

Reconstruction of the Aortic Valve and Root: A Practical Approach  
September 14<sup>th</sup>-16<sup>th</sup> , Homburg/Saar, Germany

# *Differential Treatment of Aortopathy in BAV*

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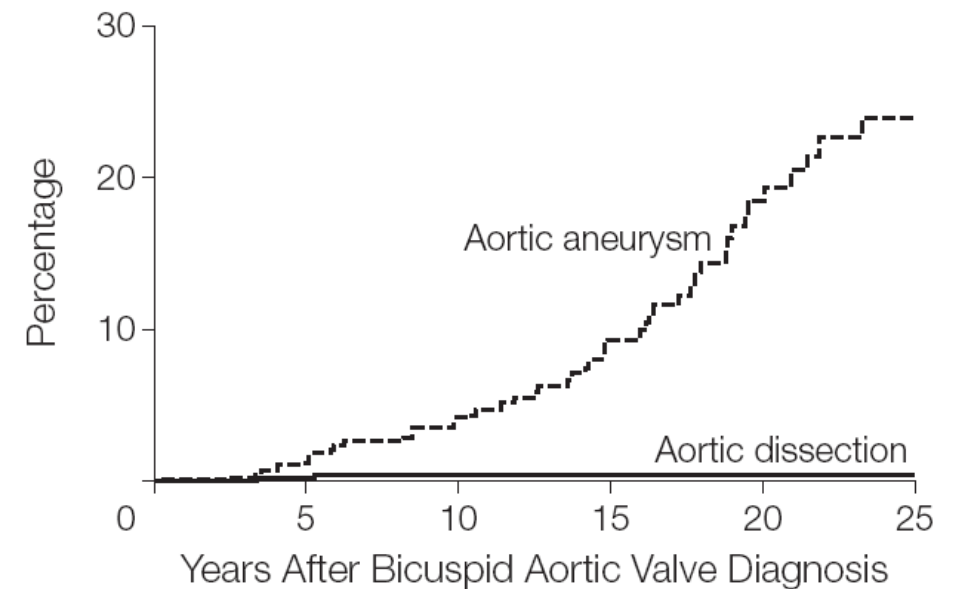
# BAV: *Overview*

- 1 – 2% of the population
- Disease of cusps and proximal aorta
- Combination of genetic and hemodynamic factors lead to aortopathy and valvular deterioration
- Patients with BAV insufficiency usually younger (2<sup>nd</sup>/3<sup>rd</sup>/4<sup>th</sup> decade) compared to those with BAV stenosis (5<sup>th</sup>/6<sup>th</sup> decade).
- 1/3 of patients having valve sparing and repair (Brussels-Homburg-Paris)

# BAV: *Aortopathy*

## Incidence of Aortic Complications in Patients With Bicuspid Aortic Valves

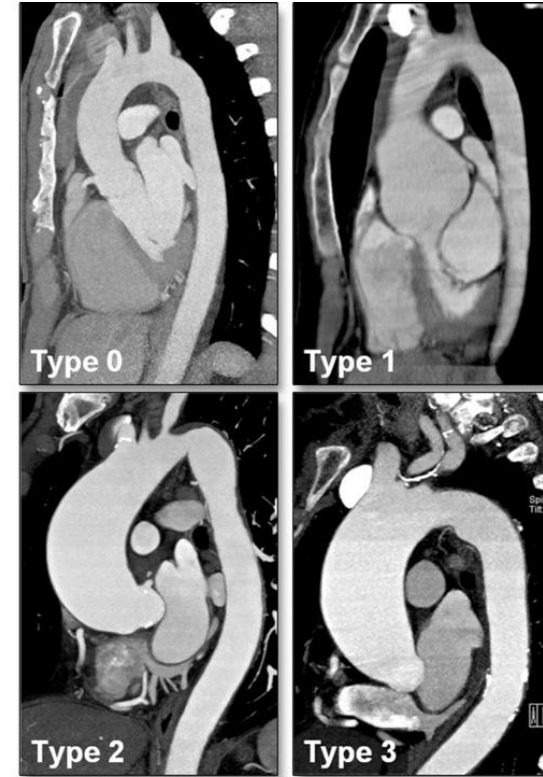
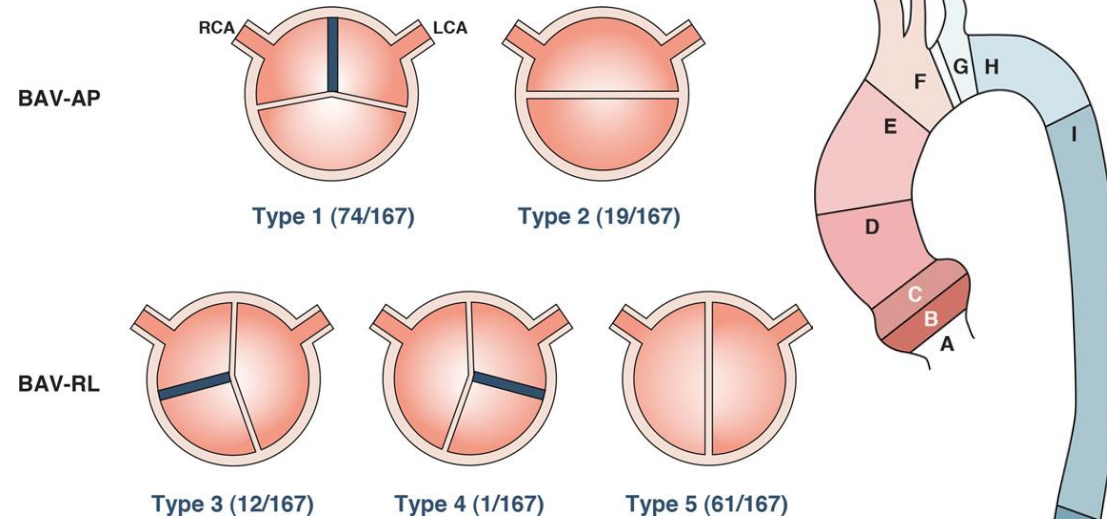
- Observational Cohort
- 416 patients with BAV
- Survival similar to general population
- High incidence of aneurysm formation
- Low incidence of aortic dissection but higher than general population



No. at risk	0	5	10	15	20	25
Aortic aneurysm	384	352	309	186	88	39
Aortic dissection	416	387	348	209	110	53

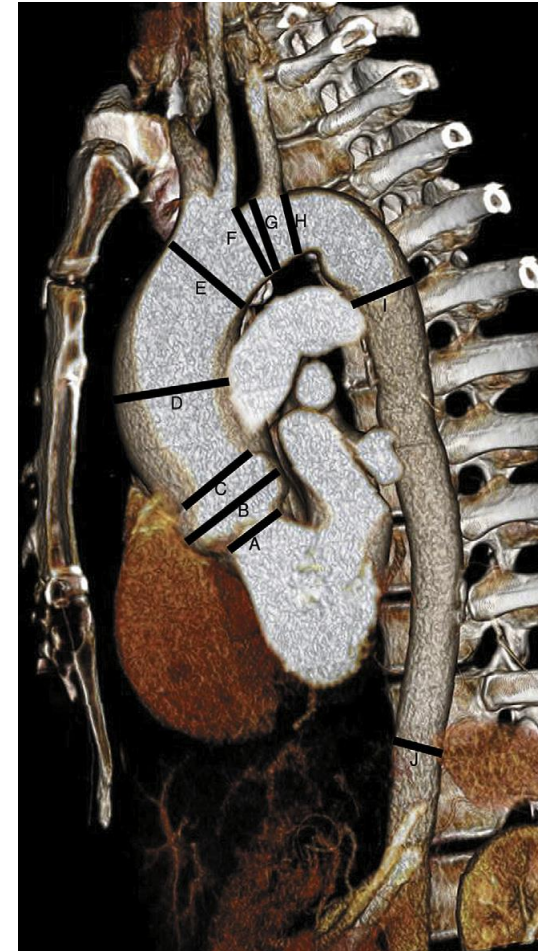
# BAV: *Kang/Song Classification*

- 167 patients evaluated with MDCT and Echo for possible surgery
- 56% BAV-AP vs. 44% BAV-RL
- Aortopathy:
  - Type 0: 27%
  - Type 1: 20%
  - Type 2: 29%
  - Type 3: 23%
- Increased incidence of AI in BAV-AP configuration vs. AS in BAV-RL
- Normal aorta was most common in BAV-AP (33%)
- Type 3 aortic dilatation common in BAV-RL (40.5%)



# BAV: *Fazel/Miller Classification*

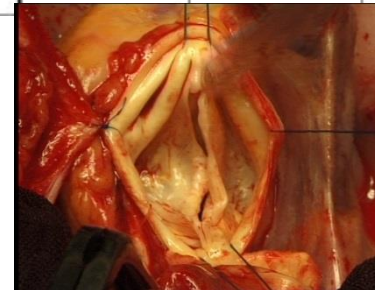
- 64 patients identified from surgical and radiologic databases for BAV associated aortopathy
- Four clusters of aortopathy:
  - Cluster I: Aortic root (n=8)
  - Cluster II: Tubular aorta (n=9)
  - Cluster III: Tubular aorta/arch (n=18)
  - Cluster IV: Diffuse Dilatation (n=29)



# BAV: *Sievers Classification*

- 304 surgical specimens and operative reports collected over 5 years
- Centered on the number of raphe and the type of cusp fusion

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:							
V	F	I	6 (2)	1 (0.3)	79 (26)	22 (7)	3 (1)	6 (2)
A	U	S	7 (2)	5 (2)	119 (39)	15 (5)	3 (1)	6 (2)
L	N	B (I + S)		1 (0.3)	15 (5)	7 (2)	2 (1)	2 (1)
V	C	No			3 (1)	1 (0.3)		
U	T							
L	I							
A	O							
R	N							

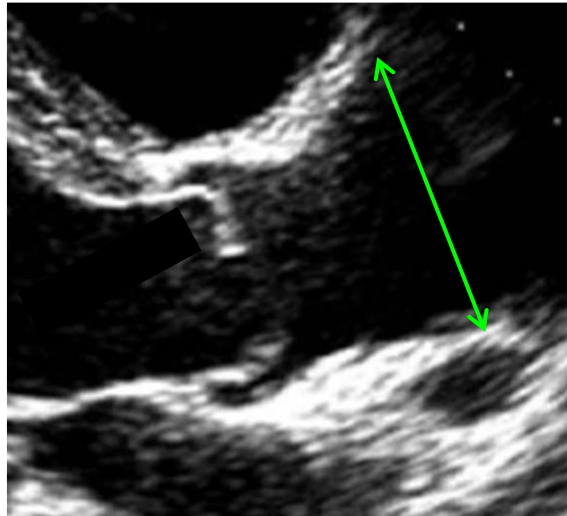


# BAV: *Classification Summary*

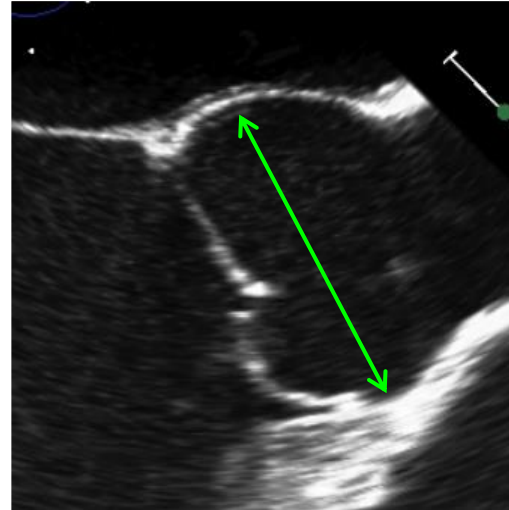
- Classification systems derived from different populations
- BAV is a heterogenous entity with distinct sub-types
- Correlation between valvular morphology and pattern of aortic dilatation may suggest a pathophysiologic link
- No clear classification system geared towards BAV repair

# Brussels' BAV repair: *Treatment of aortopathy*

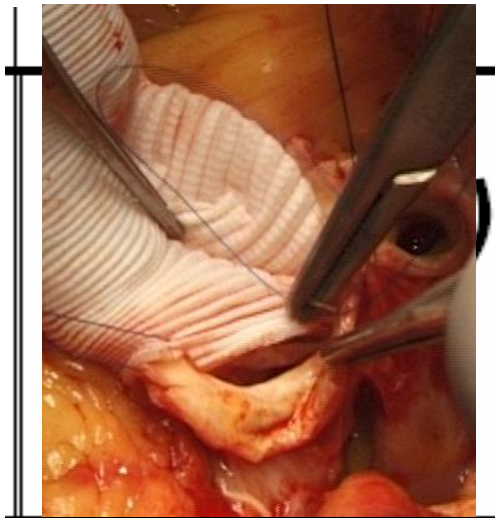
Asc Aorta dilatation



Aortic root dilatation



Cusp repair + SCAA Rempl.

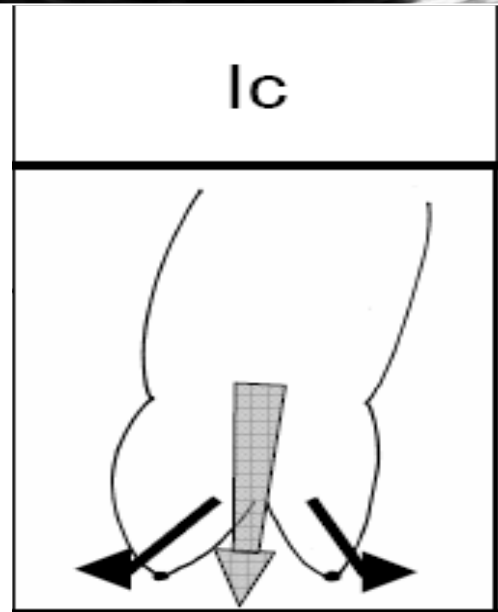
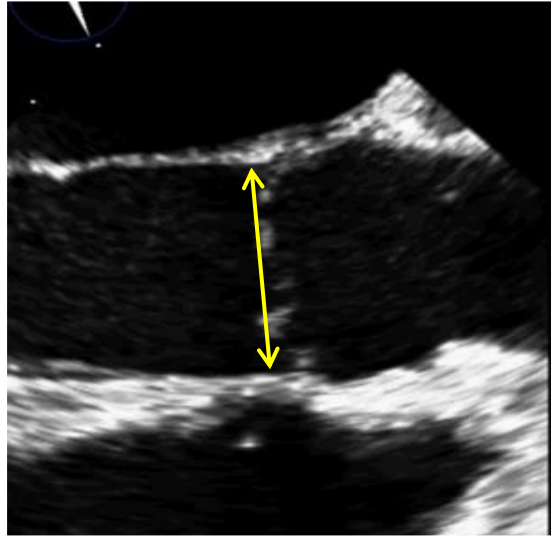


Cusp repair + VSReimplantation





# Brussels' BAV repair: *VAJ Dilatation in BAV Insufficiency*



➤ 28 mm

*de Kerchove et al. JTCVS 2010*

➤ 30 mm

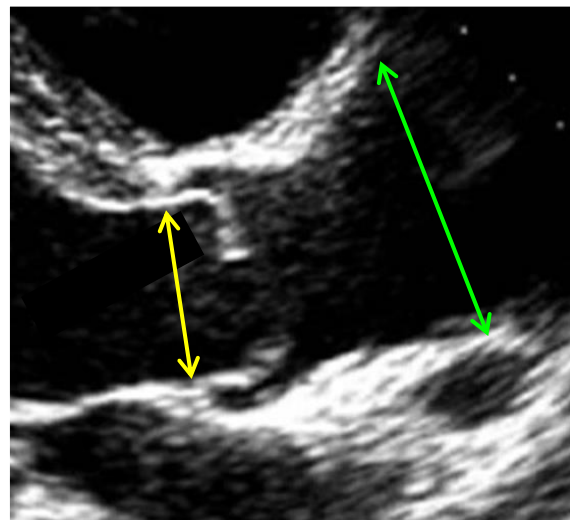
*Schäfers et al. JTCVS 2013*

➤ 30 mm

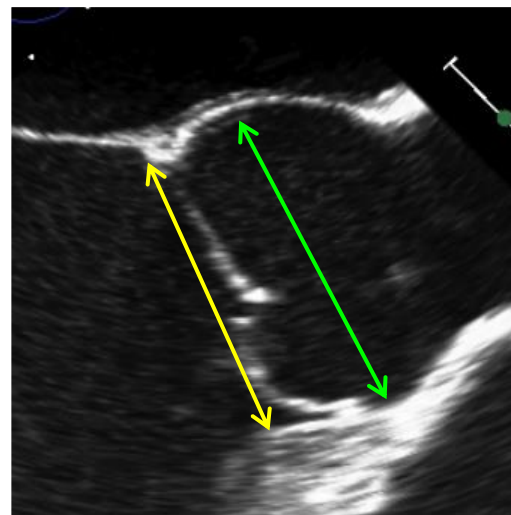
*Al-Atassi et al. EJCTS 2015*

# Brussels' BAV repair: *Treatment of aortopathy* (Early experience)

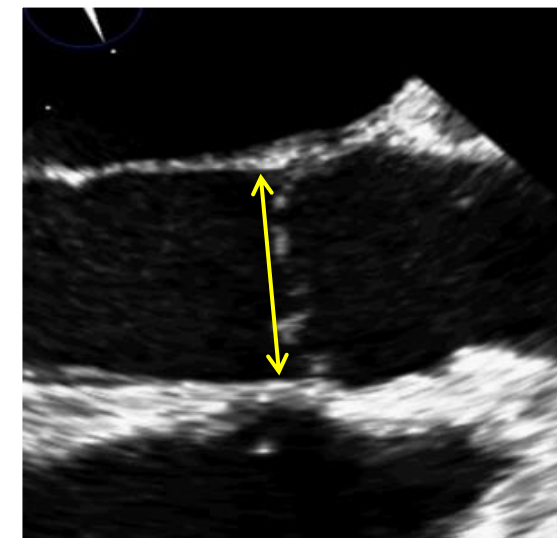
Asc Aorta dilatation



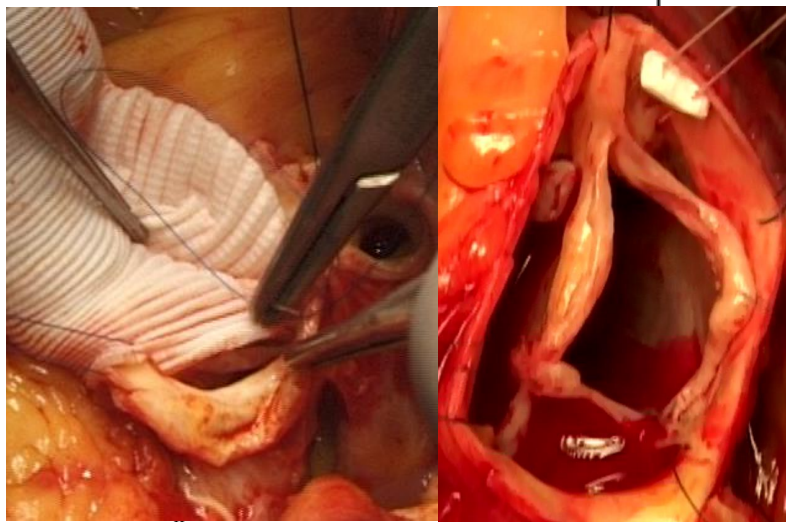
Aortic root dilatation



NI aorta



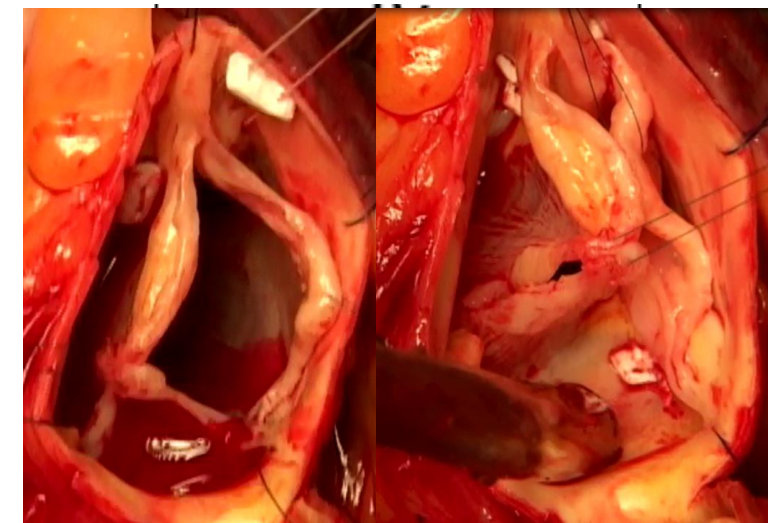
Cusp repair + SCAA Rempl. + SCA



Cusp repair + VSReimplantation

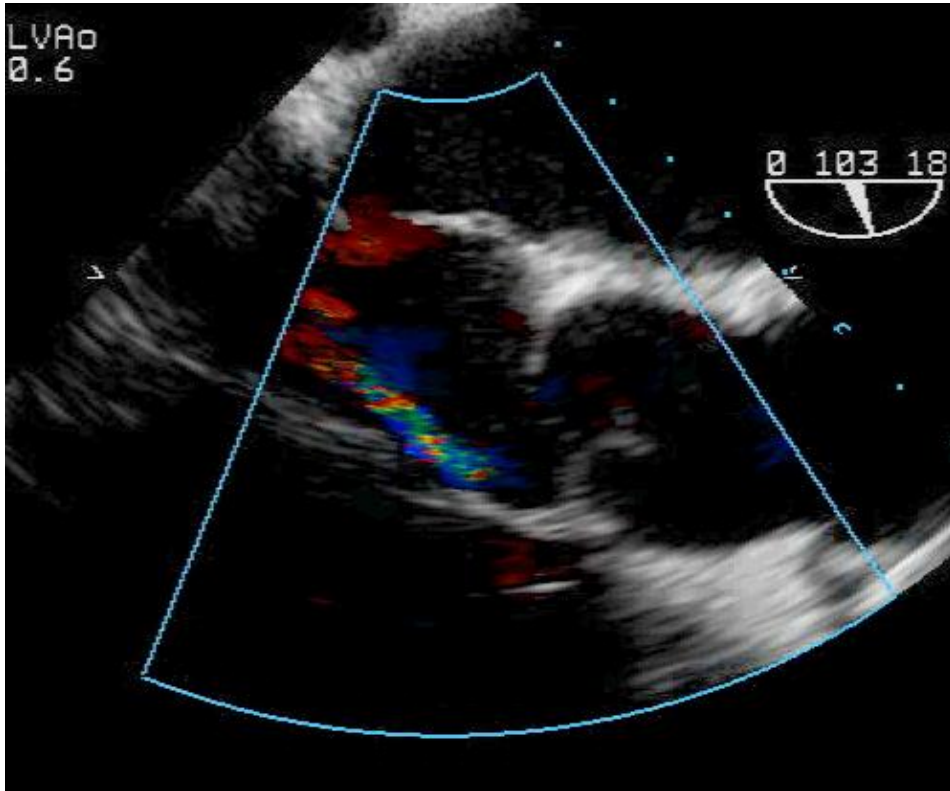


Cusp repair + SCA

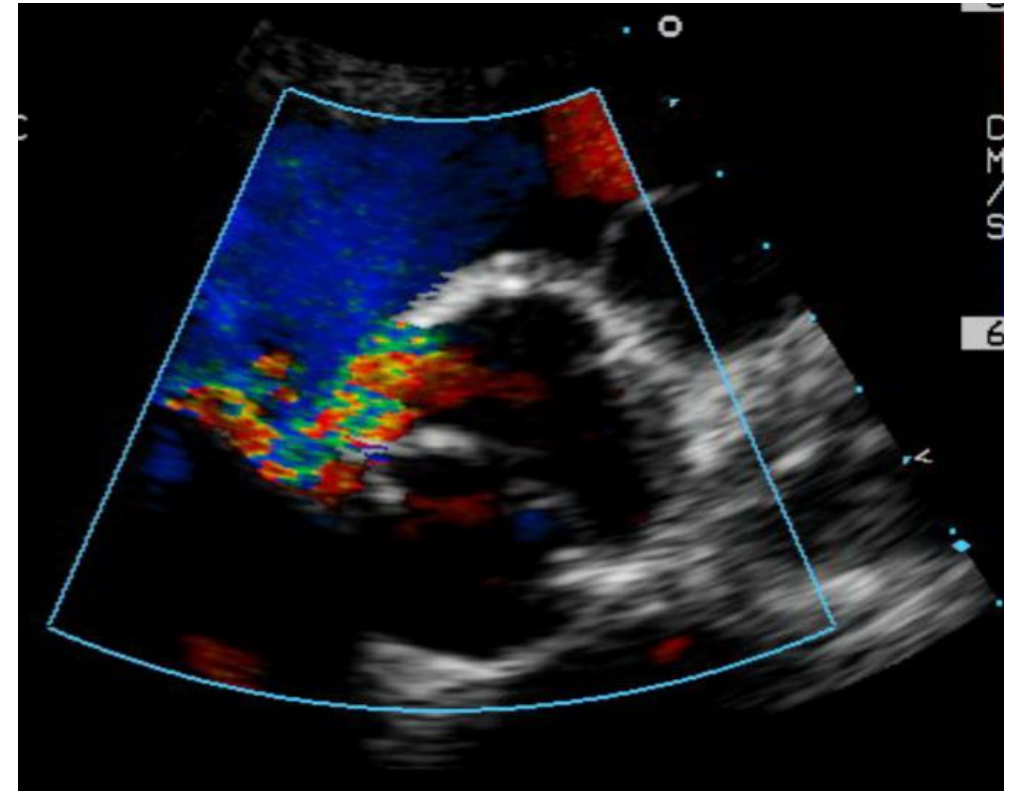


# Brussels' BAV repair: *Fate of SCA – Acute complication*

**Cusp perforation !**



**Fistula Aorta – RV !**



# Brussels BAV repair: *Results of BAV repair*

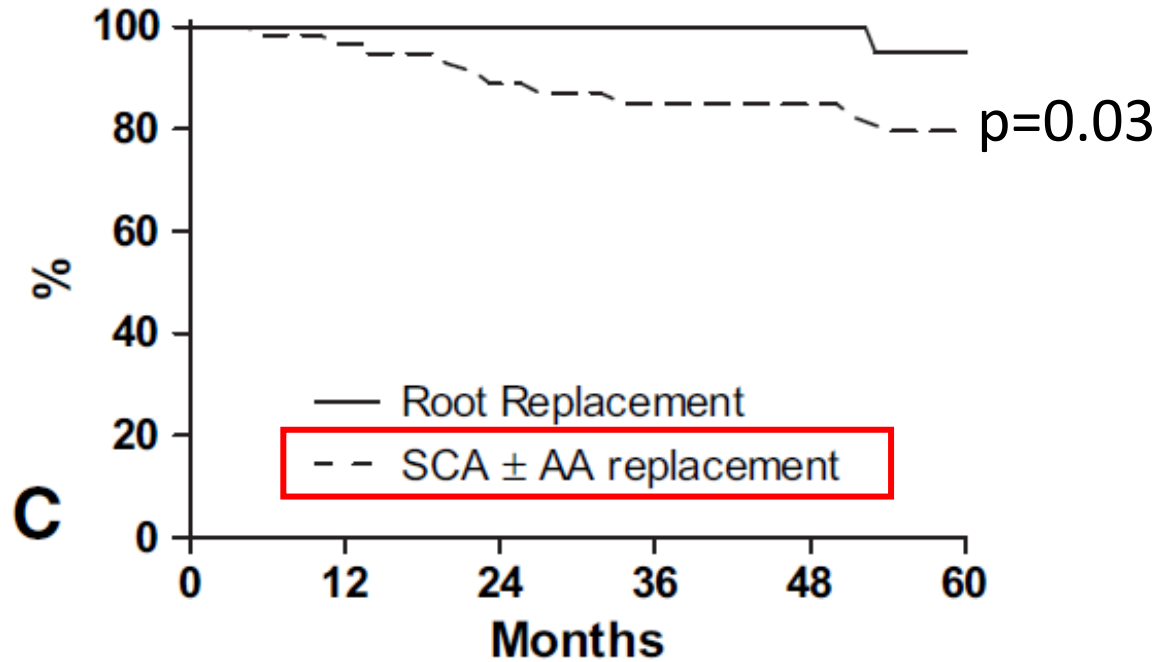
TABLE E1. Early and late aortic valve reoperations

Year	Interval	Valve type	Aortic root intervention	Raphé repair	Other cusp repair technique(s)	Failure mode	Mechanism of failure	Type of AV reoperation
<b>Early AV reoperations</b>								
1997	day 7	1	SCA	Direct suture	FMP	AI	<u>Suture dehiscence</u>	Re-repair
1998	day 12	0	Remodeling; SCA	—	FMP	AI	<u>Cusp prolapse</u>	Ross procedure
1998	day 6	0	SCA	—	Patch on perforation	AI	<u>Coaptation defect</u>	Ross procedure
2006	day 10	1	SCA	Shaving	FMP; FMR	Fistula	Aorta–right ventricle fistula	Re-repair
2008	day 6	1	SCA	Shaving	FMP; direct suture of perforation	AI	<u>Suture dehiscence</u>	Re-repair
<b>Late AV reoperations</b>								
1996	8 y	1	AA replacement	Direct suture	Decalcification	AS	Calcification	Bioprosthesis
2000	7 y	1	SCA	Shaving	FMP; FMR	AI+AS	Cusp prolapse, calcification	Bioprosthesis
2001	2 y	1	SCA	Patch*	—	AI	<u>Cusp prolapse</u>	Ross procedure
2002	6 y	1	SCA	Direct suture	FMR	AI	<u>Cusp prolapse (PTFE rupture), calcification</u>	Ross procedure
2002	6.5 y	0	Remodeling; SCA	—	FMP	AI	Endocarditis	Re-repair
2002	6.5 y	1	SCA	Direct suture	FMR	AI	<u>Cusp prolapse</u>	Re-repair
2007	2 y	0	SCA	—	FMP; FMR; patch on perforation	AI	<u>Cusp prolapse</u>	Bioprosthesis

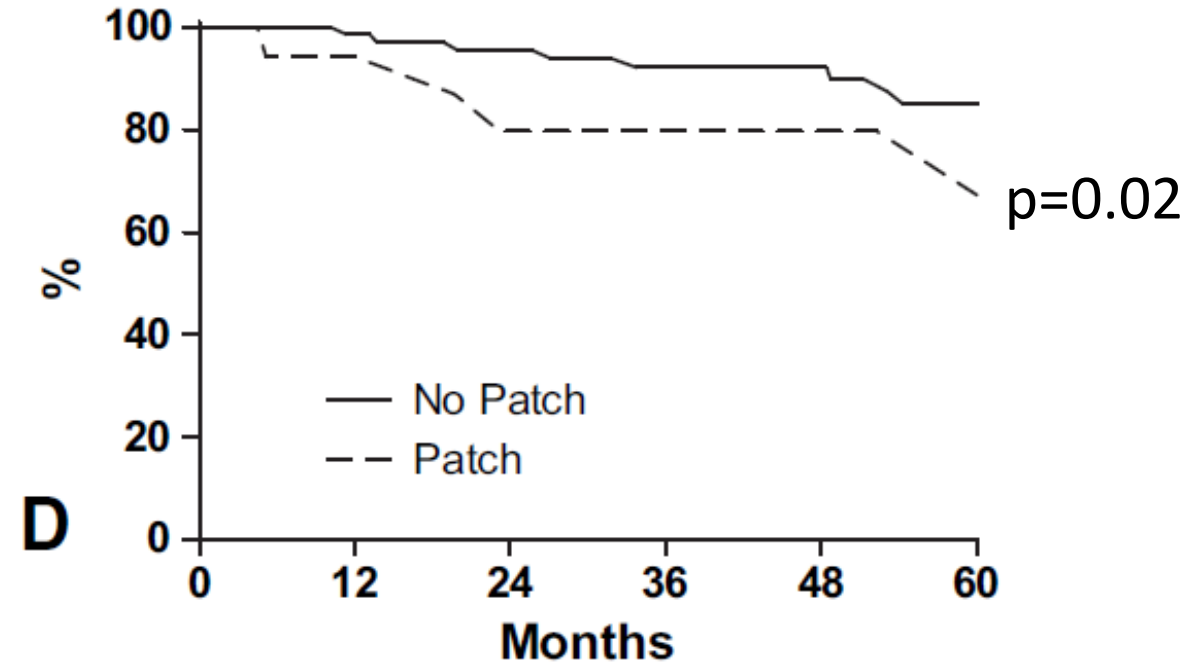
SCA, Subcommissural annuloplasty; AA, ascending aorta; AI, aortic insufficiency; AV, aortic valve; AS, aortic stenosis; PTFE, polytetrafluoroethylene; FMP, free margin plication; FMR, free margin resuspension (with 7-0 PTFE). \*Tricuspid valve autograft patch was used in this patient.

**3/4 Recurrent Regurgitation ! (prolapse)**

# Brussels BAV repair: *Results of BAV repair*



<u>No. at risk</u>	0	12	24	36	48	60
Root Rep	52	47	40	32	26	20
SCA ± AA	65	56	47	39	35	26

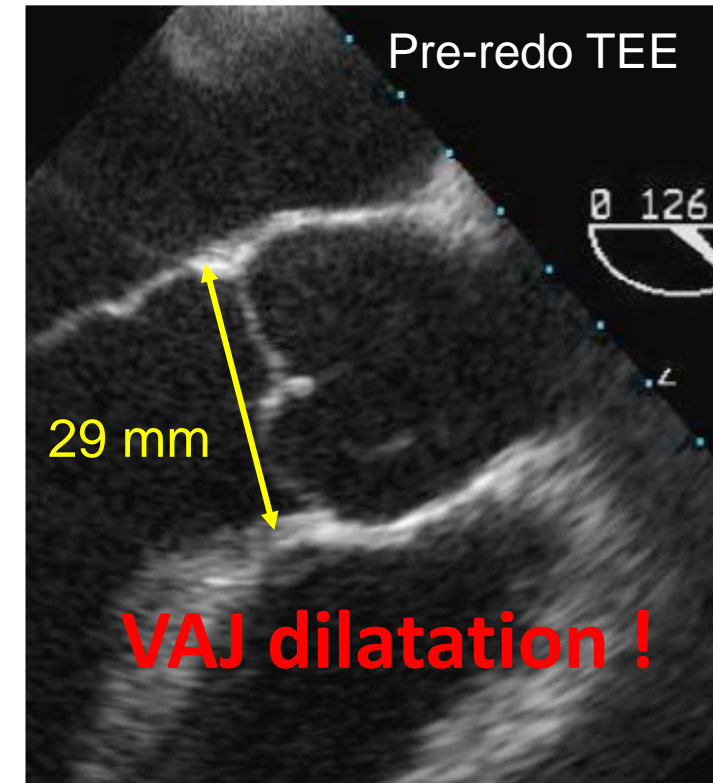
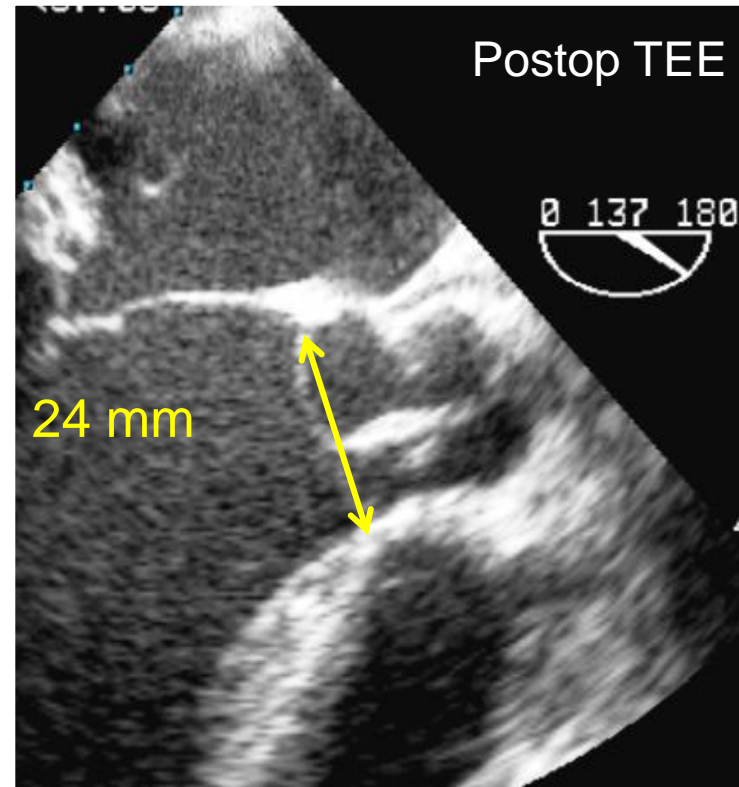
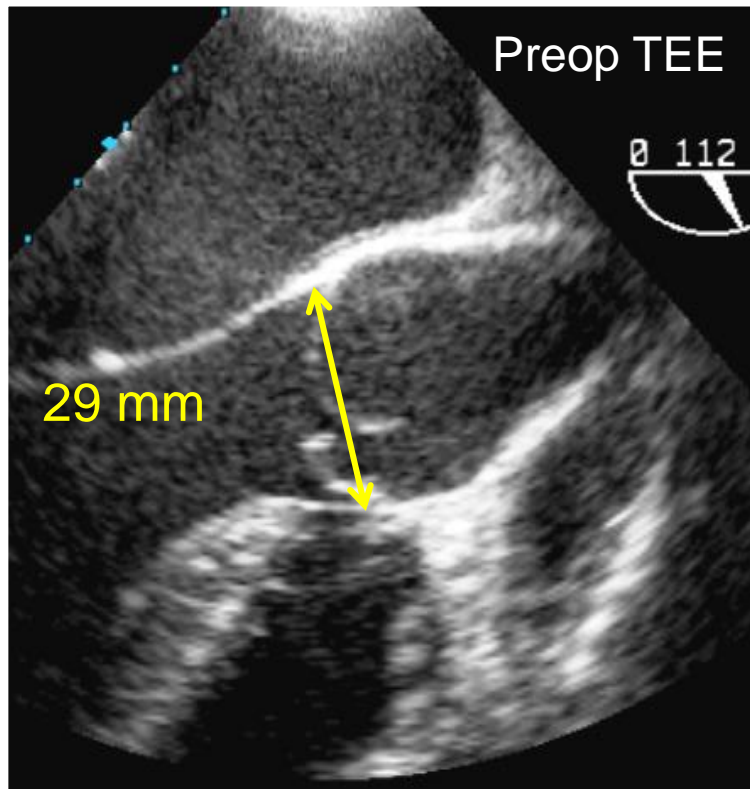


<u>No. at risk</u>	0	12	24	36	48	60
Patch	19	14	12	10	9	6
No Patch	77	71	62	50	43	31

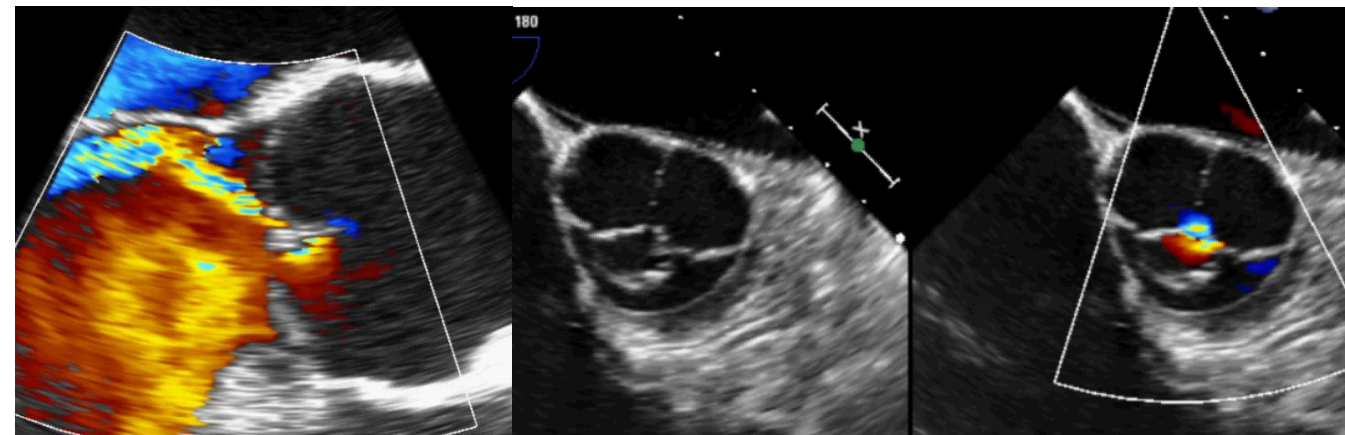
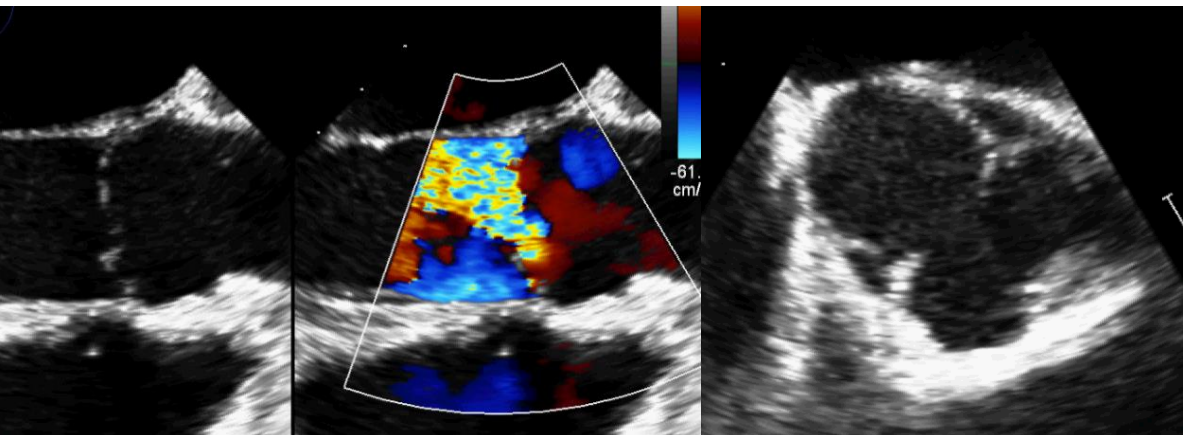
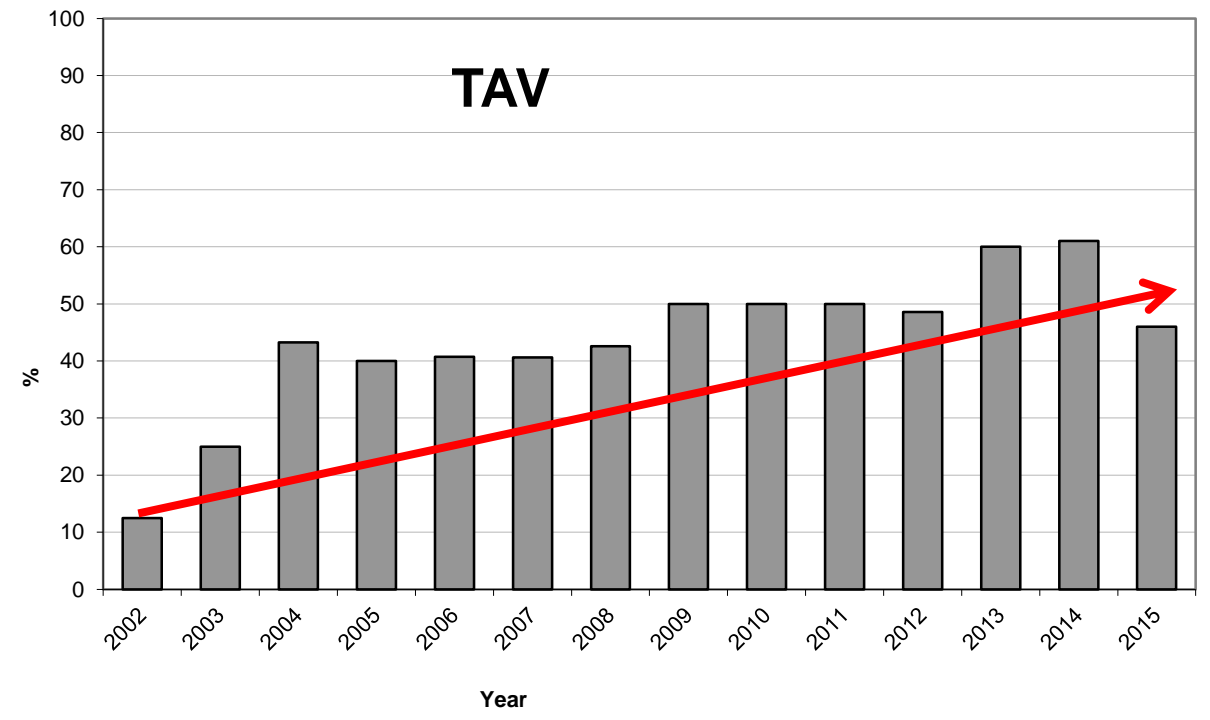
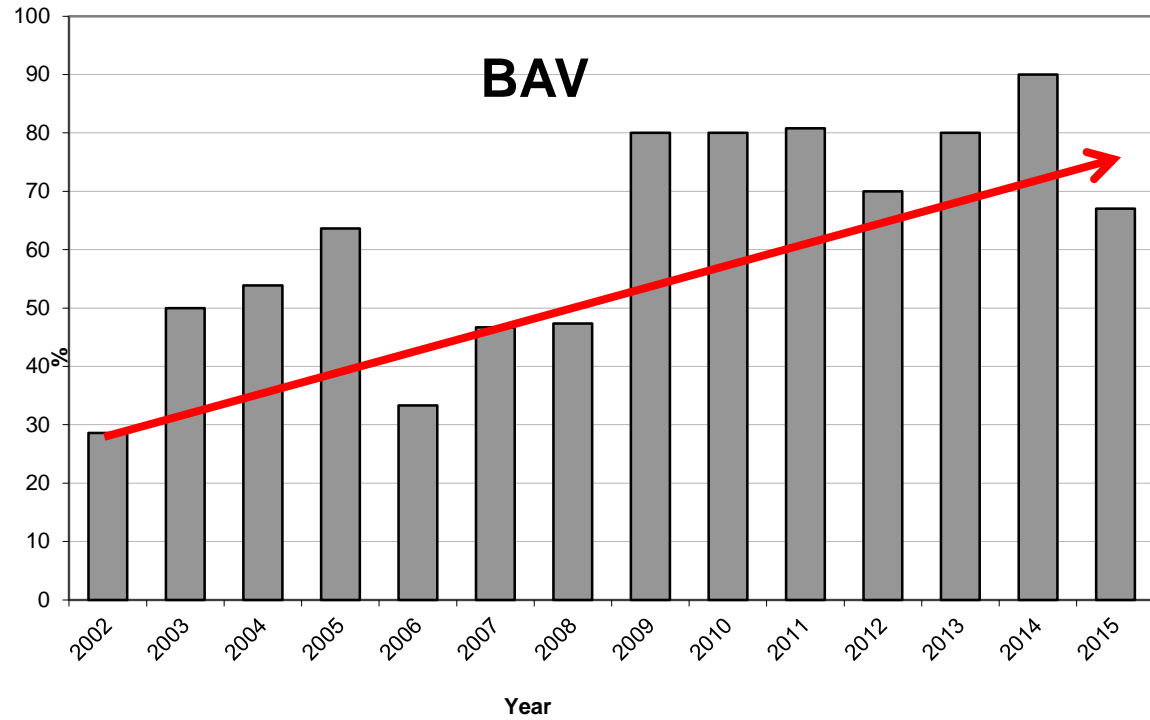
# Brussels' BAV repair: *Fate of SCA – Chronic complication*

30 y♂: **BAV** raphe res. + direct closure + FM resusp. (Gtx) + SCA →

6.5 y later: AI 3+



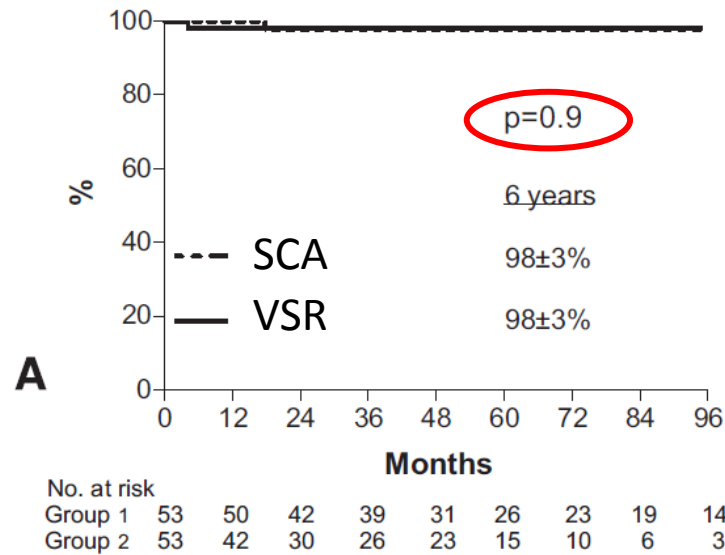
# Brussels' BAV repair: *Aorta repair – Late experience*



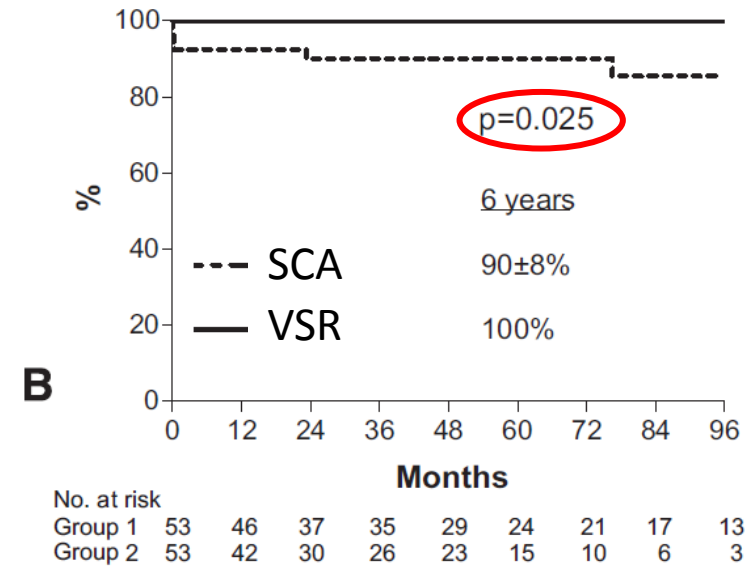
# Brussels' BAV repair: *SCA vs VSR* – Matched comparison

L. de Kerchove J Thor Cardiovasc Surg 2011;142:1430-8

Overall Survival

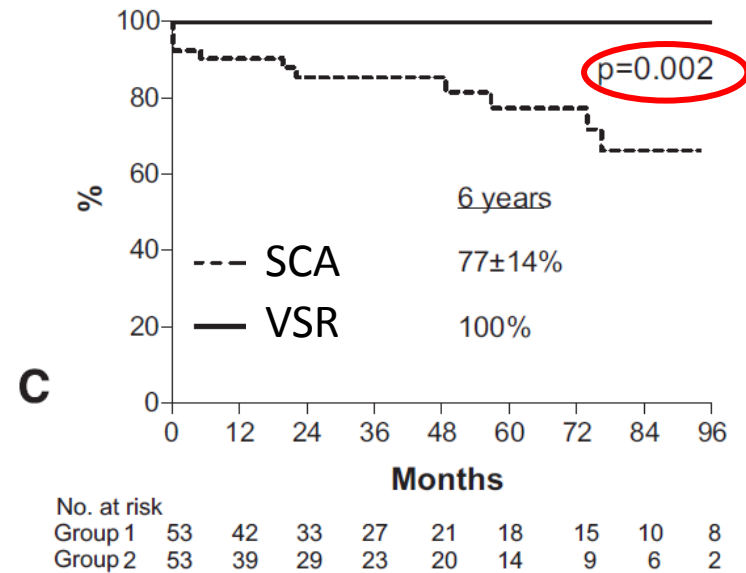


Freedom from reoperation



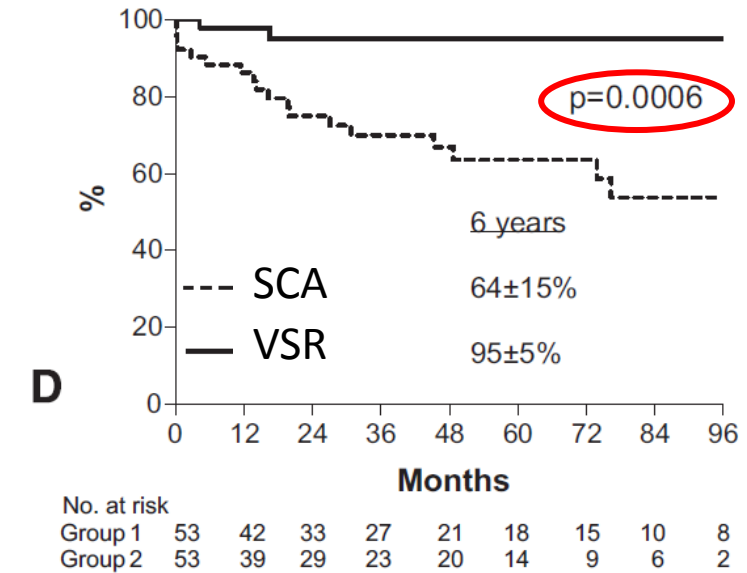
Freedom from

AI > 2+



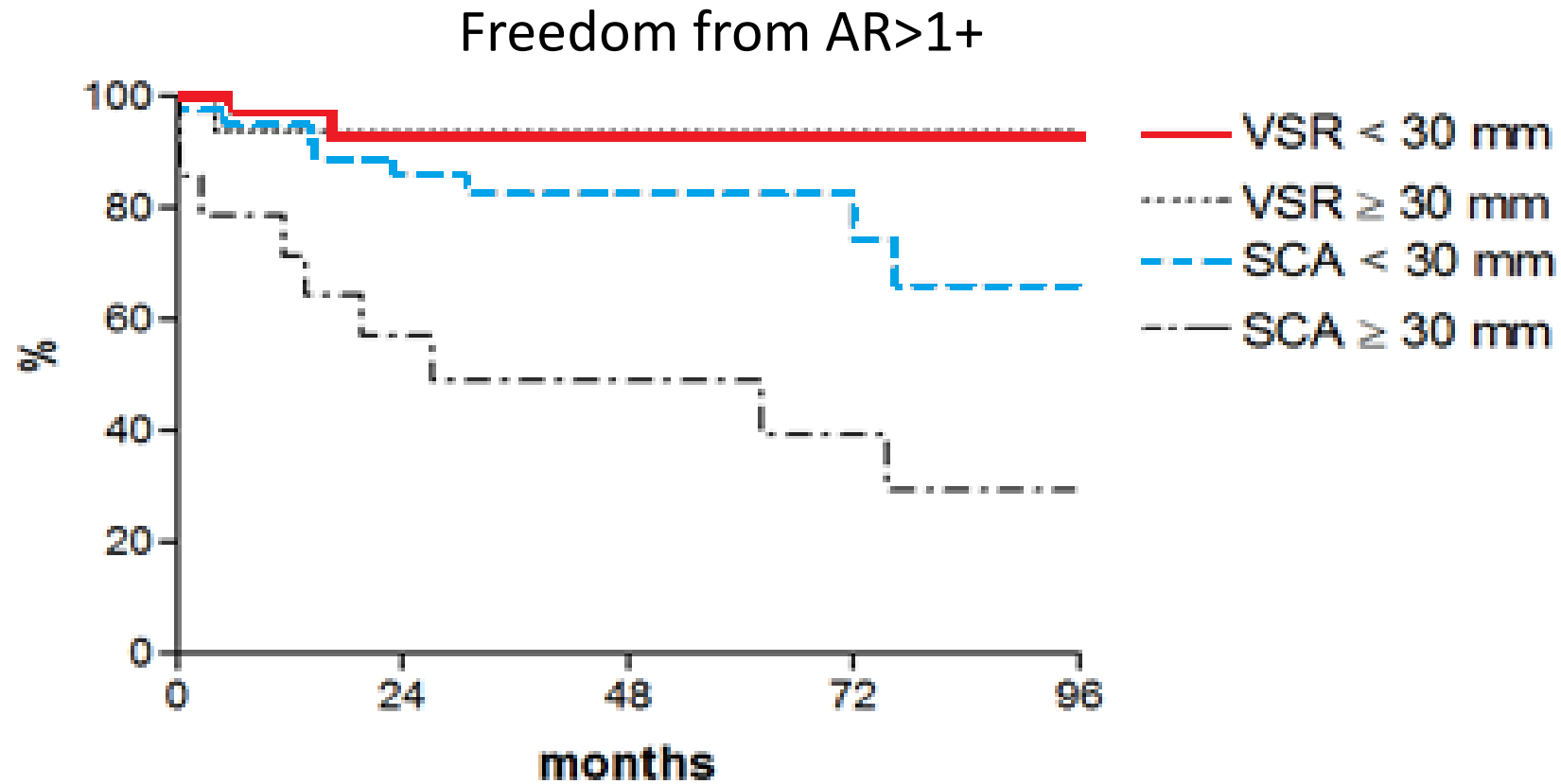
Freedom from

AI > 1+





# Brussels' BAV repair: *VAJ in BAV repair* – Role of annuloplasty

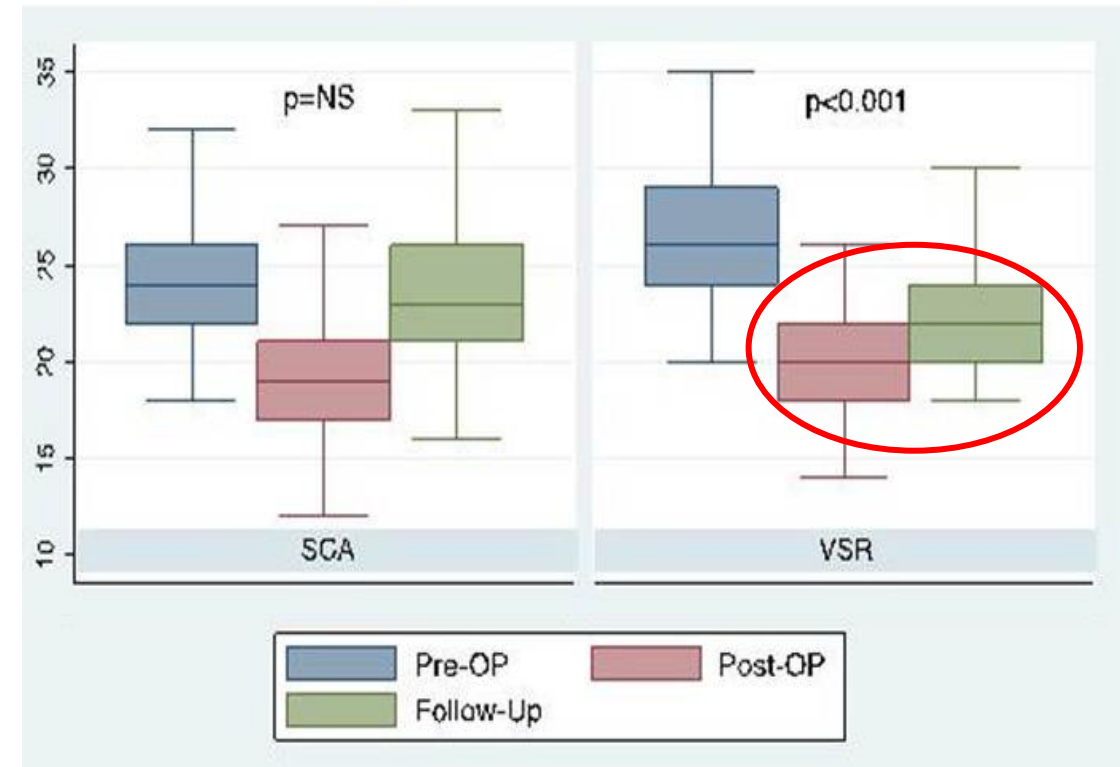
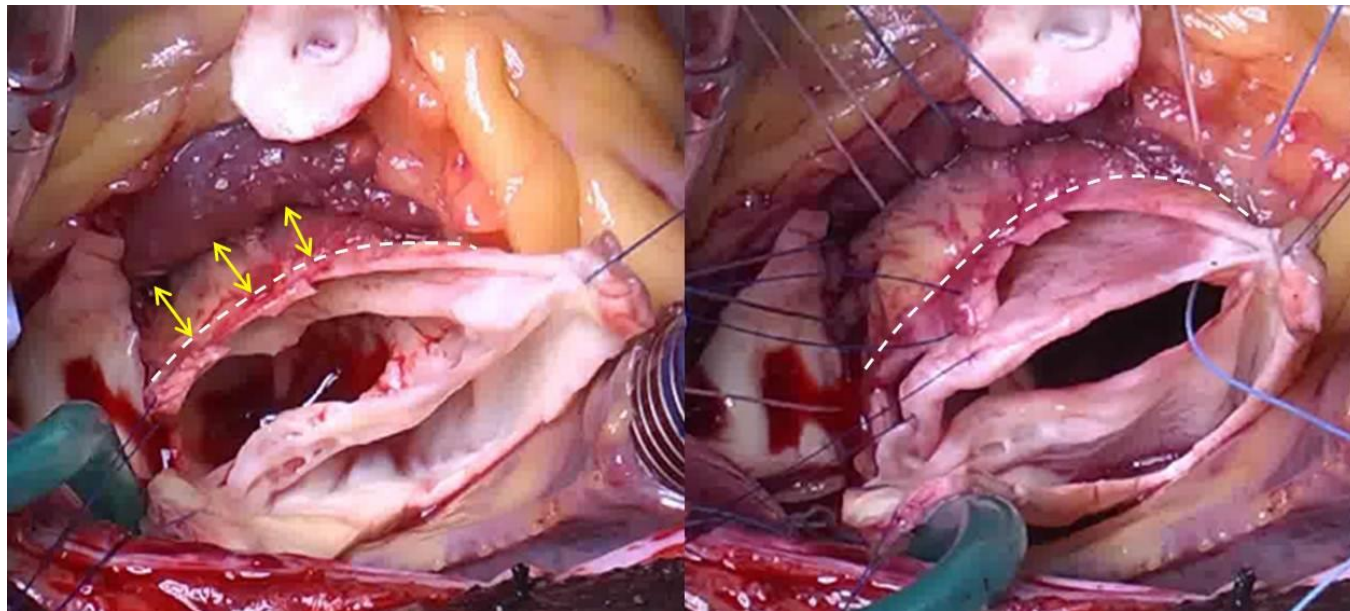


Pts. at risk:

37	20	12	5	1
23	7	5	2	1
39	29	18	10	4
14	7	5	4	2

# Brussels' BAV repair: *Why is VSR so good?*

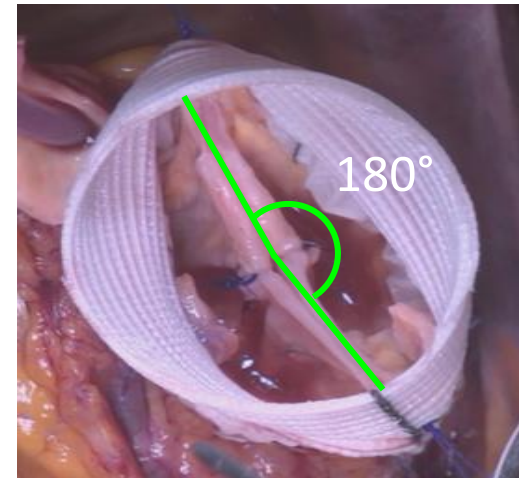
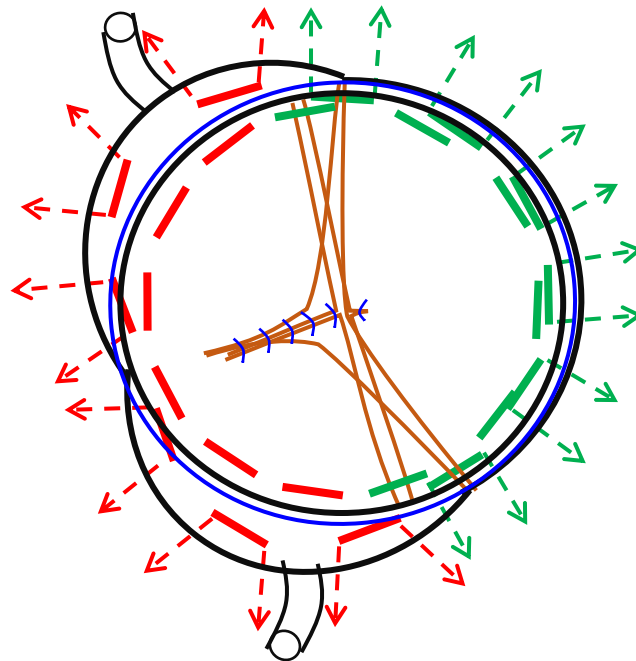
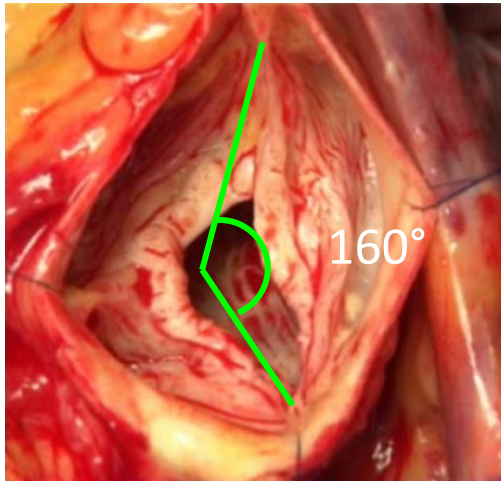
1. Circumferential prosthetic annuloplasty → **Stable over time**
2. Remodel BAV geometry to 180°
3. Optimal Coaptation



# Brussels' BAV repair: *Why is VSR so good?*

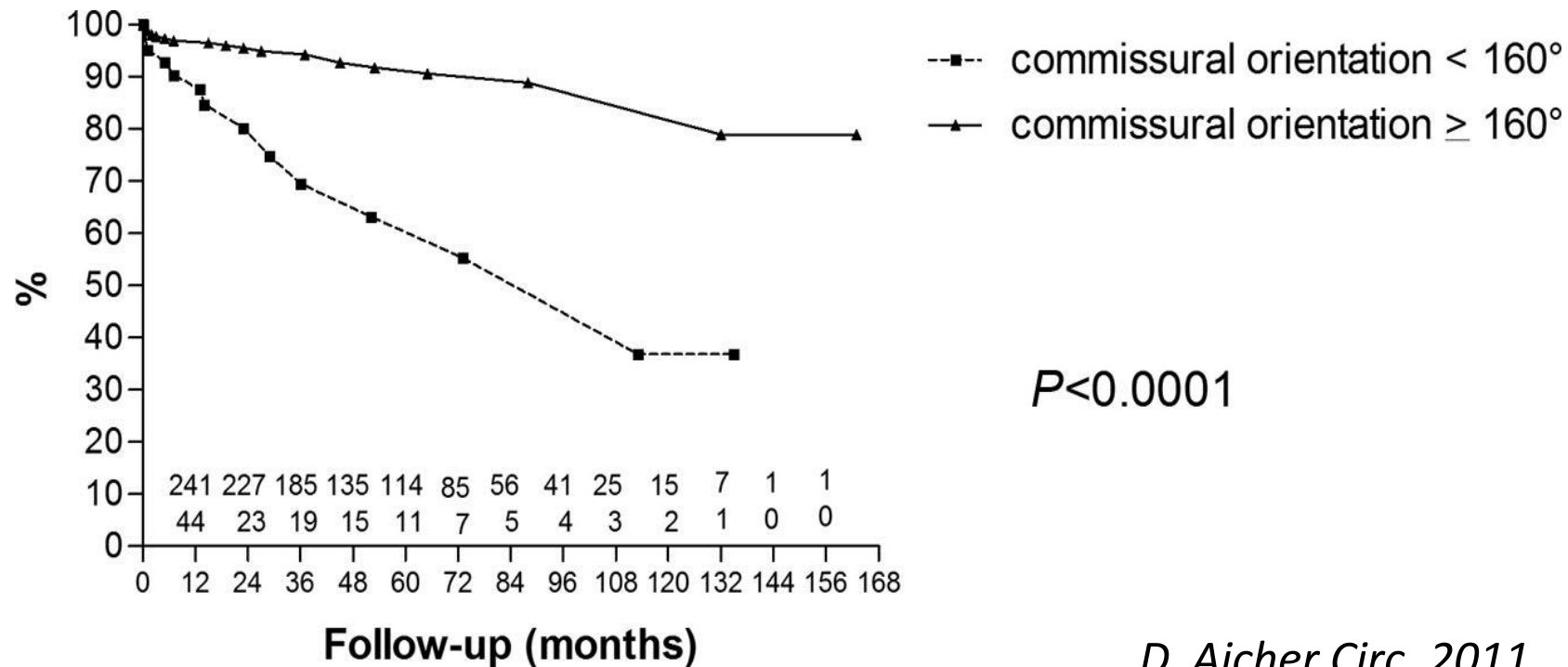
1. Circumferential prosthetic annuloplasty  $\longrightarrow$  **Stable over time**
2. Remodel BAV geometry to 180°
3. Optimal Coaptation

*"Assymmetric annuloplasty"*



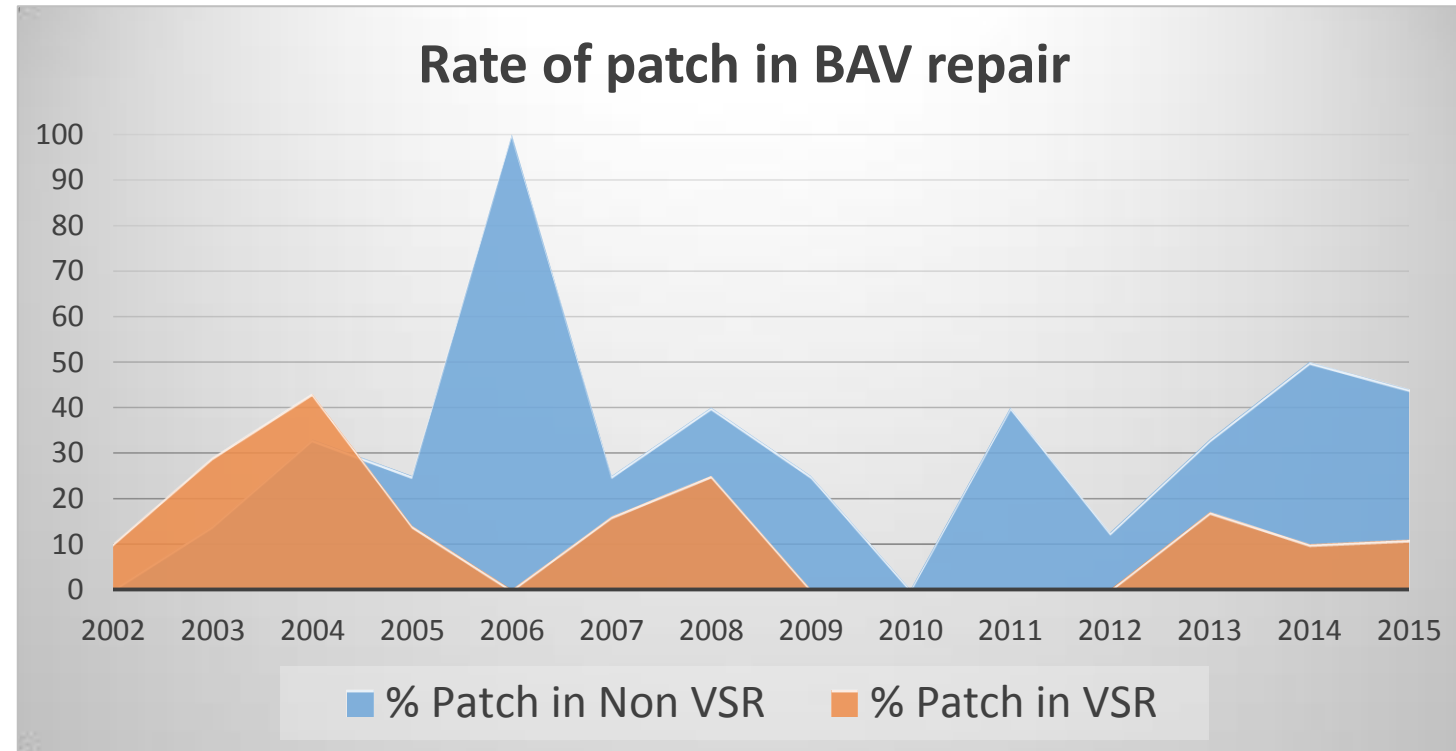
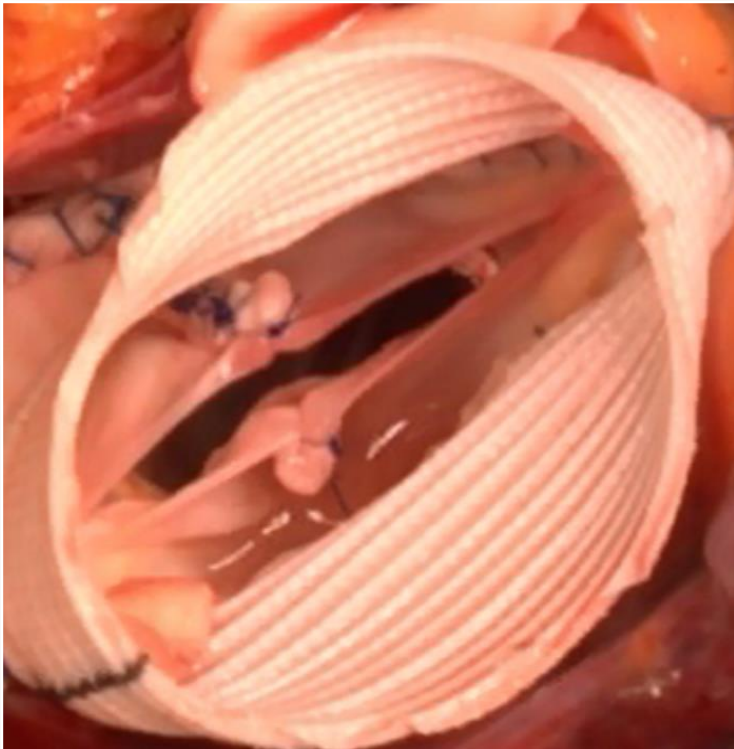
# Brussels' BAV repair: *Why is VSR so good?*

1. Circumferential prosthetic annuloplasty → **Stable over time**
2. Remodel BAV geometry to 180° → **Durable configuration**
3. Optimal Coaptation



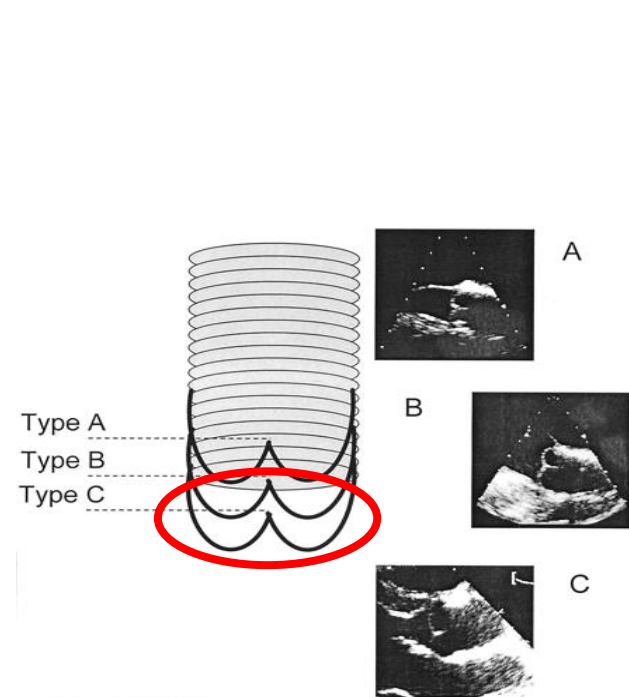
# Brussels' BAV repair: *Why is VSR so good?*

1. Circumferential prosthetic annuloplasty → **Stable over time**
2. Remodel BAV geometry to 180° → **Durable configuration**  
→ **Reduce the need of patch**
3. Optimal Coaptation

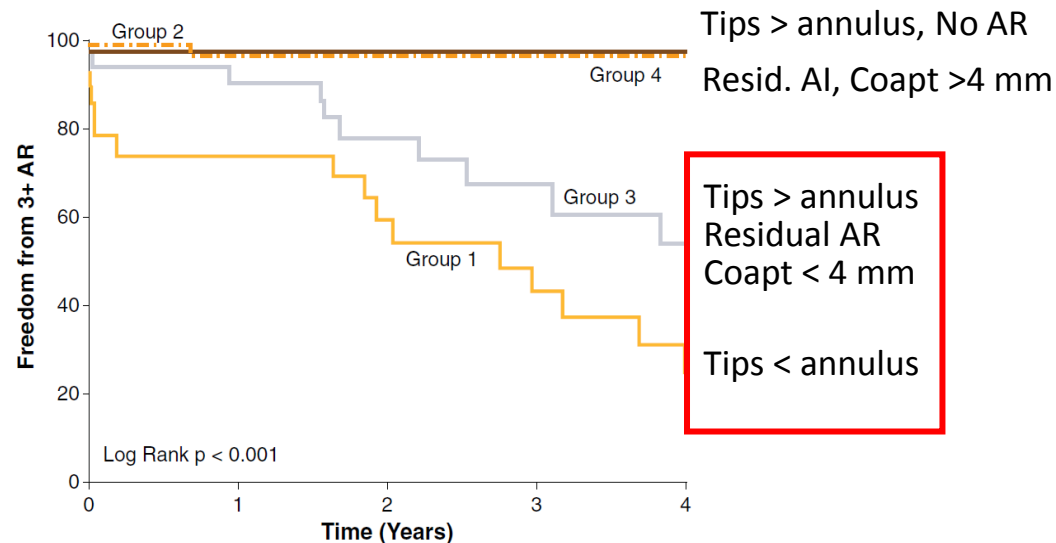


# Brussels' BAV repair: *Why is VSR so good?*

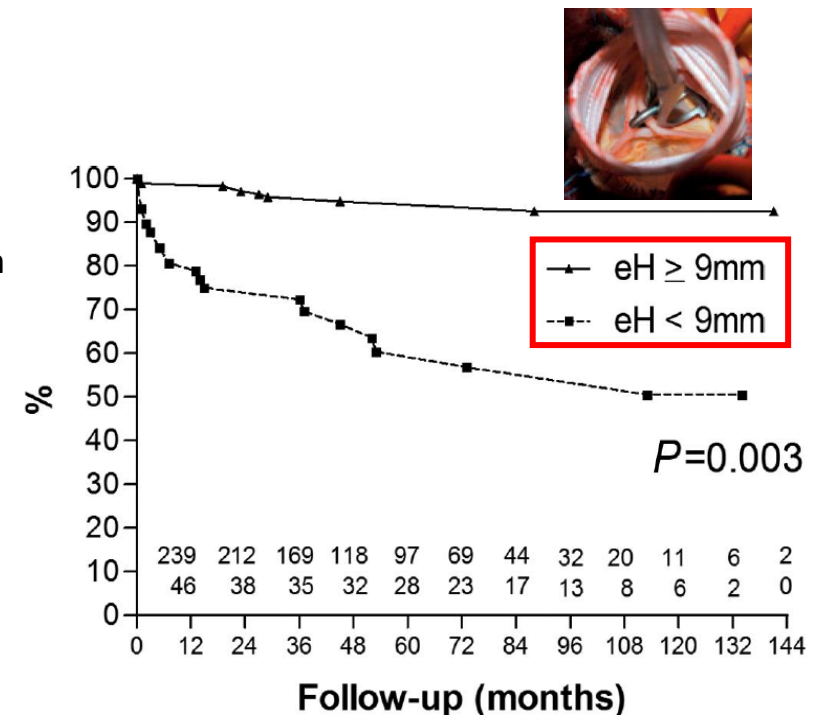
1. Circumferential prosthetic annuloplasty → **Stable over time**
2. Remodel BAV geometry to 180° → **Durable configuration**  
→ **Reduce the need of patch**
3. Optimal Coaptation



Pethig K. ATS 2002



le Polain JB. JACC Card. Im. 2009

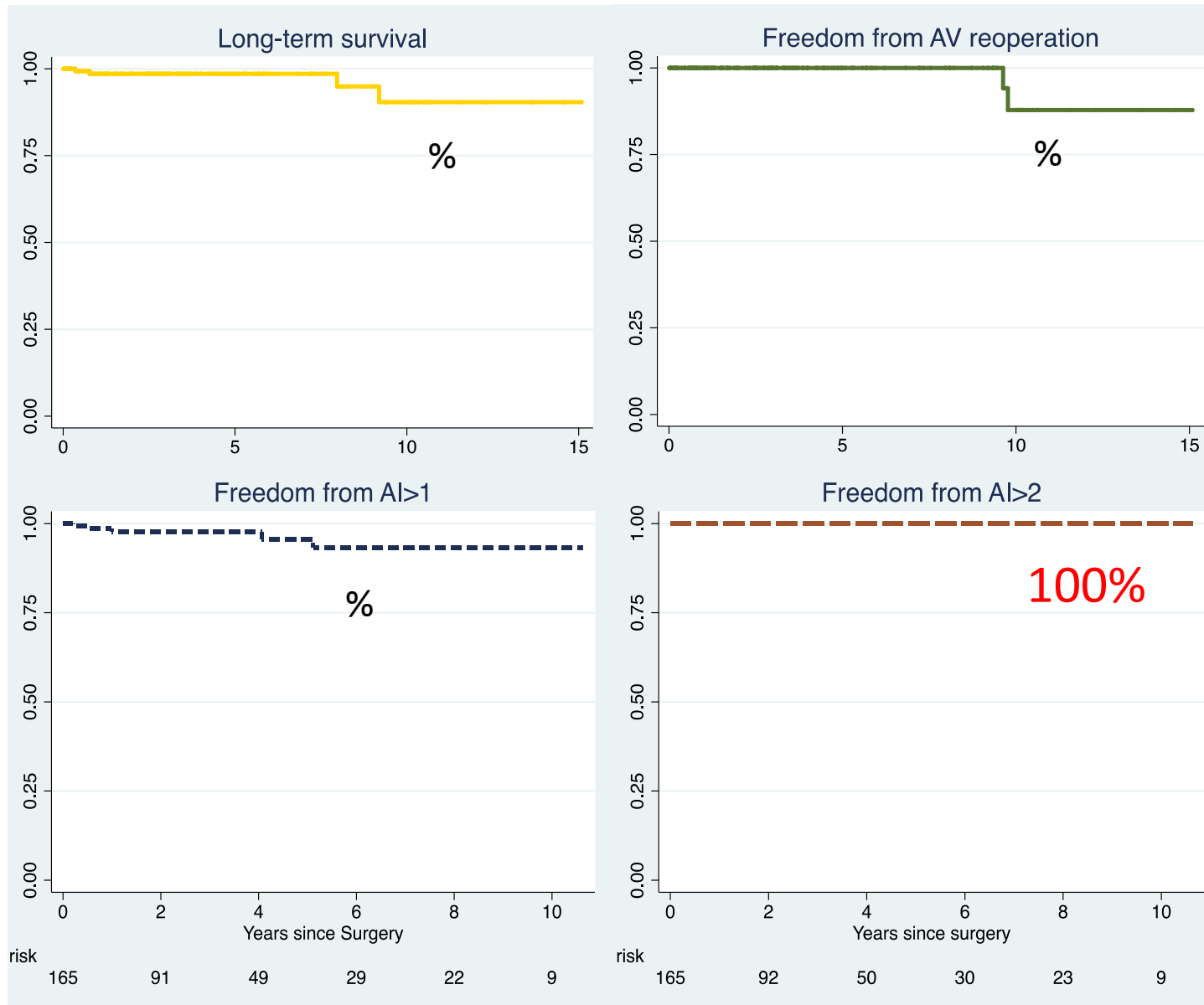


Aicher D. Circ. 2011

# Brussels BAV repair: *Updated results - 165 BAV repair with VSR*

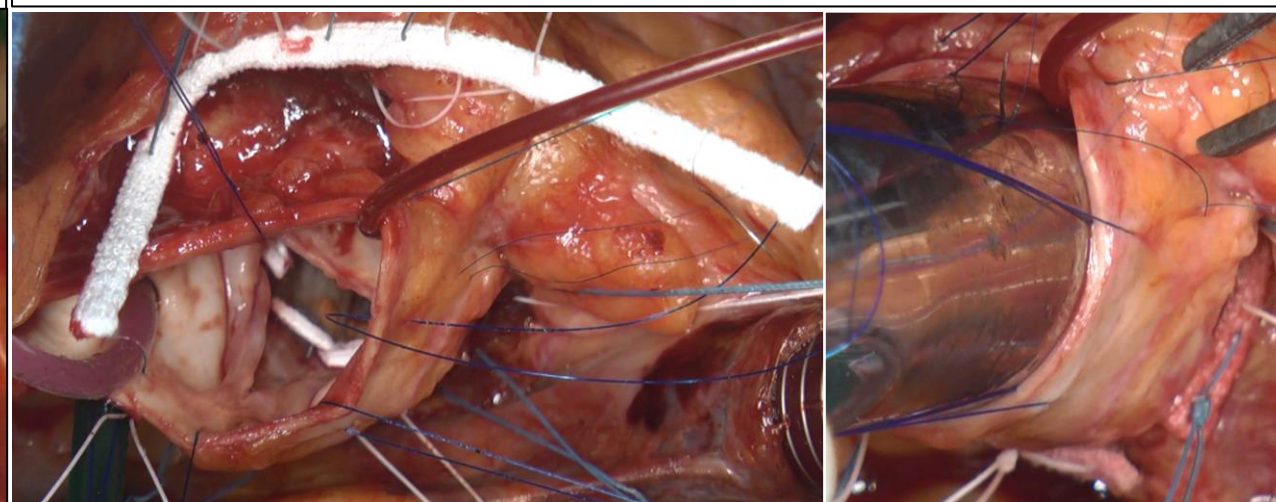
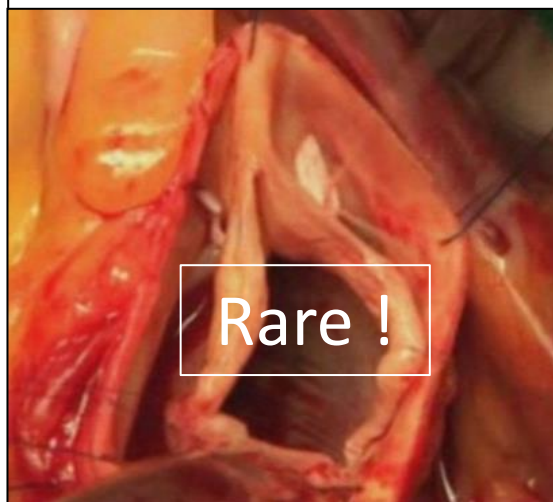
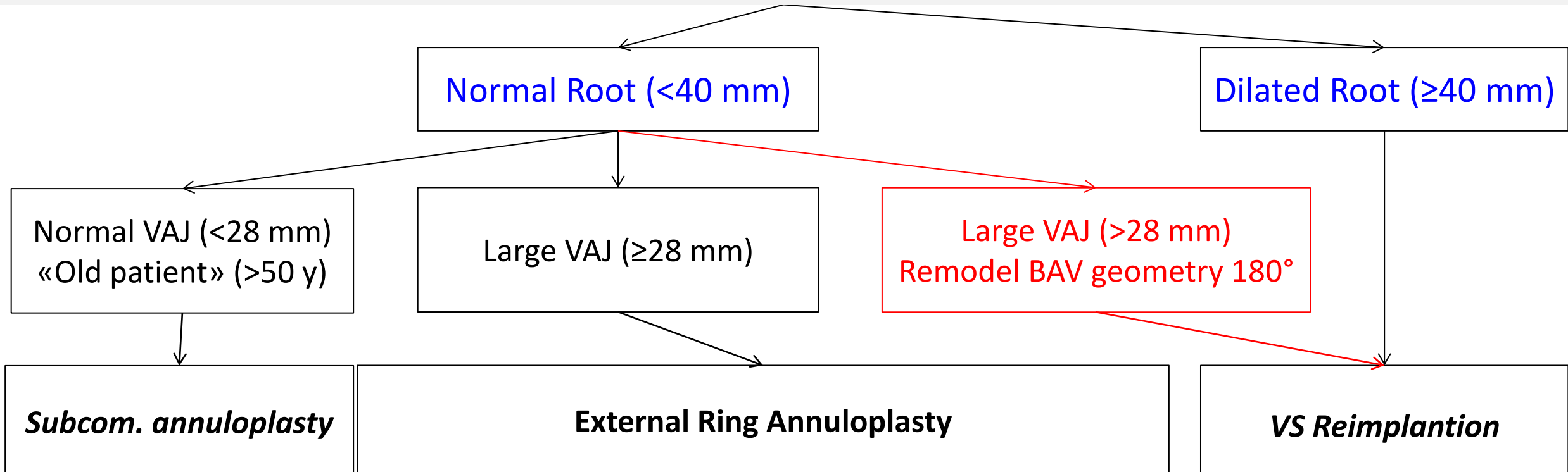
No operative mortality

5 (3%) pts with AI>1+



3 Stenosis:  
- 2 FE resusp Gtx!  
- 1 Raphe decalc + patch

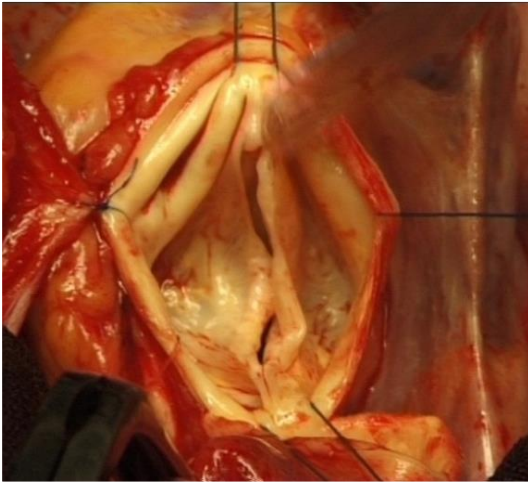
# Brussels BAV repair: *Current approach*





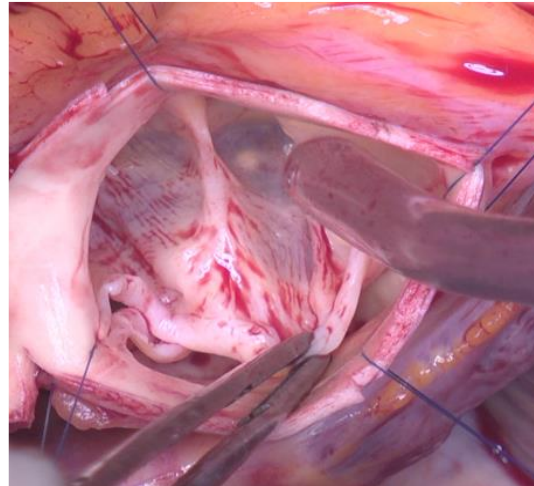
# Brussels BAV repair: *Cusp phenotypes*

→ Spectrum of cusp dysmorphism



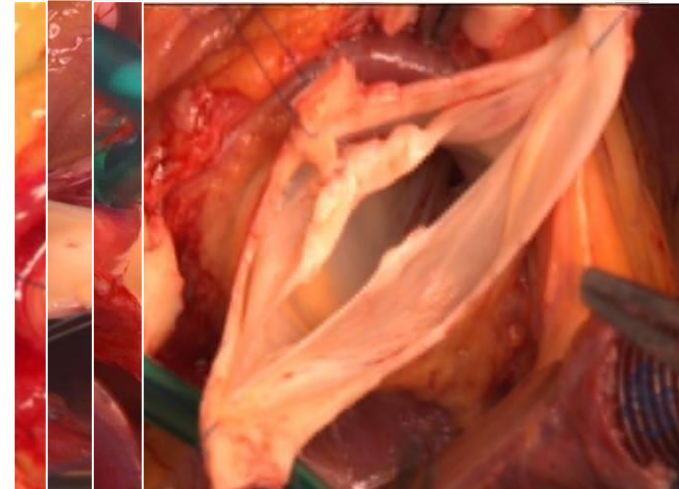
Type 0 (*Sievers Classif.*)

- No raphe
- $\approx 180^\circ$
- Prolapse



Type 1 (*Sievers classif.*)

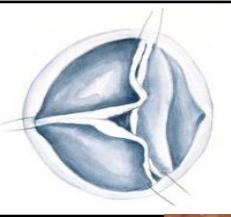
- Nearly or complete fusion of CC
- “small/thin” raphe
- $>160^\circ - 180^\circ$
- NI cusp height
- Prolapse



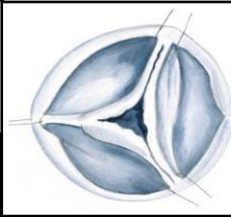
- Incomplete fusion of CC
- Thickened raphe
- $120^\circ - 160^\circ$
- Short cusp height
- Restrictive

# Brussels' BAV repair: *Cusp repair – Early experience*

**Type 0**



**Type 1**

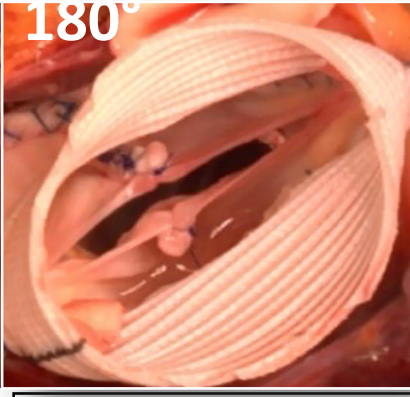
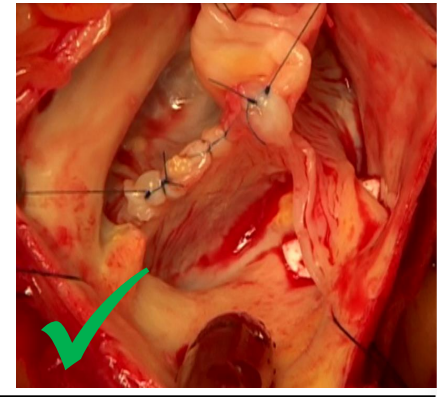
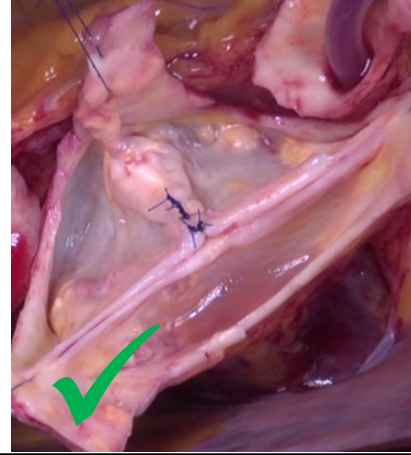
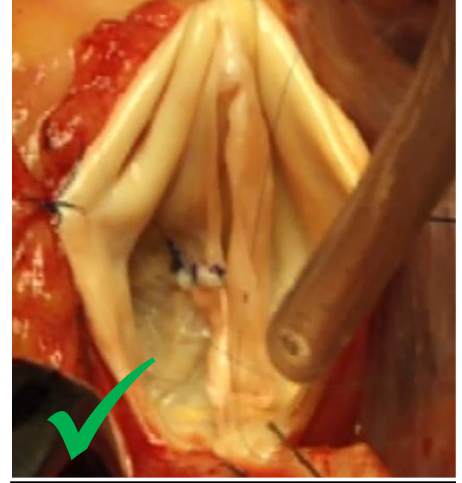
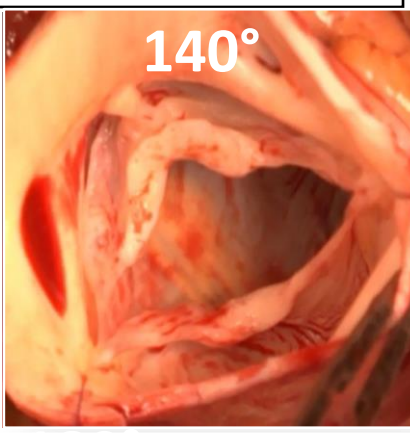
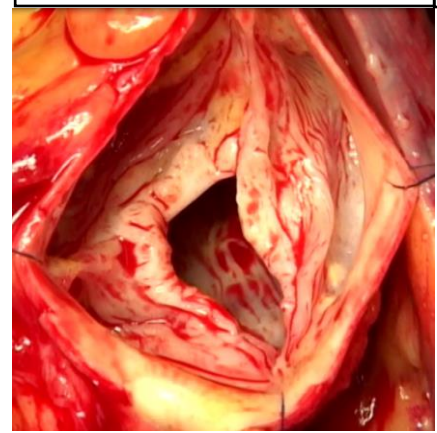
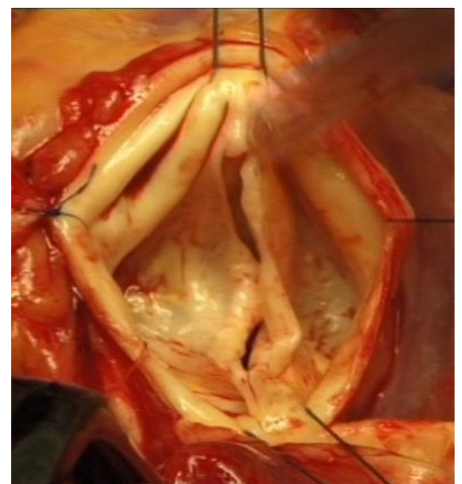
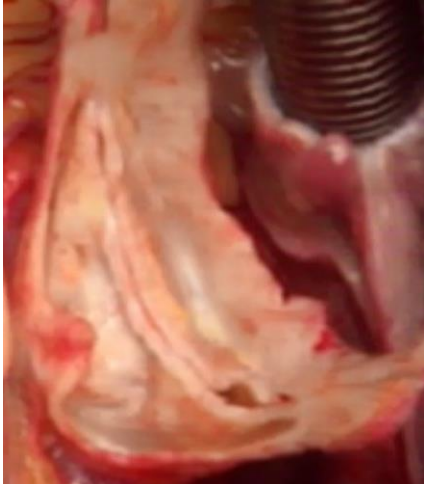


Prolapsing

Restrictive

Adequate

Inadequate



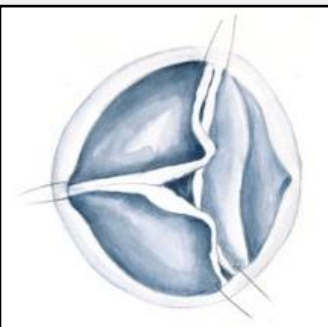
~~FM resusp. Glx~~

Cusp plication

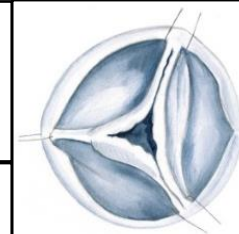
Thinning ± Direct closure

Triang. patch

# Brussels' BAV repair: *Cusp repair – Actual approach*



## Type 1 – 120°

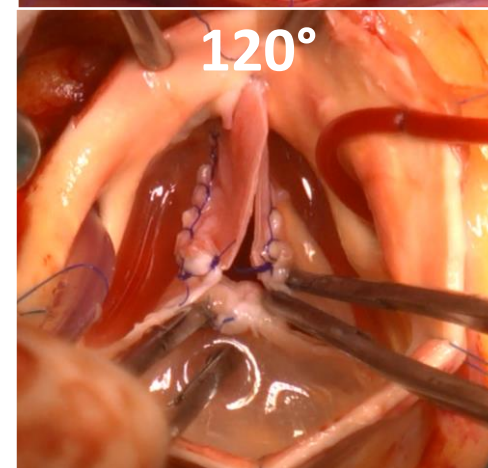
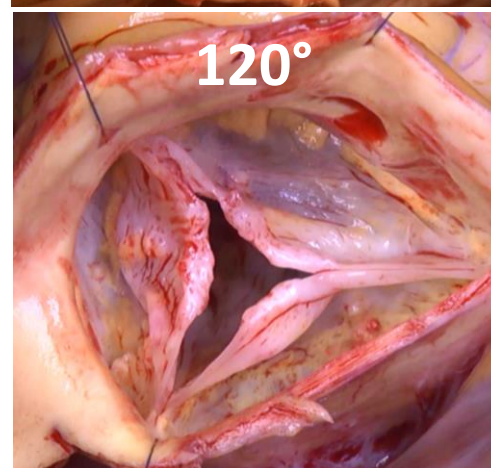
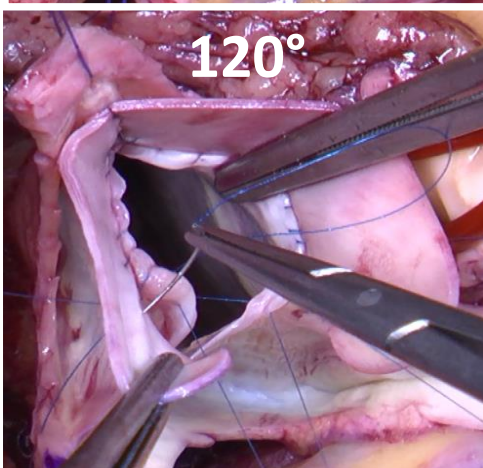
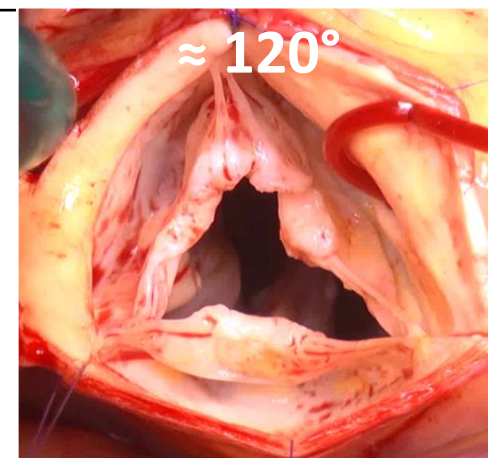
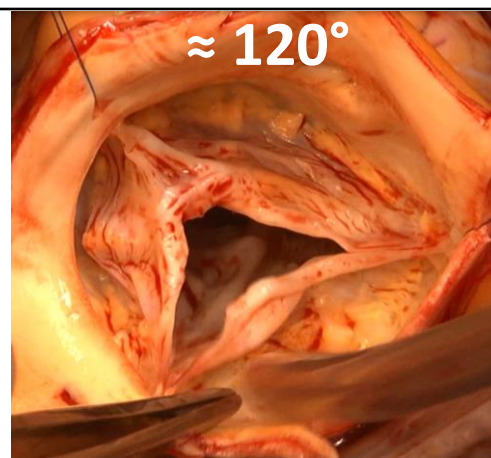
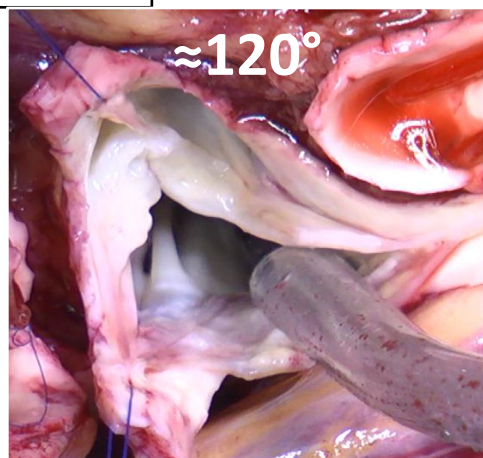


Prolapsing

Restrictive

Adequate

Inadequate

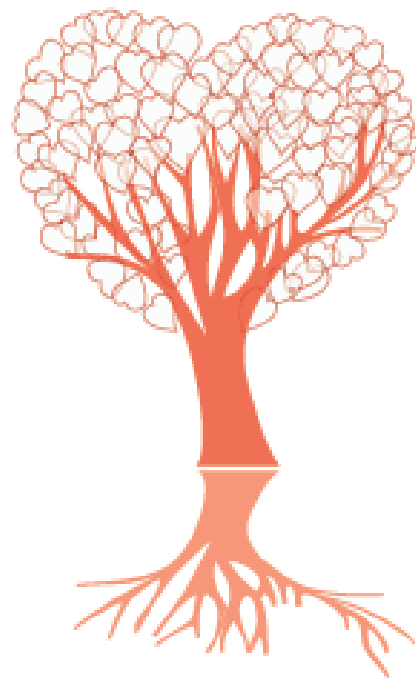


# Brussels BAV repair: **Conclusions**

*BAV repair is a durable alternative to replacement for young adults,  
if all pathological components of the BAV are treated*

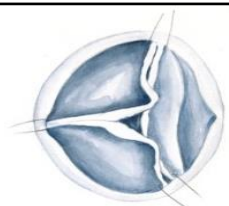
- ✓ Deep circumferential annuloplasty
  - ✓ Optimized geometry at 180° or 120°
  - ✓ Optimized coaptation 9-10 mm eH
- Cusp repair + VS Reimplantation = **The “Ideal tool”**  
+ Circumferential annuloplasty **“Alternative in normal root”**

*Thank you*

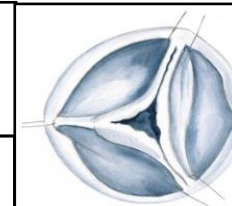


# Brussels' BAV repair: *Cusp repair – Early experience*

**Type 0**



**Type 1**

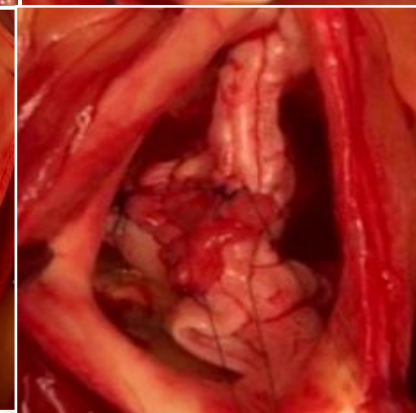
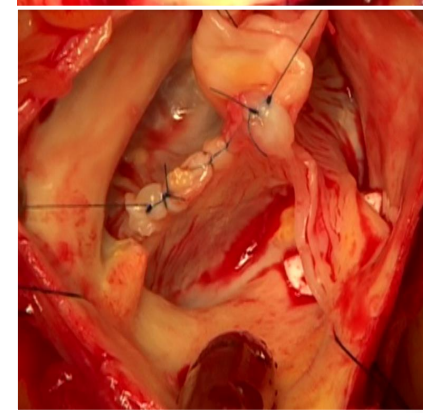
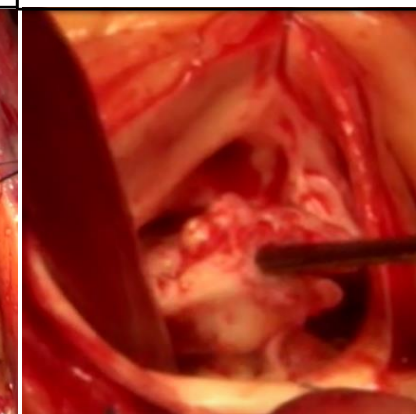
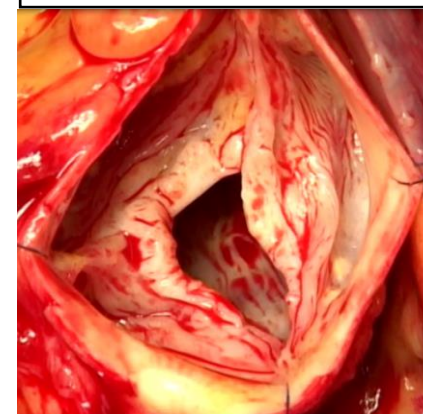
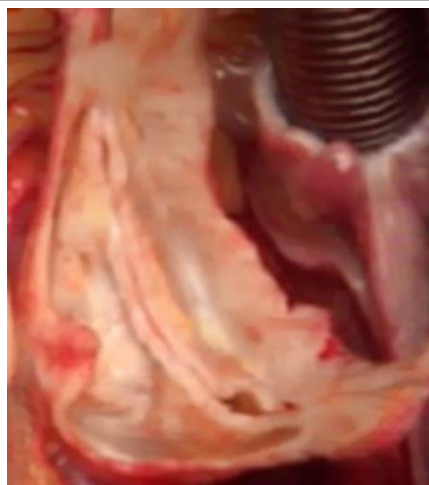
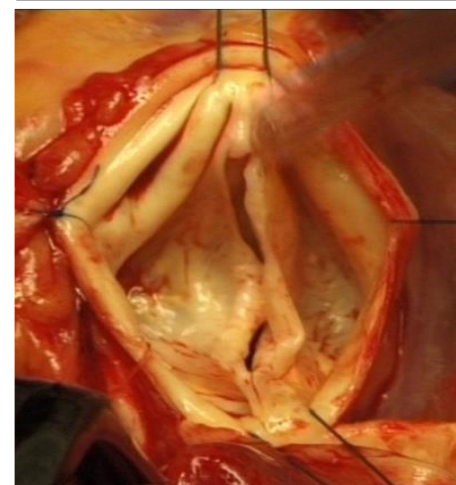


Prolapsing

Restrictive

Adequate

Inadequate



Cusp plication

FM resusp. Gtx

Thinning ± Direct closure

Triang. patch

# Brussels' BAV repair: *VAJ in BAV repair – Role of annuloplasty*

Groups	Preop VAJ ∅	Postop VAJ ∅	VAJ reduction	P value
SC Annuloplasty	27.5 ± 3.3	23.6 ± 3.6	4 ± 2.2	< 0.001
VS Reimplantation	28.3 ± 3.5	21.4 ± 2.2	7 ± 2.6	< 0.001
P value	0.16	< 0.001	< 0.001	

# Brussels BAV repair: *Results of BAV repair*

## Freedom from reoperation

BAV repair

<

TAV repair

- **81% (10 y) J. Price ATS 2013**

- 84% (7 y) P. Casselman JTCVS 1999

- 50% (10 y) H. Schaff JTCVS 2010

- 81% (10 y) D. Aicher EJCTS 2010

- **90% (10 y) J. Price ATS 2013**

- 94% (12 y) T. David JTCVS 2010

- 93% (10 y) D. Aicher EJCTS 2010



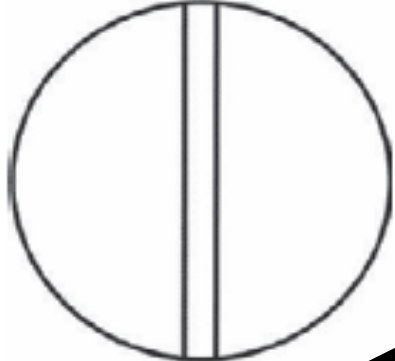
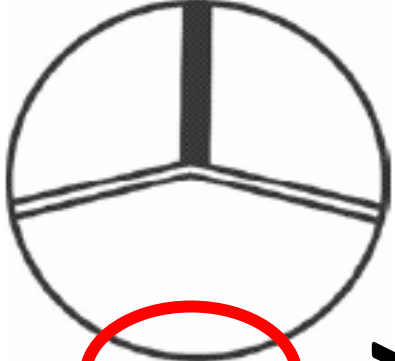







# Brussels BAV repair: *Solution - The Valva sparing reimplantation*

1. Circumferential prosthetic based annuloplasty
2. Modify commissure orientation ( $\approx 180^\circ$ )
  - Improve durability (?)
  - Reduce the need of patch repair
3. No increased mortality
4. Reproducible

*Kari F. , Miller C. ICVTS 2014*

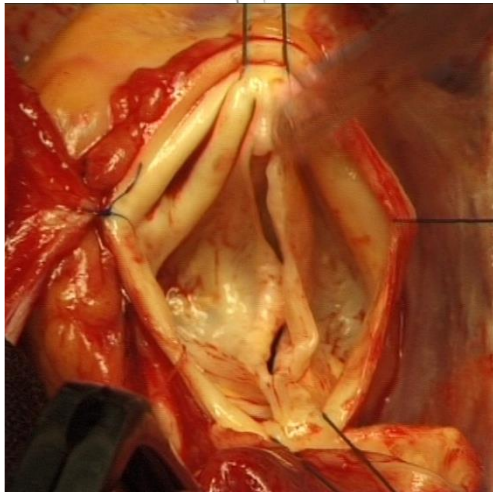
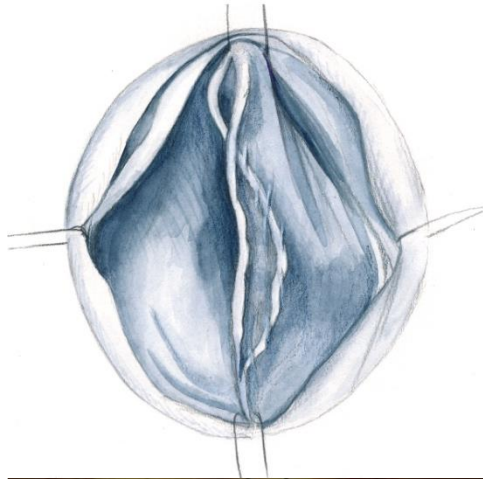
- 1997 – 2013: 85 VSR in BAV
- At 8 years: 98% overall survival, 90% FF reoperation

# Brussels BAV repair: *Anatomical classification*

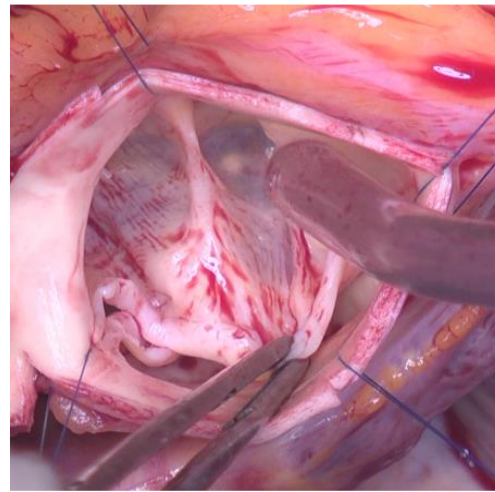
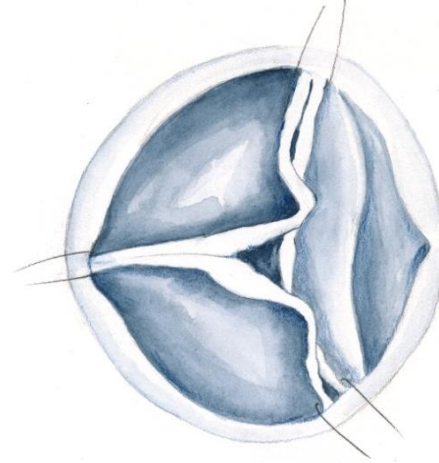
<u>main category:</u> number of raphes	0 raphe - Type 0		1 raphe - Type 1			2 raphes - Type 2		
								
	21 (7)		269 (88)			14 (5)		
<u>1. subcategory:</u> spatial position of cusps in Type 0 and raphes in Types 1 and 2	lat 13 (4) 	ap 7 (2) 	L - R 216 (71) 	R - N 45 (15) 	N - L 8 (3) 	L - R / R - N 14 (5) 		
<u>2. subcategory:</u>								
V A L U L A R	F U N C T I O N	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)		

# Brussels BAV repair: *Type 0 and Type 1 cusp lesions*

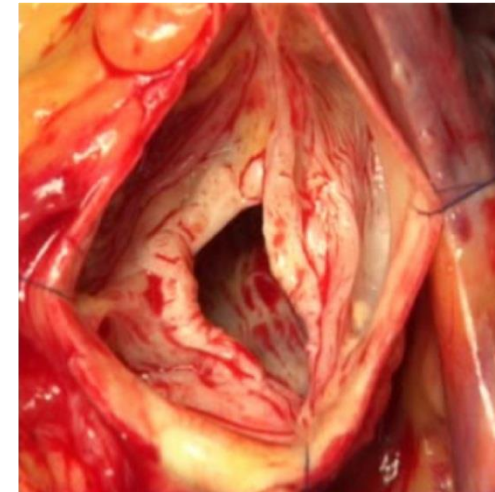
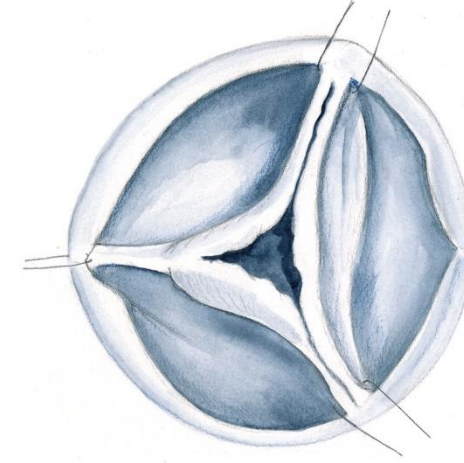
Type 0 prolapse



Type 1 prolapse



Type 1 restrictive



# Brussels BAV repair: *Risk factor 4° - Commissure orientation*

- Impact of commissural orientation not confirmed in 84 BAV repair with valve sparing reimplantation

Table 2: Cox model

Reoperation		
Preoperative angle	0.978	0.6
Postoperative angle	0.972	0.6
Change of angle	0.993	0.6
AR progression		
Preoperative angle	1.003	1.0
Postoperative angle	1.002	1.0
Change of angle	0.999	1.0
AR 1+		
Preoperative angle	1.001	1.0
Postoperative angle	0.990	1.0
Change of angle	0.989	1.0
AR 2+		
Preoperative angle	0.968	1.0
Postoperative angle	1.014	1.0
Change of angle	1.047	1.0

Hazard ratios (mid) and *P*-values (right) are given.  
AR: aortic regurgitation.

But,  
Sievers' BAV type 1 (vs  
type 0) had negative  
effect on valve  
performance ( $p = 0.017$ )

# Brussels' BAV repair:

## Bicuspid AV Syndrome

- 1-2 % most common congenital heart malformation

→ AI from 3<sup>rd</sup> – 4<sup>th</sup> decade of life

→ AS from 5<sup>th</sup> – 6<sup>th</sup> decade of life

*Tzemos N. JAMA 2008*

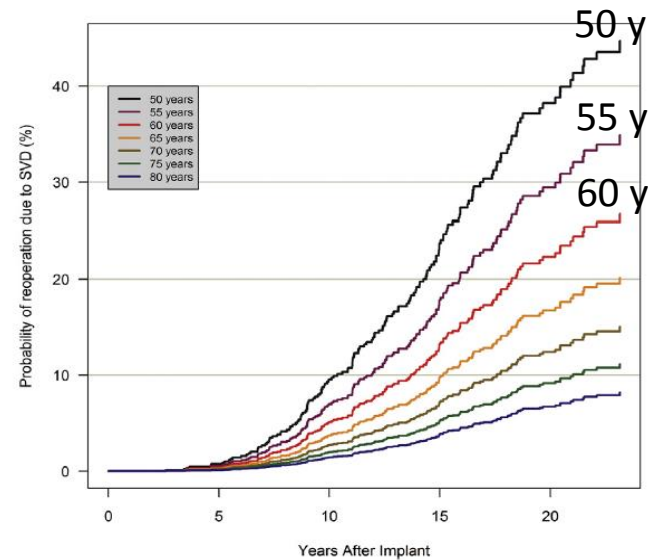
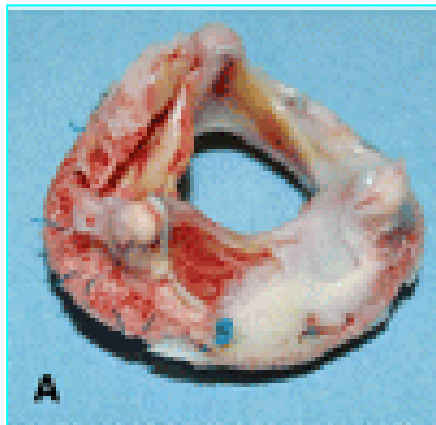
Mean age of BAV repair  $43 \pm 12$  years

*de Kerchove L. JTCVS 2011*

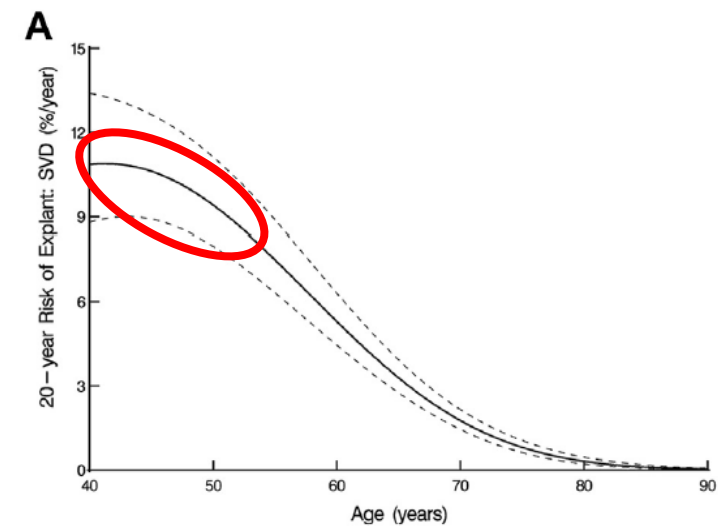
# Brussels' BAV repair

## Young adults

- Active lifestyle
- High rate of early SVD



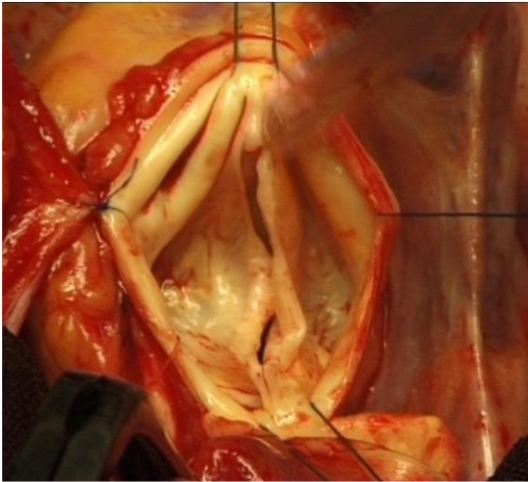
*Bourguignon T. Ann Thor Surg 2015*



*Johnston DR. ATS 2015*

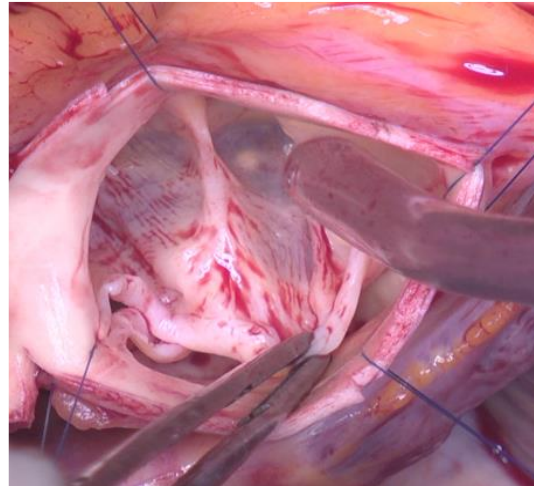
# Brussels BAV repair: *Cusp phenotypes*

→ Spectrum of cusp dysmorphism



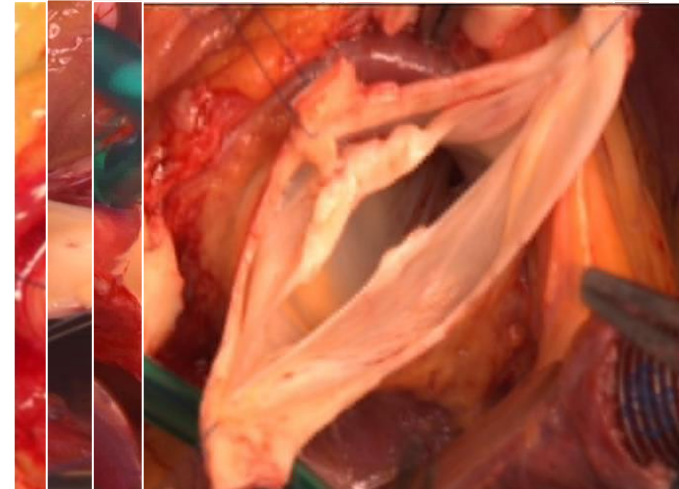
Type 0 (*Sievers Classif.*)

- No raphe
- $\approx 180^\circ$
- Prolapse

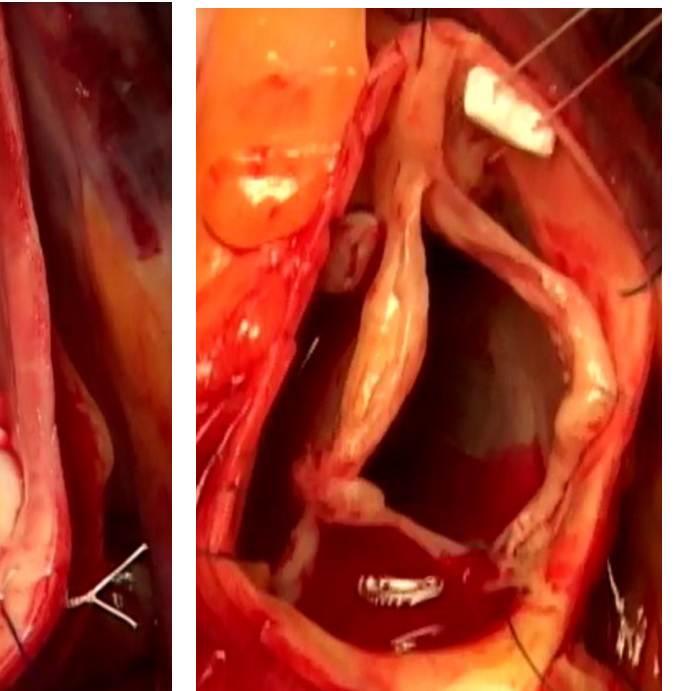
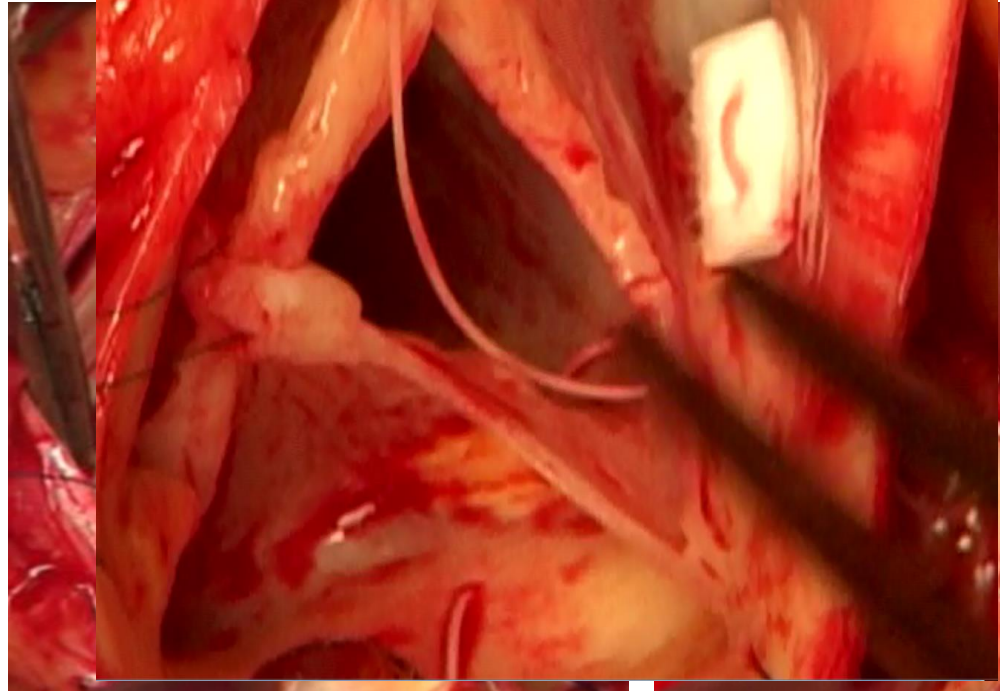
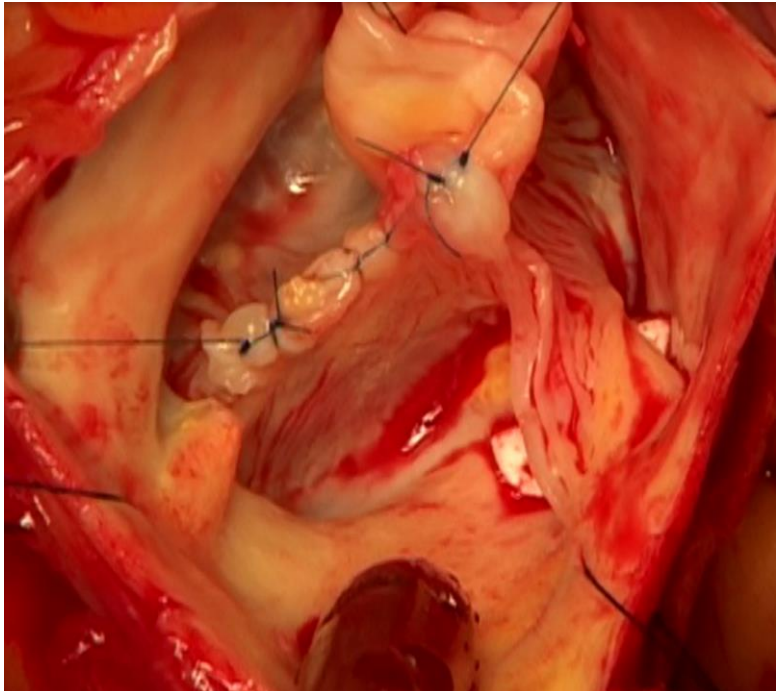
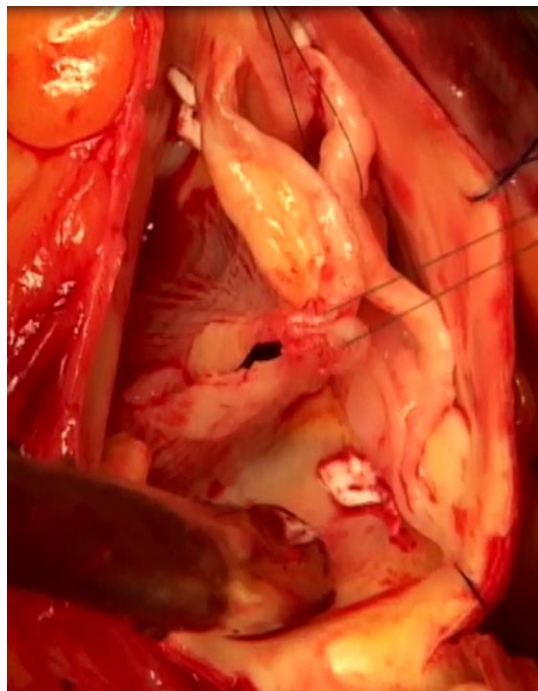
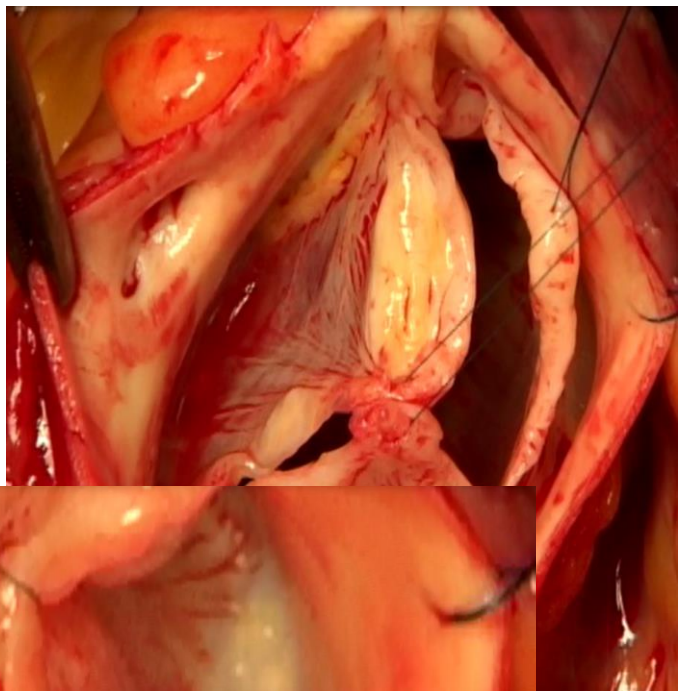
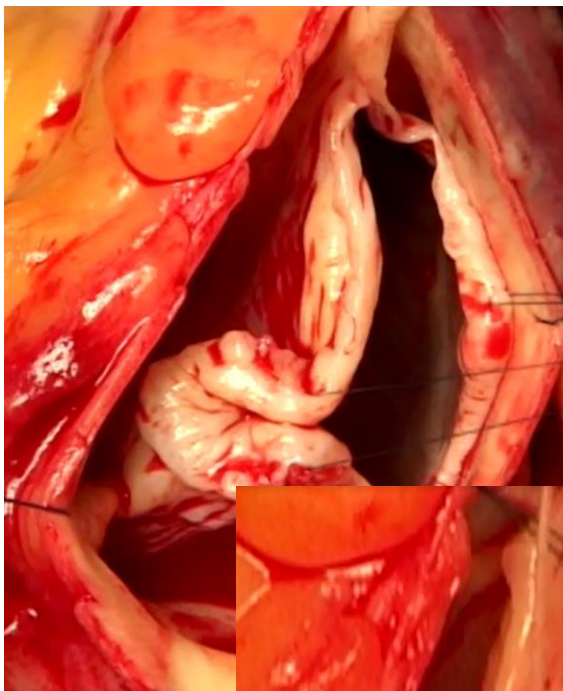
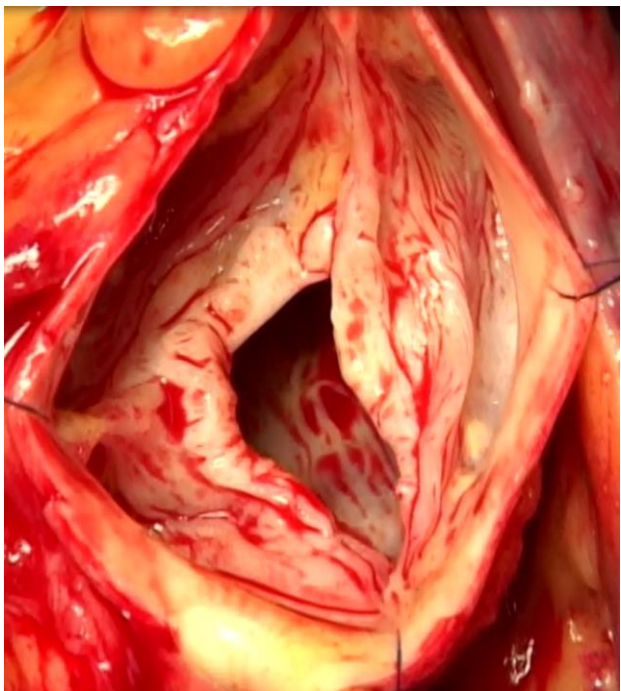


Type 1 (*Sievers classif.*)

- Nearly or complete fusion of CC
- “thin” raphe
- $>160^\circ - 180^\circ$
- NI cusp height
- Prolapse



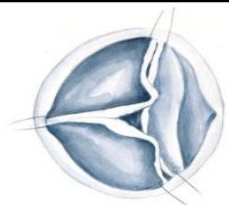
- Incomplete fusion of CC
- Thickened raphe
- $120^\circ - 160^\circ$
- Short cusp height
- Restrictive





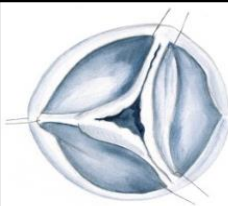
# Brussels' BAV repair: *Cusp repair – Early experience*

**Type 0**



**Type 1**

Conjoin Cusp morphology ?

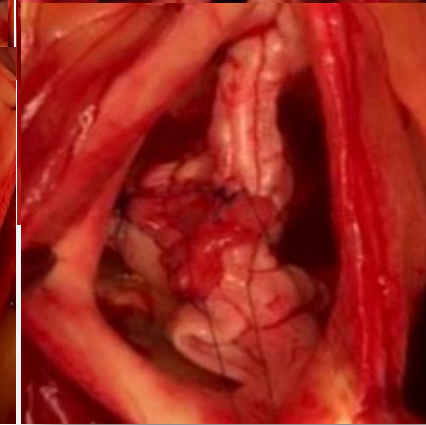
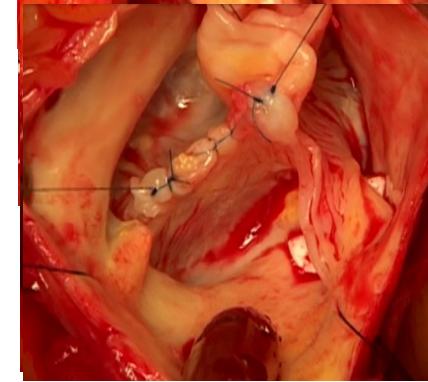
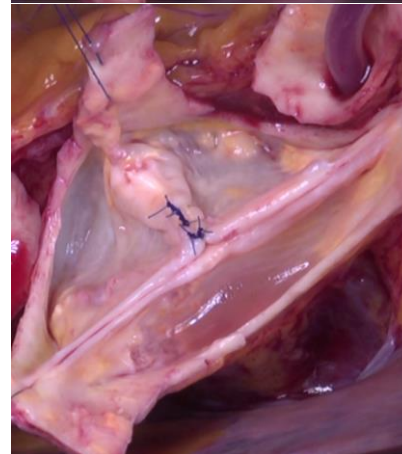
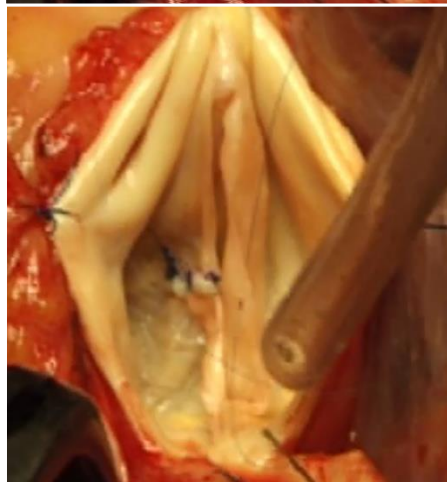
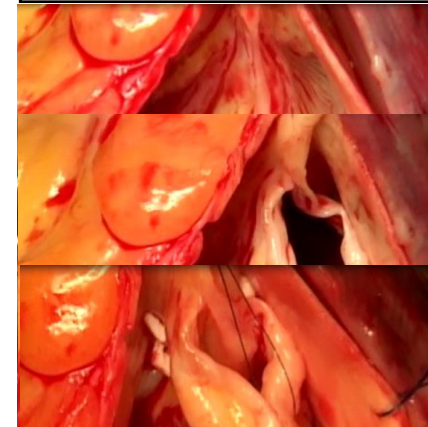
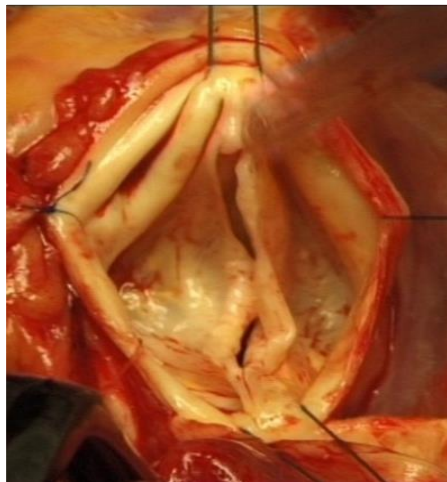
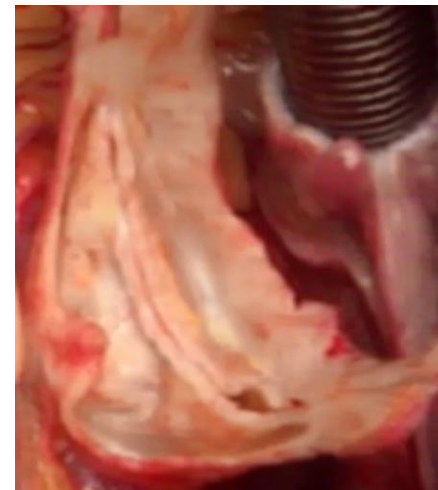


Prolapsing

Restrictive

Adequate

Inadequate

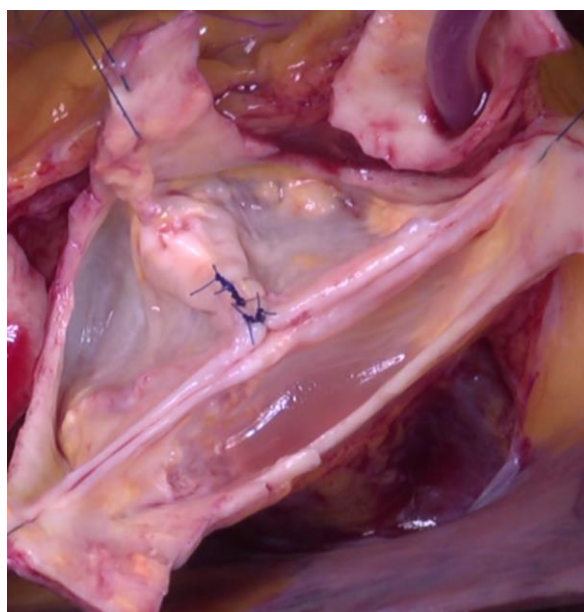
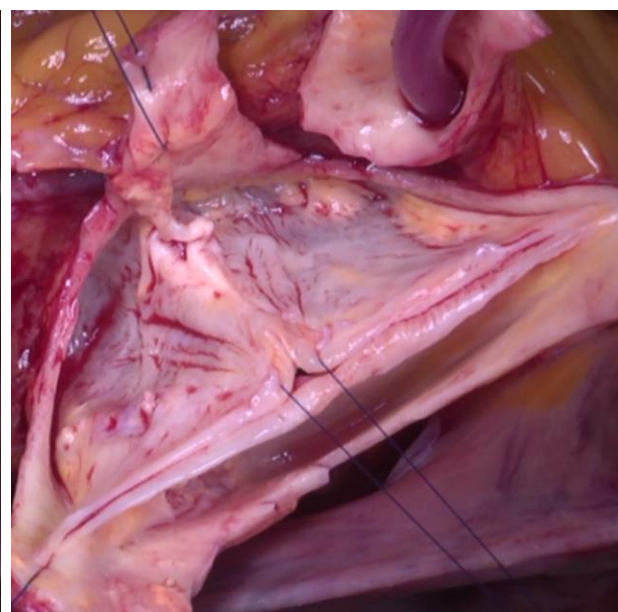
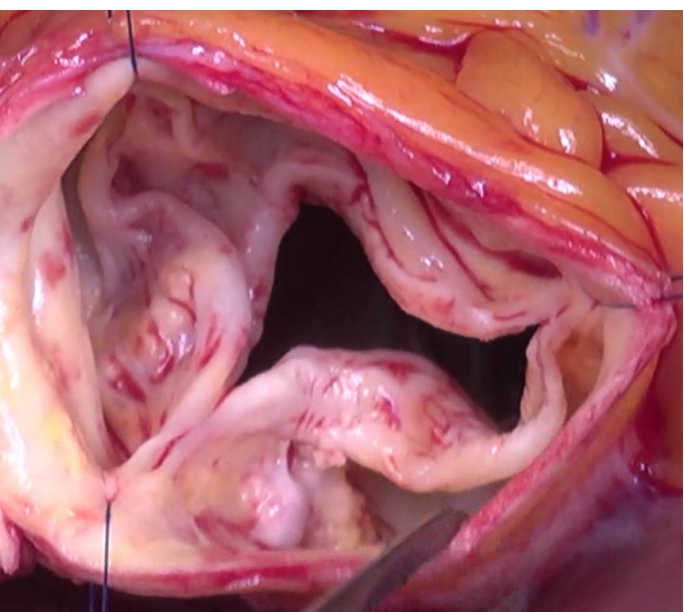


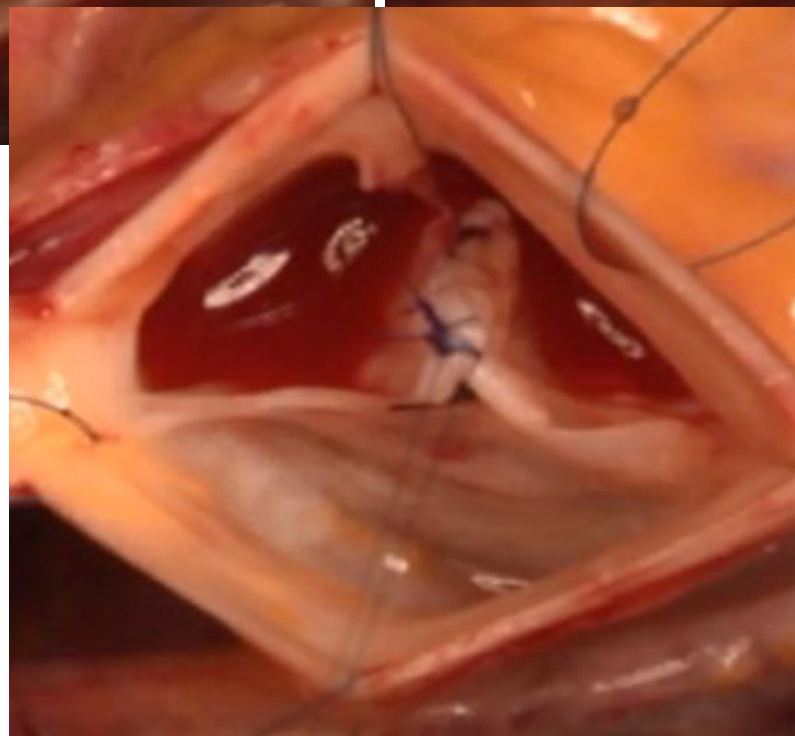
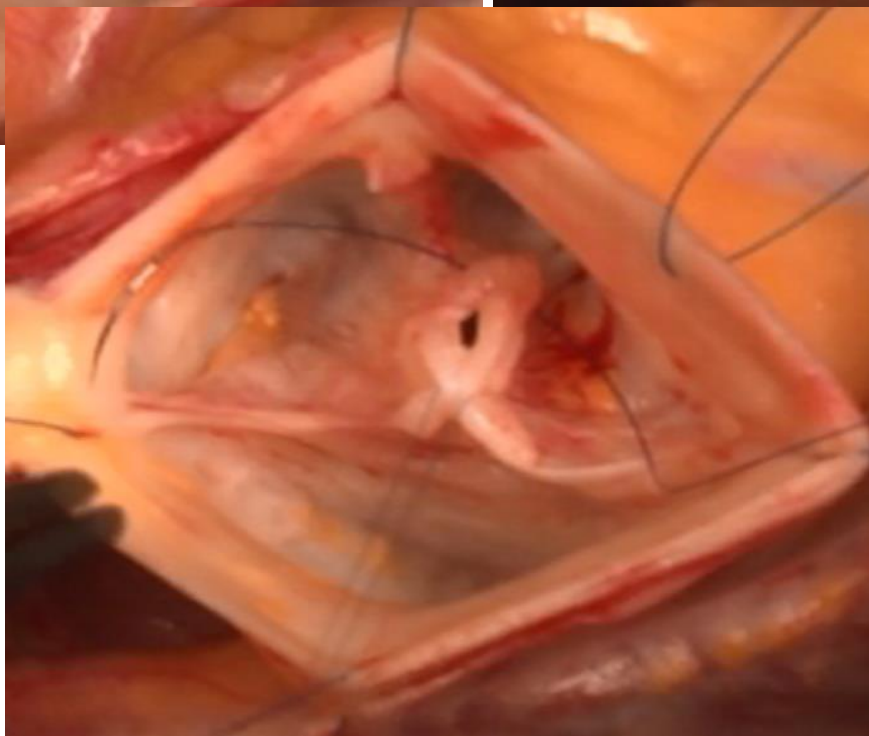
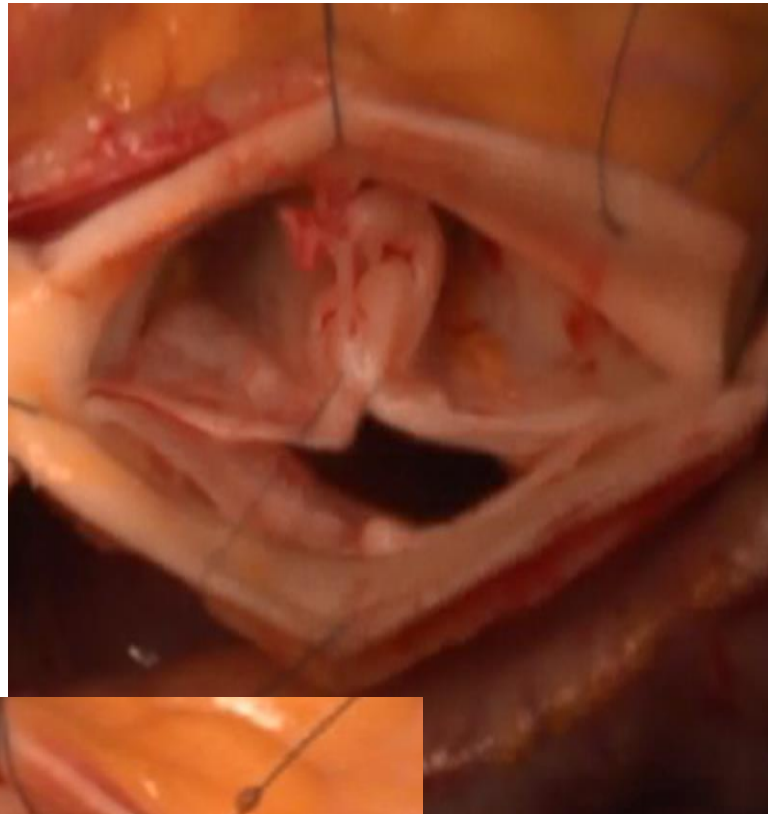
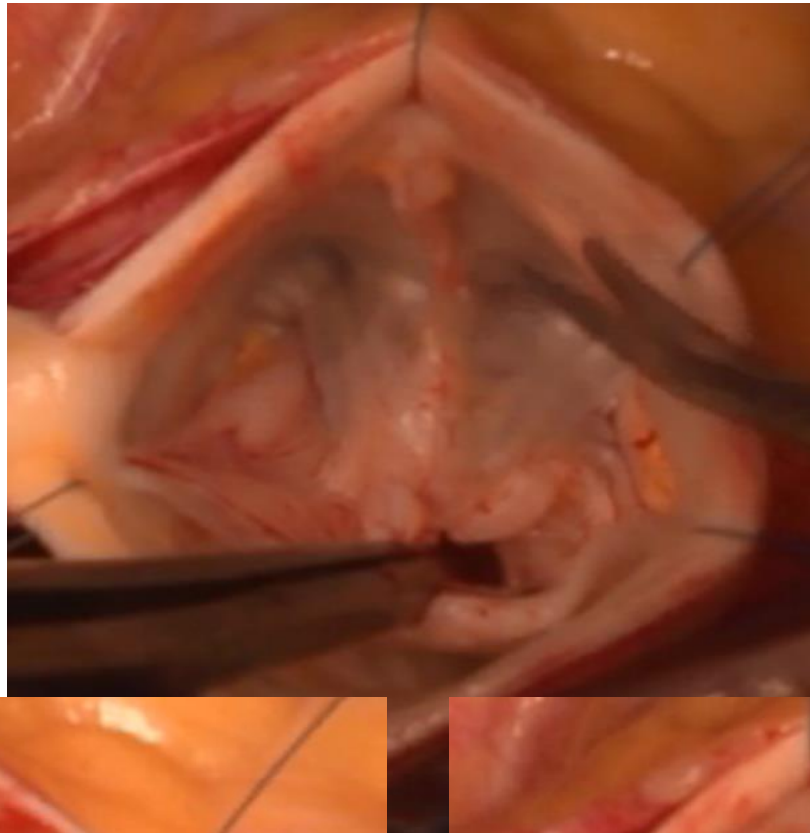
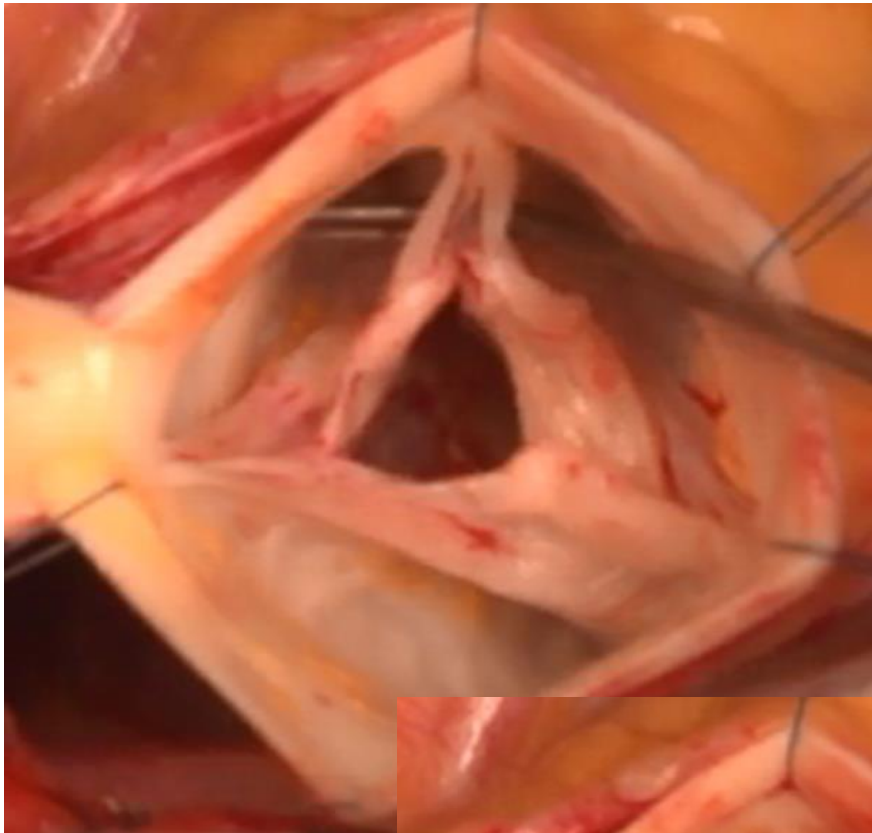
FM resusp. Gtx

Cusp plication

Thinning ± Direct closure

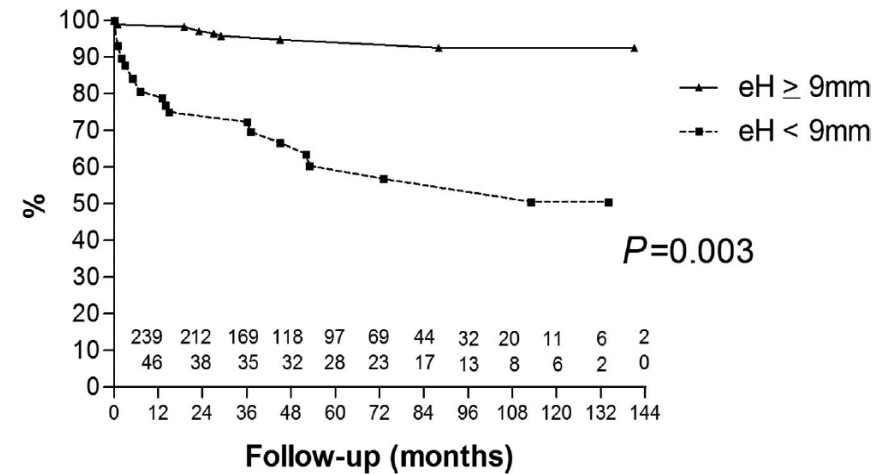
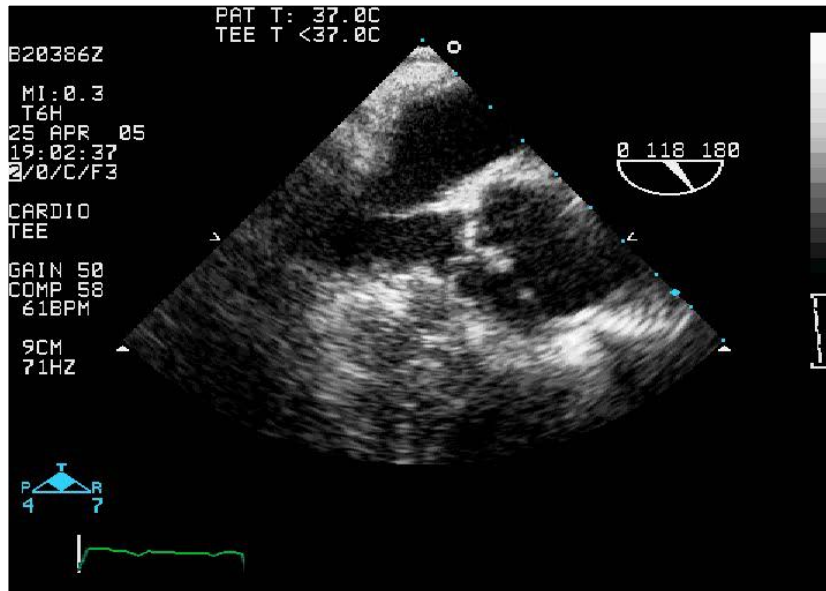
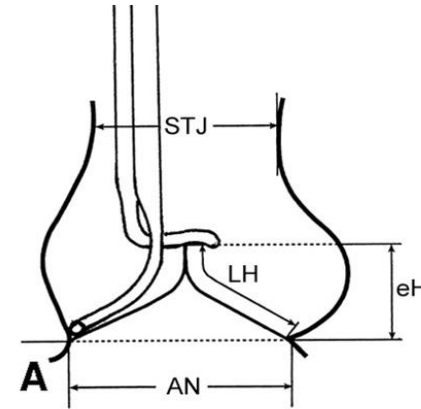
Triang. patch





# Brussels BAV repair: *Solution 1°- Optimal coaptation*

- Effective height (eH)  $\geq 9$  mm
- Coaptation length  $\geq 4$  mm
- No/minimal residual AR
- A good valve opening



Aicher D. Circ. 2011

# Brussels' BAV repair: *SCA vs VSR – Matched comparison*

L. de Kerchove J Thor Cardiovasc Surg 2011;142:1430-8

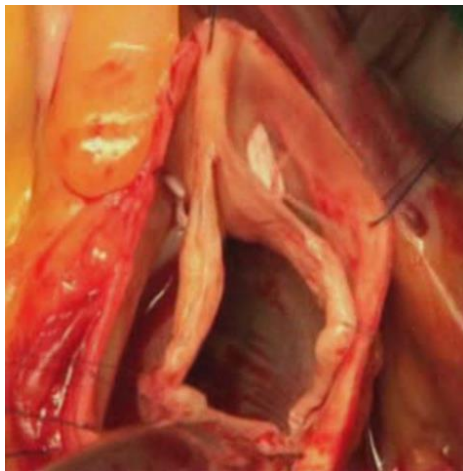
161 patients, elective BAV repair (1995-2010)

- SCA/no anpl n=87
- VSR n=74

Matching criteria:

- AR 0-2+ or  $\geq 3+$
- Ao root  $\varnothing$  <35 mm, 36-40 mm, 41-45 mm, 46-50 mm, >51mm

SCA

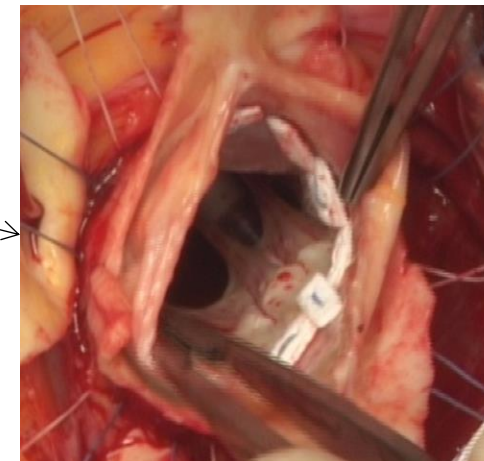


Median FU: 50 months, IQR [26-96]

Matching 1:1

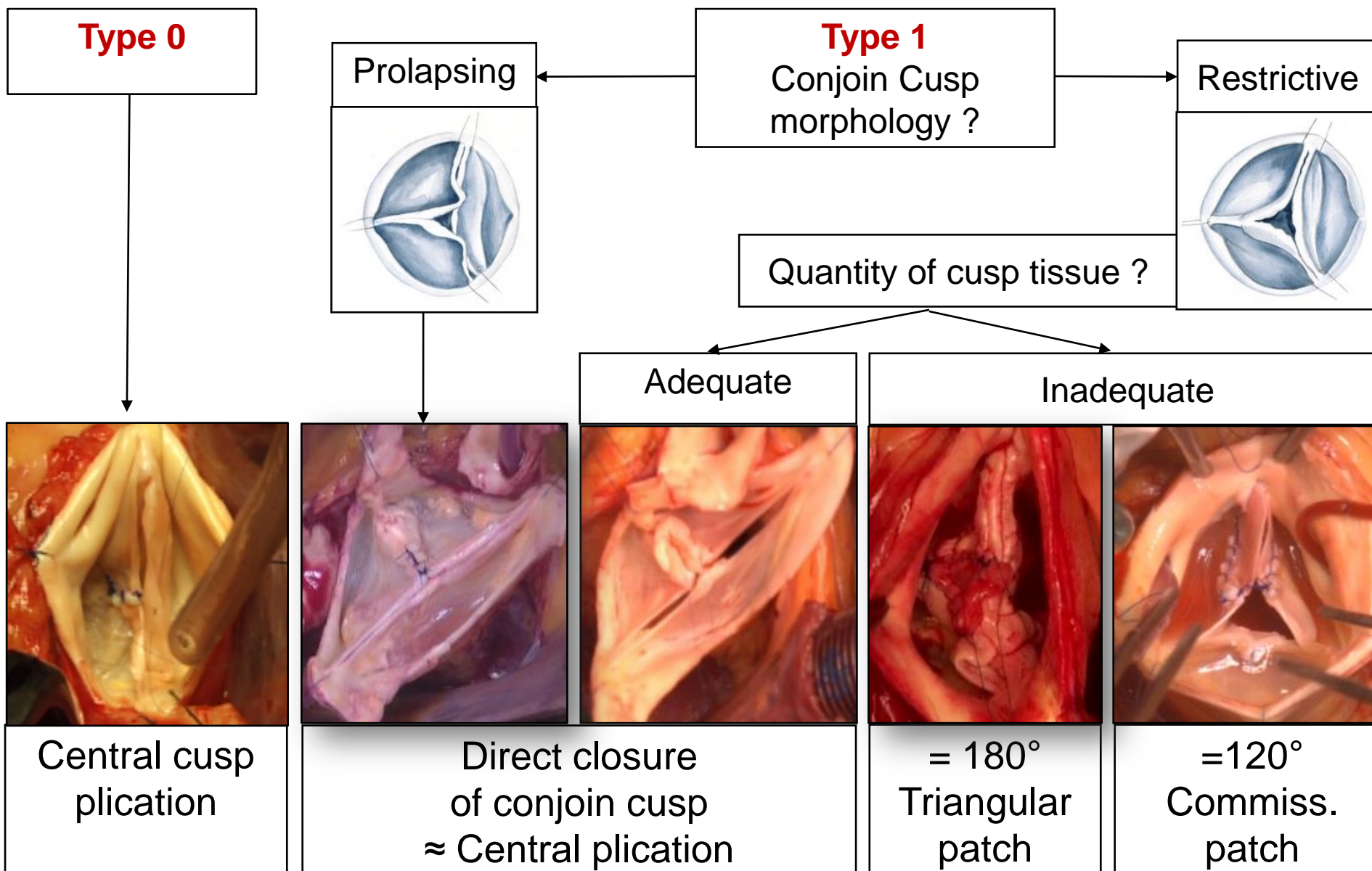
53 pairs

VSR



Median FU: 34 months, IQR [13-63]

# Brussels' BAV repair: Cusp repair following different phenotypes



# Brussels BAV repair: *Updated results*

BAV repair with Reimplantation: 0% operative mortality

