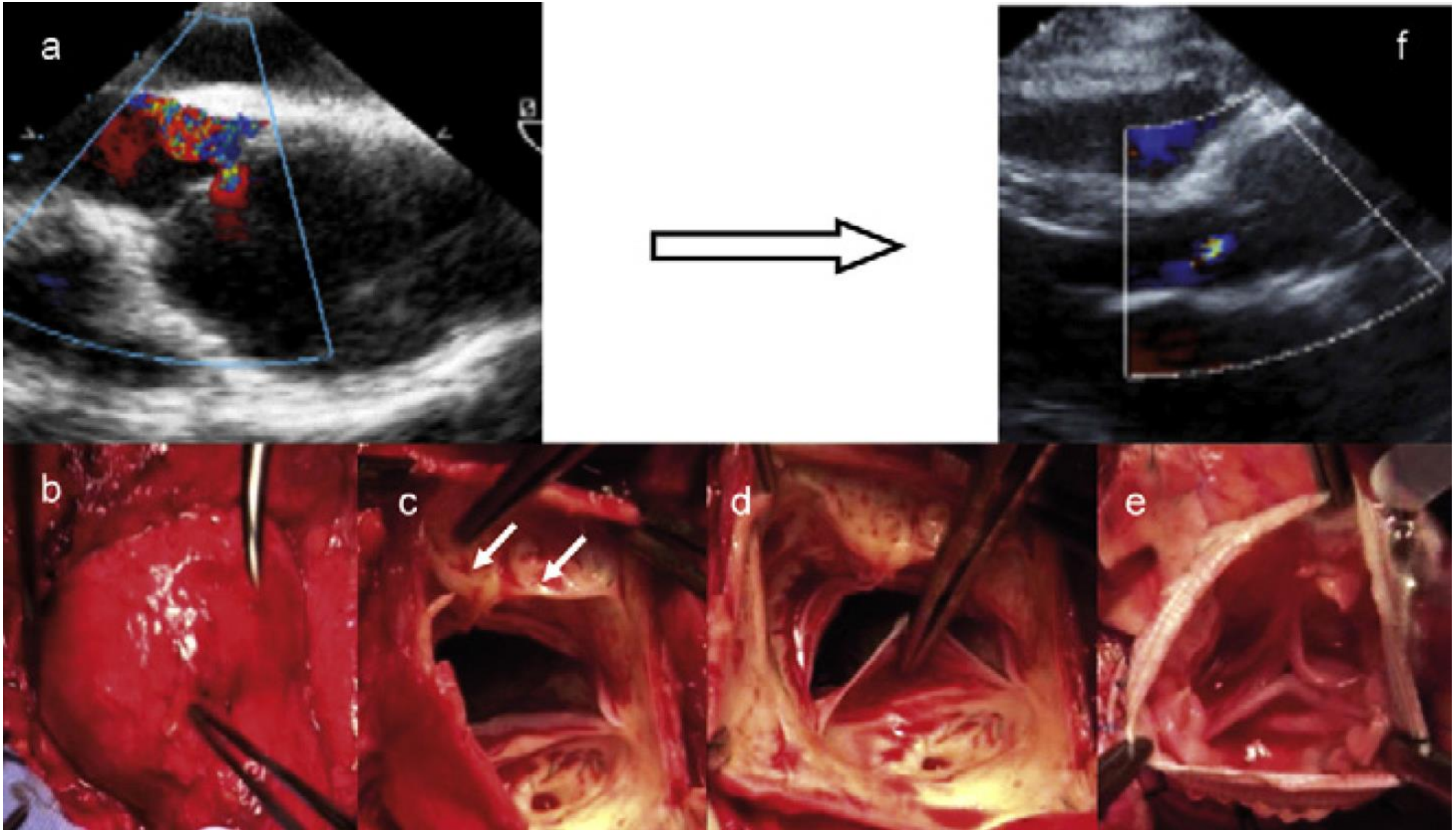
Ross operation in AI: Patch in Non-Retracted Valves



H.J. Schäfers et al. J Thorac Cardiovasc Surg 2010



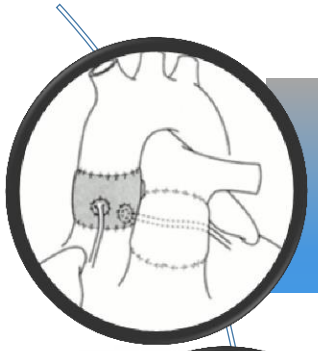
Z. Mosala Nezhad et al. Eur J Cardiothorac Surg. 2014



de Kerchove L., EJCTS 2010; 38:326-332

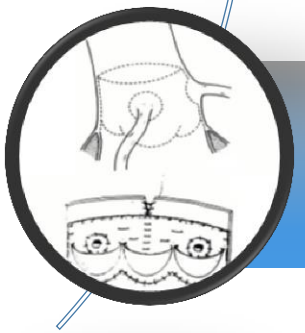
Ross operation in AI: When the Ross fails…

Mechanisms of failure in different techniques



autograft dilatation +/- AI

AI (autograft distorsion)



AI (autograft distorsion)